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Transport Sector Energy Planning by Network Analysis: A Case Study of Kathmandu Valley

by

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A THESIS

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled "Transport Sector Energy Planning by Network Analysis: A Case Study of Kathmandu Valley" submitted by Aprin Bajracharya in partial fulfillment of the requirements for the degree of Master of Science in Energy System Planning and Management.

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ABSTRACT

Kathmandu Valley is undergoing rapid urbanization, high population growth, urban sprawl and increased motorization which has led to the problems of congestion, pedestrian/vehicular conflict, environmental degradation and poor public transport operation and services. Because of low cost and high mobility on congested and narrow roads, the two-wheeler population is dominant in valley whose share out of registered public vehicles and private LDV gradually increased from 80.07% in 2007/08 to 83.16 % in 2017/18. Meanwhile, the share of PT decrease from 3.92% in 2007/08 to 2.91% in 2017/18. Private cars and motorcycles, which make up 71% of the total number of operational vehicles, currently meet just 41% of the total travel demand but consume 53% of the total energy. High-occupancy public transport vehicles like buses and minibuses comprise only 1.4% of the total number of vehicles but meet 37% of the travel demand and consume just 13% of the total energy (Dhakal,2006). However, the existing PT modes are not serving well, not sufficient, inefficient, overcrowded. Currently, PT facilities are being operated through numerous individual private operators that are often poorly assigned to routes.

Public vehicles operate in more than 200 routes in Kathmandu valley. (MOPIT/JICA, 2012; Sajha Yatayat,2013). The distribution of bus in those routes are randomly decided by private operators. Hence, this research work is all about finding out the optimum number of required buses in the top ten routes of Kathmandu Valley out of 163 routes of study. Out of 10 routes, in one route from Sankhu to Ratnapark, requirement of buses are more than the available vehicles plying at that route, where as in other routes, the requirement of buses is less than the available vehicles plying on the routes. Microsoft Excel-Solver tool is used for preparing the transportation optimization model.

The total number of vehicles at present scenario was 618 for all routes of study & the number reduced by 41% to 365 at optimized scenario. Similarly, the total transportation cost for all routes at present scenario is Rs. 30,25,558 for 618 number of vehicle & the total transportation cost for all routes at optimized scenario is Rs.18,60,058 for 365 number of vehicles. The total saving is Rs.11,65,500 which is equal to 39% of total transportation cost at present scenario. Similarly, from the view point of energy consumption, the total energy Consumptions by vehicles at different routes is 890,594 MJ at present scenario which is reduced by 38% to 549,420 MJ at optimized scenario. The amount of energy consumption that can be saved is 341,174 MJ. This means that

the requirement of fuel is also less in the optimized scenario which results in less environmental pollution. From the view of environmental emissions, the air pollutant gases (CO_2, CH_4, N_2O, NO_X, CO, NMVOC, SO_2) & particulate matters $PM_{2.5}$ decreases by 57%, 44%, 66%, 62%, 22%, 20%, 20%, & 42% in Route 1, Route 2, Route 3, Route 4, Route 5, Route 6, Route 7 & Route 8 respectively in optimized scenario. In case of Route 9, those gases & particulate matters under consideration except methane gas increases very high. Also, in case of route 10, the air pollutant gases such as: N_2O, NMVOC, NO_X, CO increases high in optimized scenario.

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LIST OF ABBREVIATIONS

PT	Public Transportation
CBS	Centre Bureau of Statistics
DOTM	Department of Transportation Management
Pass-km	Passengers-kilometers
TD	Travel Demand
WB	World Bank
Pv	Present Value
O & M	Operation & Maintenance
MJ	Mega Joule
NMVOC	Non Methane Volatile Organic Compound
OR	Operation Research
MOPIT	Ministry of Physical infrastructure and Transport
JICA	Japan International Cooperation Agency
KSUTP	Kathmandu Sustainable Urban Transport Project
O-D	Origin-Destination
SUE	Stochastic User Equilibrium
LDV	Light Duty Vehicles
KMC	Kathmandu Metropolitan City
LMC	Lalitpur Metropolitan City

CHAPTER ONE: INTRODUCTION

1.1 Background

Kathmandu valley covers an area of 721.87 sq.km covering parts of Kathmandu (approx.85%), Lalitpur (approx. 50%) and Bhaktapur districts. Kathmandu valley lies in Bagmati zone of central development region and covers whole of Kathmandu and Bhaktapur districts and parts of Lalitpur district. Taking about the land use, the landscape of Kathmandu valley is dominated by cultivated land covering about 47% of the total 722 sq.km of the valley. Forested land covers about 251 sq.km i.e about 34% of the valley area. Built-up area consisting of residential area covers more than 14 %, commercial / mixed residential and commercial has been increasing since the previous decades and now covers about 5%. Kathmandu valley has been a centre of economic growth since long ago and being a capital city of the country, its growth has been booming rapidly. The development of market infrastructures within the core center of Kathmandu valley and centralized government functions established the core urban centre as the most desired place to live in. With increasing economic opportunities, urban facilities, better education facilities and development of roads, the migration of people from rural areas to urban areas increased. (Khokhali,2017)

The total population of Kathmandu valley in the census year 2011 was 2,517,023 with the annual growth rate of 4.63%. This represents the 9.23% of entire population of country in mere 0.49% area of the country. The Central Bureau of statistics of Nepal has projected the Kathmandu valley's population to be 27,77,255 by 2016 A.D. (Khokhali,2017)

1.2 Public Transportation in Kathmandu valley

Public transport is a shared passenger transport service, which is available for use by anyone who pays the set fares. It generally operates on fixed routes and may include modes such as 3-wheeler, mini/micro buses, buses, trolleybuses, trams, trains and ferries. Besides reducing congestion and air pollution by providing transportation services to a large number of people, high capacity public transport systems may also influence the urban form and quality of life in cities. A good public transport system makes efficient use of urban space, provide efficient and affordable mobility, and access to work, school/colleges, social, recreation and economic activities. A standard bus occupies the same space that of two cars but carries almost forty times more passengers. A major cause of concern in developing countries is that while urbanization continues to happen rapidly, the modal share of public transport is decreasing or remains stagnant. This is mainly because of lack of investment in the sector, weak regulations and poor quality of services. In the absence of a strong commitment by the government to provide an efficient formal public transport system, in many developing countries, private individuals or small companies provide informal public transportation services. These private operators are often driven by profits rather than public service. The situation is similar in Kathmandu, where over the past 10 years, population has increased by 4.32 % per year and motorization has increased by 12% per year (CBS 2011; DOTM, 2013) while the modal share of public transport has remained stagnant (MOPIT/JICA,2012).

Out of approximately 3.4 million one-way person trips made each day, nearly 41% percent are made on foot, while almost 28% are made on public transport (MOPIT/JICA, 2012 and SMEC, 2013). The travel pattern is highly radial with most trips starting or ending in the central business District (CBD) of Kathmandu. Public transport services are provided by several thousand private Operators, which are organized into mode-specific associations and operate along over 200 routes as shown in Table 1. The share of low occupancy vehicles such as minibuses, microbuses and tempos operating within Kathmandu Valley accounts for 94% of total public transport vehicles, while share of large buses is only 6% (MOPIT/JICA, 2012). The two-wheeler population is dominant in valley whose share out of registered public vehicles and private LDV gradually increased from 80.07% in 2007/08 to 83.16 % in 2017/18. Meanwhile, the share of PT decrease from 3.92% in 2007/08 to 2.91% in 2017/18 (DOTM,2020). Private cars and motorcycles, which make up 71% of the total number of operational vehicles, currently meet just 41% of the total travel demand but consume 53% of the total energy. High-occupancy public transport vehicles like buses and minibuses comprise only 1.4% of the total number of vehicles but meet 37% of the travel demand and consume just 13% of the total energy (Dhakal,2006).

Table 1: Number of operating public transport vehicles and their routes within the kathmandu valley

Types of Public Transport	Passenger Capacity	Number of Operation Route	Number of Operating Vehicles
Tempo	11-13	21	913
Micro Bus	10-16	90	2036
Mini Bus	26-35	107	2036
Large Bus	35-50	4	336
Total		222	5321

(MOPIT/JICA, 2012; Sajha Yatayat, 2013)

1.3. Scope of Work

This research mainly deals with the energy planning of public transportation within the Kathmandu Valley by the help of network analysis. The various routes of public vehicles plying inside the Kathmandu Valley will be studied & travelling demand of all route will be calculated & analyzed. Optimization of transport network will be carried out of the top 10 routes to find out the required number of vehicles. The comparative details analysis will be done with the current scenario & optimum scenario on the basis of transportation cost, energy demand & environment emissions.

1.4. Problem Statement

Public transportation in Kathmandu Valley is mostly provided by the private transport associations on the various routes. In the past, there was more low occupancy vehicles plying on the road. But, now a day, the situation has improved since the private transport associations are also providing the high occupancy mass transportation service. But whatever is the situation, they are not well planned to determine the required number of vehicles needed in the vehicle route based on the travel demand. Just, they are determining the number based on their casual approach. This situation has led to the inefficient supply of vehicle in the route which results in the supply of more vehicle in such route where travel demand is less & supply of less vehicle in such route where the travel demand is more. This further lead to the more energy demand of the vehicles & subsequently more environment pollutions. Hence, energy planning of the public vehicles is needed & this research work deals with the same through the help of network analysis of operation research.

1.5. Objectives

1.5.1 Main Objectives

- To perform Energy planning of the Top 10 routes of Kathmandu Valley by transportation network model

1.5.2 Specific Objectives

- To find out the travel demand of vehicle routes of Kathmandu Valley.
- To find out the optimum number of required vehicles in the top ten routes of study.
- To Compare the optimized scenario & current scenario on the basis of transportation cost, energy demand & environmental emissions.

1.6. Assumptions

- The population distribution of different wards of different metropolitan city, municipality etc was interpolated for fiscal year 2075/76 from the 2067/68 census data by taking the annual population growth rate of Kathmandu valley for each year basis.
- Population growth rate of 4% (The World Bank, 2013) for Kathmandu valley & effective population equal to 28 % (Sajha Yatayat, 2014) was taken.

CHAPTER TWO: LITERATURE REVIEW

This Chapter Two include the review of different researches done on the field of transportation sector. The different journal papers, previous works done on the same field by different concerned organization gives clear idea about the past researches done on the field of transportation sector. The research that should be done was identified. There is limited work done on the field of transportation problem by network analysis of operation research tools.

2.1 Past research done on Transportation Sector Problem

The Study was done on to optimize the requirement of bus distribution in different routes of Pokhara Sub-Metropolitan City based upon the distribution of passenger in different time duration. The optimization of distribution of Bus is done by using Premium solver in the Microsoft Excel spreadsheet platform. The result clearly shows that Out of 251 buses available from the Pokhara Bus Entrepreneurs Association, only 234 buses were required which further show the fact that the distribution of bus in some route was inadequate whereas in some route, the distribution of bus exceed the maximum number of required bus (Shakya.et al,2013). Till date, no such works have been done so far to optimize the requirement of vehicle on different other routes & such works need to be carried out especially at that city where there is inefficient management of Public Transportation.

The past research has been done on the route optimization of urban public transportation based on operation research technique. The researcher has developed an optimization model minimizing the number of transfers made by travelers as a travel may prefer a longer route with fewer transfers than a shorter path with many transfers. The model is mixed integer programming because it contains large amounts of binary variables. Travel demand is highly variable at different time of day. However, the model represents decisions for a single period, considering a critical time, for example, the peak hours of the morning when demand is usually higher. They have used the Software GAMS 22.7 and its solver CPLEX. The multi-objectives optimization method was used & the objective function was to maximize the demand to be served by the bus service, minimize the operating cost, minimize the cost of travel & minimize the transfer.

About 77% of demand was satisfied & total number of transfers was 52 in their result. The result was consistent with the assumptions of the model. Nevertheless, this is only an academic exercise because it does not incorporate aspects that could be relevant in a real application (Jaramillo, Gonzalez, & Gonzalez, 2013).

The past research was done on the Evaluation and Optimization of urban public transportation networks which show how to compute distances and routes efficiently for large networks. The researcher has shown how to evaluate the average transportation cost of the passengers in a public transportation network. He has also developed the heuristic algorithm which improves a public transportation network using the average transportation cost as the objective's functions. An efficient method for the passenger assignment problem, Vehicle assignment problem & heuristic algorithm to improve the vehicle routes was also presented in the research. (Mandl,1980)

The DHV Route Optimization model, developed in Netherlands, was used in three Metropolitan areas in South Africa to assist in the optimization of bus and taxi route networks. The model determines the most optimal set of road-based routes, subject to resource constraints by minimizing the total travel time and number of transfers between the routes. The DHV Model makes use of operation research techniques to identify the optimal set of routes and frequencies to meet the demand for public transport, subject to resource constraints such as the operating budget and vehicle fleet. In the DHV model, the optimization is primarily approached from the interest of the public transport user. The main aim of model is to satisfy the needs of the passenger in terms of the reduction in the travelling time (more direct routes, higher frequency and less waiting time etc.) and the reduction in the number of transfers. The distinct results of the model responding to the various demand patterns in the three areas demonstrated the role and benefit of the model. (Van Zyl, 1999)

Network model is a useful technique to analyze and formulate transportation problem due to its stable and smooth characteristics The paper locate the shortest route using network model as the shortest routes provides the effective minimum transportation cost. Other method such as North-west Corner Rule was also used to see the minimum transportation cost & for testing optimality. Extreme Difference method was also used. The transportation cost based on Network Model came to be Tk.192544 which is similar to the cost obtained by Extremum Difference Method while by North-West Corner Rule the cost incurred was Tk. 193149.This demonstrates that the Model described in the paper provides more effective transportation cost in comparison to the cost by North-West Corner Rule.(Uddin.et al,2011)

The New Delhi, capital city is immersed in pollution and congestion by private as well as public transport vehicles and an everyday increase of private vehicle population. Increasing levels of air pollution, a traffic management crisis, urban population growth and limited infrastructure making the situation worse. In order to tackle the problems many short-term measures were in place, such as applying vehicular emission norms, switching to cleaner fuels and phasing out old vehicles. The challenge is to integrate policies, technologies and businesses to develop sustainable infrastructure for Delhi that can fulfil the needs for transport at the moment and flexible enough to accommodate for the future. The objective of the research is to develop alternative scenarios and analyse how different technologies and policies may work for the future. It is a conscious effort to put the desk research and interviews with stakeholders in the form of plausible alternatives of sustainable future for passenger transport in Delhi. (Beella et al,2002)

Indian cities face a transport crisis characterized by levels of congestion, noise, pollution, traffic fatalities and injuries. This crisis has been worsened by the extremely rapid growth of India's largest cities, limited and outdated transport infrastructure, rampant suburban sprawl, sharply rising motor vehicle ownership and use, deteriorating bus services, a wide range of transport modes sharing roadways, and mainly uncoordinated and inadequate transport planning. Hence, the researcher study about the key trends in India's transport system and travel behavior, analyzes the extent and cause of the most severe problem and recommends various policies that would help mitigate India's urban transport crisis. (Puncher et al, 2005)

There are some studies in the past related to environmental emission and energy demand from transportation in the Kathmandu Valley. Some researcher studied the sectoral energy-use patterns, including transport sector and the associated emissions in the Kathmandu Valley. The focus of the study was to build the inventory of pollutant emissions in the Valley (Shrestha & Malla,1996). Some researcher studied the extension of trolley bus in the Kathmandu valley and its impact on the reduction of petroleum fuel consumption and greenhouse gas emission up to the year 2025 (Pradhan et al, 2005). Some researcher studied the feasibility of the introduction of hydrogen vehicles in the Kathmandu Valley and its impact on the reduction of fossil fuel emissions from vehicles and import of fossil fuels for the period 2005-2020 (Ale &

Shrestha,2009). Shrestha and Raj Bhandari analyzed the sectoral energy consumption, including transport sector and emissions in the Kathmandu Valley for the period 2005-2050. Shakya and Shrestha studied the electrification of transport system, mainly electric train, in Nepal using the hydropower resource of the country and the resulting reduction in greenhouse gas emission and improvement in energy security for the period 2015-2050. The focus of this study was the electrification of the transport sector. Dhakal analyzed the implications of different transportation policies on future energy demand and environmental emissions from passenger vehicles in Kathmandu Valley up to the year 2020. This study does not cover the freight vehicles and the various possible scenarios such as the fuel efficiency improvement of vehicles, introduction of hybrid car, electric bikes etc.

The study has been undertaken to estimate the road transportation energy demand and associated environmental emissions from both passenger and freight vehicles in the Kathmandu valley for the period 2016-2030 and to analyze the various possible transportation policies and their impact on energy demand and environmental emissions. The result has shown that there will be tremendous growth of vehicle fleets, particularly small vehicles like motorbikes and LDV in the Kathmandu valley in the coming fifteen years if they are left uncontrolled. These small vehicles will consume 65% of the cumulative fuel demand in the valley and produce 58% of total CO2, 84% of total CO, 92% of total HC, 32% of total NOx and 65% of total PM_{10} emissions within the analysis period and will further deteriorate the environment in the valley. However, the various alternative scenarios (Public Bus Penetration, Improved Fuel Economy, Electric motorbike and Hybrid Electric Car) developed in this study have indicated that if some policy interventions are made, both energy demand and emission level can be reduced significantly. (Bajracharya & Bhattarai, 2016).

Some research has been done on the effects of the transport sector electrification in Nepal using the hydropower resource of the country under three different scenario (electric vehicle penetration, electric mass transportation mainly Trolley bus & combined scenario).The alternative scenario have shown how to increase in energy consumption and pollutants levels can be limited through measures such as encouraging a shift to bues, reducing the population and substitution of electricity for diesel and gasoline vehicles. The study strengthens the advantages of implementation of hydroelectricity in transport sector to reduce the fossil fuel dependency and GHGs emissions which addresses the issue of energy security. (Dhital & Shakya,2012)

Transporting massive amounts of oil products is essential to optimize the total efforts from leaving origins (refineries) until reaching destinations (depots). Abduljabbar et al. in their research paper develop integer mathematical programming model to satisfy this oil transportation optimization problem. From a mathematical point of view, this paper presents a series of equations to modeling some aspects of the real transportation and attempts to optimize the transporting assignments from refineries to depots. The final objectives are to minimize the transportation distance and the transportation cost. The adopted approach is to run the program using I-log software. The outcomes of this study are highly feasible in reality to achieve the best refinery to depots assignments with the minimized transportation distance as well as the total transportation cost (Abduljabbar, Tahar, & Razik, 2011).

The study carried out by Bale et al. explores route and routing problems in road transportation system and focus on route optimization and its techniques. The techniques were categorized as hard computing (non-intelligent) and soft computing (intelligent) techniques Non-intelligent techniques include Dijkstra's Algorithm, A* search Algorithm, ALT, Arc Flags, Contraction Hierarchies. This computing techniques are suitable for deterministic and certainty conditions & optimization involving static distances, cost and defined constrains & is not suitable for dynamic and uncertainty conditions. Multi -criteria and scenario cannot be computed effectively. Intelligent techniques include Fuzzy Logic, ANN, GA, Ant Colony Algorithm, ABSE. This computing techniques are suitable for prediction, reasoning and adaptability & optimization involving dynamic traffic situations and events. But, this techniques requires hybridization for high performance especially in multi- scenario. (Bale , Ugwu, & Nwachukwu, 2016).

Finding an initial basic feasible solution is the prime requirement to obtain an optimal solution for the transportation problem. Ahmed et al. in their paper propose a new approach to find an initial basic feasible solution for the transportation problems. In the proposed approach, an allocation table is formed to find the solution for the transportation problem. That's why this method is named as Allocation Table Method (ATM). Efficiency of allocation table method has also been tested by solving several number of cost minimizing transportation problems and it is found that the allocation table method yields comparatively a better result. Also, the proposed allocation method provides comparatively a better initial basic feasible solution than the results obtained by other methods such as: North West Corner Method, Row Minimum Method, Vogel's

Approximation Method etc which are either optimal of near to optimal. (Ahmed M. M., Khan, Uddin, & Ahmed, 2016).

The study carried out by Aliyu et al. employ a transportation model to find the minimum cost of transporting manufactured goods from factories to warehouses to distributors. The data was modelled as a linear programming model of transportation type and represented as transportation tableau which was solved with R programming and TORA software version 1.0.0 to generate its initial basic feasible solution and optimal solution. From the result of analysis, it is shown that all three methods of initial basic feasible solution (North-West corner method, least cost (minimum) method and Vogel Approximation) method gave varying answers. And after the optimization, all the three methods gave the same result. This indicates that , all the three methods can be used to find an optimal (best) solution for a given transportation problem. (Aliyu, Usman, Babayaro, & Aminu, 2019).

The study carried out by Chimba et al. analyze integrating Origin-Destination (O-D) survey with Stiochastic User Equilibrium (SUE) in traffic assignment. The two methods are widely used in transportation planning but their applications have not yet fully integrated. While O-D gives a generalized trip patterns, purpose and characteristics, SUE provides optimal trip distributions using the characteristics found in O-D survey.Traffic assignment from the SUE was slightly different from those initially assigned using O-D, indicating there was optimization. The assignment on new route was increased by 13.8% from the one assigned using O-D while assignment on the existing link was reduced by 22%.The findings from this study showed the possible benefit of integrating O-D with other trip assignment optimization approaches. By integrating O-D survey with optimization algorithms like UE or SUE can result in a well-balanced links which take into account all possible con- strains.(Chimba et al.,2012).

2.2 Transport problem

The transportation problem is generalized network flow problem in which products are supplied to certain number of destinations in such a way as to maximize profit and minimize the cost. The objective in a transportation problem is to fully satisfy the destination requirements within the operating production capacity constraints at the minimum possible cost. It aims at providing assistance to the top management in ascertaining how many units of a particular product should be transported from each supply origin to each demand destinations to that the total prevailing demand for the company's product is satisfied, while at the same time the total transportation costs are minimized.

Mathematical Model of Transportation Problem

Mathematically a transportation problem is nothing but a special linear programming problem in which the objective function is to minimize the cost of transportation subjected to the demand and supply constraints.

Let a_i = quantity of the commodity available at the origin i,

b_j = quantity of the commodity needed at destination j,

c_{ij} = transportation cost of one unit of a commodity from origin I to destination j,

and x_{ij} = quantity transported from origin I to the destination j.

Mathematically, the problem is Minimize $z = \Sigma\Sigma\, x_{ij}\, c_{ij}$

S.t.

$\Sigma x_{ij} = a_i$ i= 1,2,…..m

$\Sigma x_{ij} = b_j$, j= 1,2,…..,n and $x_{ij} \geq 0$ for all i and j .

A typical transportation problem is shown below.

Table 2: A transportation matrix

					Supply
		D_1	D_2	D_3	
	S_1	3	1	M	5
	S_2	4	2	4	7
	S_3	M	3	3	3
Demand		7	3	5	

It deals with sources where a supply of some commodity is available and destinations where the commodity is demanded. The classic statement of the transportation problem uses a matrix with the rows representing sources and columns representing destinations. The algorithms for solving the problem are based on this matrix representation. The costs of shipping from sources to destinations are indicated by the entries in the matrix. If shipment is impossible between a given source and destination, a large cost of M is entered. This discourages the solution from using such cells. Supplies and demands are shown along the margins of the matrix. As in the example, the classic transportation problem has total supply equal to total demand.

The network model of the transportation problem is shown in Fig 2 below. Sources are identified as the nodes on the left and destinations on the right. Allowable shipping links are shown as arcs, while disallowed links are not included

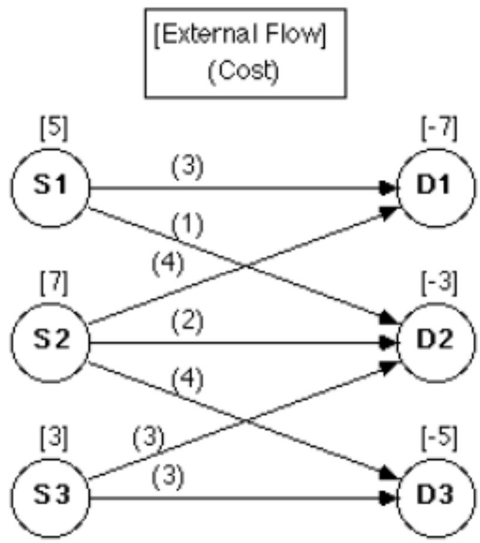


Figure 1: A network flow diagram

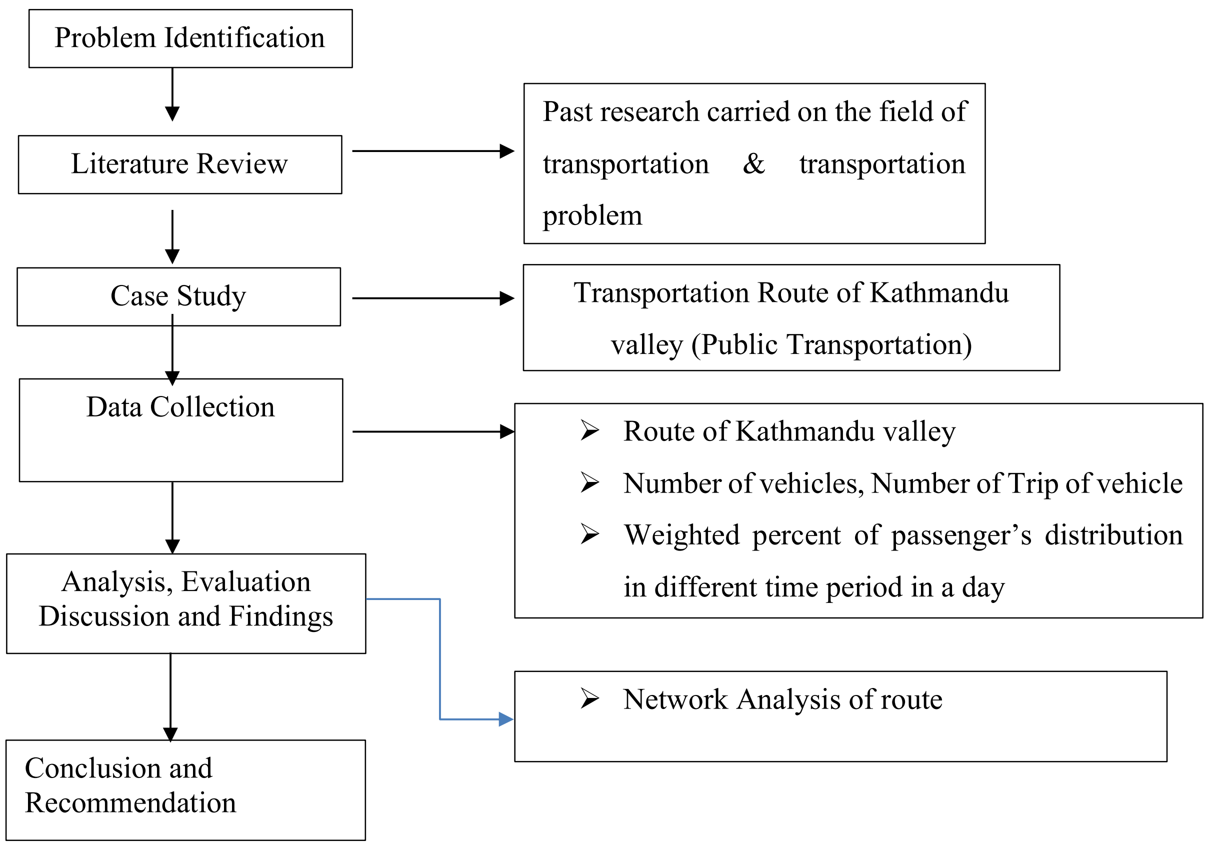
The circles in Figure 1 are called nodes in the terminology of network flow problems and the lines connecting the nodes are called arcs. The arcs in a network indicated the valid paths, routes or connections between the nodes in a network flow problem. When the lines connecting the nodes in a network are arrows that indicate a direction, the arcs in the network are called directed arcs. The nodes S1, S2 and S3 are supply nodes and D1, D2 and D3 are demand or receiving nodes.

CHAPTER THREE: METHODOLOGY

The chapter three deals with the methods used in my thesis. Since, my thesis is all about the route optimization of Public Transportation of Kathmandu Valley, extensive field-based survey has been done to acquire data. Network analysis tool of operation research has been used to analyze the data and find out the optimize solution.

3.1. Research Methodology

It mainly consists of following steps used in my research work.



3.2 Research Tool

Since, transportation network problem is the main aspects of my thesis. Network analysis of operation research tool has been used in my research work to find out the optimum solution of required number of vehicles needed in the Top 10 Routes of Kathmandu Valley.

3.3 Data Collection

- Only a few data was available regarding the Public Transport Route of vehicle plying on the Kathmandu Valley. Neverthless those few data was also very much difficult to find out. The list of public vehicle route plying on the Kathmandu valley was collected from Nepal Yatayat Mahasangh, Balkumari.
- To calculate the Travel Demand of route, the number of vehicles, number of vehicles available on the day, Number of Trip performed by vehicles, distance of route was necessary. The data regarding number of vehicles, number of vehicles available on the day, Number of Trip performed by vehicles was taken mostly from, field survey of vehicles & also from the vehicle associations office & Google map was used for finding out the distance of route.
- The population of ward of different Metropolitan city, Municipalities was taken from the central bureau of statistics.
- Extensive field survey was done for calculating the flow of passengers in different interval of time in a particular node among the 71 nodes available of the model.

3.4 Model Development

The objective of the model is to optimize the number of vehicles in Top ten routes of Kathmandu Valley in the present context. The main elements of the model are:

- **Decision Variable**

The decision variable are those variables in model which are subject to change and optimized and calculated by the solver. The decision variables are those set of matrix of required vehicle at different nodes at different time period of a day of a certain particular route in my model.

- **Objective Function**

The objective of the model is to minimize the total number of vehicles required in the Top ten routes of Kathmandu Valley.

- **Constraints**

A mathematical optimization model consists of an objective function and a set of constraints in the form of a system of equations or inequalities which should be satisfied.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1. Travel Demand of Routes of Kathmandu Valley

Urban public transportation in Kathmandu valley is mainly served by low occupancy bus, mini bus, micro bus, electric & gas tempo which are mostly operated by private vehicle associations. The list of public vehicle routes of Kathmandu Valley was taken from the data of Nepal Yatayat Mahasangha & Travel Demand of each route was calculated in passenger-km / year.

The Formula for Travel demand is:

$T.D = N_a * O_{av} * N_t * D_{ht} *2 *300$……………………………………(1)

Where,

N_a represents the number of available vehicles per day

O_{av} represents the weighted average occupancy

N_t represents the number of trip performed in a day

D_{ht} represents the half trip distance between a route

Note: Survey was done to find out the number of vehicles operating at each route, number of vehicles available at each route, Average trip per day of vehicle to calculate the travel demand.

The Figure 2 show that the majority of travel demand in route of study is fulfilled by Bus and Micro Bus followed by Tempo and Mini-Bus.

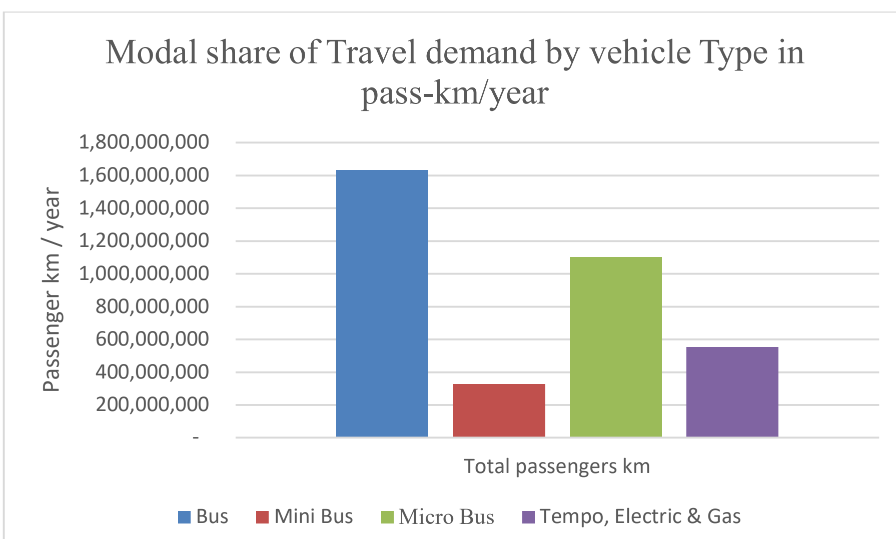


Figure 2: Modal share of Travel demand by vehicle Type in pass-km/year

(Modal share of Travel demand was calculated from the survey data of 163 routes of Kathmandu valley)

4.2 Result of Top Ten Routes of high travel demand

After calculating the travel demand of routes of Kathmandu valley, the top ten routes were calculated where the travel demand is more according to survey. The Top Ten routes are as follows & Table 3 shows the travel demand from Route 1 to Route 10 on decreasing order which mean that Route 1 has more travel demand and Route 10 has less travel demand.

Route 1 : Kirtipur – Ratnapark -Reverse
Route 2: Gopi Krishna -Balkumaripool-Reverse
Route 3: Kathmandu Bus park terminal-Ratnapark-Reverse
Route 4: Chyamasingh – Ratnapark-Reverse
Route 5: Lagankhel-RingRoad Round trip-Reverse
Route 6: RingRoad Right -Reverse
Route 7: RingRoad Left-Reverse
Route 8: Old bus park-Dakshinkali-Reverse
Route 9: Sankhu-Ratnapark-Reverse
Route 10: Madhyapur Thimi-Ratnapark-Reverse

Table 3: Top ten routes of Kathmandu Valley

S.N.	Route Description	Passengers km / year	Associations
1	Kirtipur-Balkhu-Kuleswor-Kalimati-Tripureshwor-NAC-Ratnapark-Old bus park-Reverse	139,986,630	Kirtipur yatayat committee
2	Gopikrishna-Teaching Hospital-Baluwatar- JayaNepal-Putalisadak-Anamnagar-Naya Baneswor-Koteswor-Balkumaripol-Reverse	103,456,786	Nepal yatayat mini bus committee
3	Kathmandu bus park terminal-Chabhil-Gaushala-Naya Baneswor- Maitighar-Singhadurbar-Old Buspark-Reverse	96,947,354	Madhya Upatyaka Bus Entrepreneurs Associations

S.N.	Route Description	Passengers km / year	Associations
4	Chayamasigh-Koteswor-Singhdurbar-Ratnapark-Old Bus park	88,474,090	Madhya Upatyaka Bus Entrepreneurs Associations
5	Langankhel-Ring Road Round Trip-Reverse	79,484,472	Lalitpur Mini bus Associations
6	Ring Road Right-Reverse	73,897,704	Upatyaka Swayambhu Bus sewa committee
7	Ring Road Left-Reverse	73,897,704	Upatyaka Swayambhu Bus sewa committee
8	Old bus park-Tripureswor-Kalimati-Balkhu-Dakshinkali-Sisneri-Reverse	68,755,338	Dakshinkali Bus sewa committee
9	Sakhu-Indrabati-Thali-Jorpati-Chabhil-Purano Baneswor-PutaliSadak-Old Bus Park-Reverse	57,577,896	Sakhu Bus Enterpreneurs Associations
10	MadhyapurThimi-Koteswor-Baneswor-Singhdurbar-NAC-Ratnapark	55,390,335	Thimi Mini Bus sewa samiti

4.3 Data of population of ward of Kathmandu valley

The different nodes of my thesis research work were identified. The total number of nodes were found to be seventy-one. Such nodes were grouped according to ward of different Metropolitan city, Municipality etc. Majority of nodes lies in Kathmandu Metropolitan City, other nodes lies in Lalitpur Metropolitan city, Madhyapur Thimi Municipality, Bhaktapur Municipality, Suryabinayak Municipality, Kirtipur Municipality, Gokarneshwor Municipality, Dakshinkali Municipality, Sankharapur Municipality, Kageswori-Monohara Municipality. The latest available data regarding the population of ward was the census data of 2067/68. Hence, this data was taken as bench mark value. & the data of 2075/76 fiscal year was taken for study by annual increasement of 4% of each year from 2067/68 to 2075/76 (The World Bank, 2013)

4.4 Nodes of Transportation Model

The number of nodes found in study is seventy-one and the classification of nodes according to different wards of different Metropolitan Cites & Municipalities was done as shown in Table 4.

Table 4: Nodes of Transportation model

Node no.	Node name	Ward number	Name of Metropolitan City/Municipality
1	Baluwatar	2	Kathmandu Metropolitan City
2	Narayan gopal chowk	3	
3	Teaching Hospital	3	
4	Basundhara	3	
5	Sukedhara	4	
6	Dhumbarahi	4	
7	Chapalkarkhana	4	
8	Gopikrishna	7	
9	Chabhil	7	
10	Tilganga	8	
11	Airport	8	
12	Gaushala	9	
13	Tripureshwor	11	
14	Bijulibazar	11	
15	Babarmahal	11	
16	Maitighar	11	
17	Bhadrakali	11	
18	Shahid gate	11	
19	Teku	12	
20	Kuleshwor	13	
21	Kalimati	13	
22	Balkhu	14	
23	Kalanki	14	
24	Swayambhu	15	

Node no.	Node name	Ward number	Name of Metropolitan City/Municipality
25	Machhapokhari	16	Kathmandu Metropolitan City
26	Balaju	16	
27	Banasthali	16	
28	Sitapaila	16	
29	Sundhara	22	
30	Gongabu	26	
31	Samakhusi	26	
32	Ratnapark	28	
33	Putalisadak	28	
34	Anamnagar	29	
35	Singhdurbar	29	
36	Dillibazar	30	
37	Naya baneshwor	31	
38	Shantinagar gate	31	
39	Purano Baneswor	31	
40	Tinkune	32	
41	Koteshwor	32	
42	Sinamangal	32	
43	Garighau	32	
44	Jadibuti	32	
45	Lagankhel	5	Lalitpur Metropolitan City
46	Ekantakuna	5	
47	Gwarko	7	
48	Balkumripol	8	
49	Satdobato	15	
50	Lokanthali	1	Madhyapur Thimi Municipality
51	Radhe-Radhe	3	
52	Sankhadhar Chwok	3	

Node no.	Node name	Ward number	Name of Metropolitan City/Municipality
53	Gothaghar	3	Madhyapur Thimi Municipality
54	Kosaltar	3	
55	Jagati	8	Suryabinayak Municipality
56	Chyamasingh	9	Suryabinayak Municipality
57	Srijananagr	5	
58	Suryabinayak	6	
59	Sallaghari	6	
60	Chobar	6	Kirtipur Municipality
61	Kirtipur bus park	10	
62	Tu gate	10	
63	Jorpati	6	Gokarneshwor Municipality
64	Chalnakhel	1	Dakshinkali Municipality
65	Sesnarayan	5	
66	Chaemale	8	
67	Dakshinkali Temple	6	
68	Sisneri	8	
69	Sankhu	6	Sankharapur Municipality
70	Indrayani	9	
71	Thali	9	Kageshwori-Monohara Municipality

4.5 Time distribution of population of each ward

The time duration of 15 hours of operation of public vehicles is considered in Kathmandu valley which start from 6 am to 9 pm. These total hours are divided into 5-time interval slots from 6 am to 9 am, 9 am to 12 pm, 12 pm to 3 pm, 3 pm to 6 pm & 6 pm to 9 pm. The flow of passengers / population of each ward at those time slots were given percentage weighted on the basis of survey carried at each node. A simple questionnaire as shown in ANNEX C asking the flow of passengers in those intervals of time in day was prepared. The survey questionnaire was asked to traffic police deployed at each node/place, local people at those nodes, driver, time keeper of vehicle etc. The Table 5 shows the weighted percentage of flow of passenger in each ward of different Metropolitan Cities, Municipalities.

Table 5:Weighted of time distribution of population/passengers in each ward

Ward No	6 am - 9 am	9 am- 12 pm	12 pm- 3 pm	3 pm - 6 pm	6 pm - 9 pm	Name of Metropolitan City/Municipality
2	14	31	13	35	8	Kathmandu Metropolitan City
3	13	26	18	35	9	
4	8	30	22	33	7	
7	15	26	19	33	8	
8	18	26	16	26	14	
9	13	26	18	33	11	
11	13	26	20	30	11	
12	14	29	20	33	5	
13	16	24	18	33	10	
14	13	24	21	30	13	
15	14	29	20	33	5	
16	13	28	15	33	12	
22	21	20	19	24	16	
26	19	24	18	25	15	
28	28	19	16	25	13	
29	16	25	18	35	6	
30	11	30	20	29	10	
31	9	29	19	28	14	
32	11	30	17	32	11	
5	6	30	24	33	8	Lalitpur Metropolitan City
7	9	33	23	31	5	
8	11	31	18	35	5	
15	13	25	23	35	5	

Ward No	6 am - 9 am	9 am- 12 pm	12 pm- 3 pm	3 pm - 6 pm	6 pm - 9 pm	Name of Metropolitan City/Municipality
15	13	25	23	35	5	Lalitpur Metropolitan City
1	15	35	13	33	5	Madhyapur Thimi Municipality
3	17	33	16	29	5	
8	10	33	16	33	9	Bhaktapur Municipality
9	13	31	15	36	5	
5	15	33	16	30	6	Suryabinayak Municipality
6	13	30	19	31	8	
6	13	33	23	26	6	Kirtipur Municipality
8	19	30	13	29	10	
10	18	20	24	26	13	
6	13	30	21	29	8	Gokarneshwar Municipality
1	15	33	19	29	5	Dakshinkali Municipality
5	14	35	13	33	6	
8	13	31	18	30	9	
6	15	23	20	30	13	
6	15	31	16	33	5	Sankharapur Municipality
9	14	34	14	34	5	
9	11	28	24	29	9	Kageswori-Monohara Municipality

The population distribution at different time slots of each ward was calculated using the percentage weightage of each ward. The Table 6 shows the flow of passengers at different interval of time in different wards of different metropolitan cities and municipalities.

Table 6: Time distribution of population of each ward

Ward no	6 am - 9 am	9 am- 12 pm	12 pm- 3 pm	3 pm - 6 pm	6 pm - 9 pm	Name of Metropolitan City/Municipality
2	2530	5751	2300	6441	1380	Kathmandu Metropolitan City
3	1988	4108	2783	5566	1458	
4	1800	6481	4681	7202	1440	
7	5294	9265	6618	11471	2647	
8	1285	1928	1194	1928	1010	
9	6906	14503	9668	17956	6215	Kathmandu Metropolitan City
11	523	1063	810	1198	455	
12	2495	5218	3629	5898	907	
13	4498	6574	4844	8997	2768	
14	5003	9506	8505	12008	5003	
15	10251	21434	14910	24230	3727	
16	3791	7944	4333	9389	3430	
22	2671	2514	2357	2986	2043	
26	5780	7321	5394	7707	4624	
28	3050	2079	1802	2773	1386	
29	3704	5699	3989	7979	1424	
30	3955	10549	7032	10109	3516	
31	2765	8797	5781	8546	4273	
32	2297	6265	3445	6682	2192	
5	273	1314	1040	1424	328	Lalitpur Metropolitan City
7	939	3491	2416	3356	537	
8	1755	4875	2730	5460	780	
15	2370	4741	4267	6637	948	
1	2927	6830	2439	6342	975	Madhyapur Thimi Municipality
3	1058	2078	980	1842	313	
8	916	2977	1488	2977	801	Bhaktapur Municipality
9	1408	3520	1689	4083	563	

Ward no	6 am - 9 am	9 am- 12 pm	12 pm- 3 pm	3 pm - 6 pm	6 pm - 9 pm	Name of Metropolitan City/Municipality
5	2167	4696	2348	4335	903	Suryabinayak Municipality
6	764	1834	1146	1911	458	
6	1245	3238	2242	2616	622	Kirtipur Municipality
10	1166	1332	1582	1749	833	
6	4789	11495	8142	11016	2873	Gokarneshwar Municipality
1	792	1717	990	1519	264	Dakshinkali Municipality
5	725	1846	659	1714	329	Dakshinkali Municipality
8	360	901	504	865	252	
6	666	1000	889	1333	555	
6	646	1346	700	1400	215	Sankharapur Municipality
9	632	1552	632	1552	229	
9	2093	5118	4420	5351	1628	Kageswori Municipality

4.6 Population of a node & effective population

The number of nodes which lies on a particular ward was found out. The Population of certain node was calculated by dividing the Total population of ward by the number of nodes in each ward.

Effective population is the population of people in a particular node that use public transportation. Effective population is 28% in a Kathmandu valley. (Sajha Yatayat, 2014). The Table 7 shows the effective population of Seventy-One nodes of model.

Table 7: Population of a node & effective population

Node no.	Node name	Ward number	Population	Effective population
1	Baluwatar	2	18405	5153
2	Narayan gopal chowk	3	15906	4454
3	Teaching Hospital	3	15906	4454
4	Basundhara	3	15906	4454
5	Sukedhara	4	21606	6050
6	Dhumbarahi	4	21606	6050
7	Chapalkarkhana	4	21606	6050
8	Gopikrishna	7	35296	9883
9	Chabhhil	7	35296	9883
10	Tilganga	8	7348	2057
11	Airport	8	7348	2057
12	Gaushala	9	55251	15470
13	Tripureshwor	11	4052	1135
14	Bijulibazar	11	4052	1135
15	Babarmahal	11	4052	1135
16	Maitighar	11	4052	1135
17	Bhadrakali	11	4052	1135
18	Shahid gate	11	4052	1135
19	Teku	12	18150	5082
20	Kuleshwor	13	27683	7751
21	Kalimati	13	27683	7751
22	Balkhu	14	40027	11208
23	Kalanki	14	40027	11208
24	Swayambhu	15	74554	20875
25	Machhapokhari	16	28891	8089
26	Balaju	16	28891	8089
27	Banasthali	16	28891	8089
28	Sitapaila	16	28891	8089
29	Sundhara	22	12573	3520

Node no.	Node name	Ward number	Population	Effective population
30	Gongabu	26	30828	8632
31	Samakhusi	26	30828	8632
32	Ratapark	28	11093	3106
33	Putalisadak	28	11093	3106
34	Anamnagar	29	22798	6383
35	Singhdurbar	29	22798	6383
36	Dillibazar	30	35164	9846
37	Naya baneshwor	31	30164	8446
38	Shatinagar gate	31	30164	8446
39	Purano Baneswor	31	30164	8446
40	Tinkune	32	20884	5848
41	Koteshwor	32	20884	5848
42	Sinamangal	32	20884	5848
43	Garighau	32	20884	5848
44	Jadibuti	32	20884	5848
45	Lagankhel	5	4382	1227
46	Ekantakuna	5	4382	1227
47	Gwarko	7	10742	3008
48	Balkumripol	8	15602	4368
49	Satdobato	15	18966	5310
50	Lokanthali	1	19516	5464
51	Radhe-Radhe	3	6274	1757
52	Sankhadhar Chwok	3	6274	1757
53	Gothaghar	3	6274	1757
54	Kosaltar	3	6274	1757
55	jagati	8	9161	2565
56	Chyamasingh	9	11266	3154
57	Srijananagr	5	14452	4047
58	Suryabinayak	6	6115	1712
59	Sallaghari	6	6115	1712

Node no.	Node name	Ward number	Population	Effective population
60	Chobar	6	9966	2790
61	Kirtipur bus park	10	6664	1866
62	Tu gate	10	6664	1866
63	Jorpati	6	38319	10729
64	Chalnakhel	1	5284	1480
65	Sesnarayan	5	5276	1477
66	Chaemale	8	2885	808
67	Dakshinkali Temple	6	4445	1245
68	Sisneri	8	2885	808
69	Sankhu	6	4310	1207
70	Indrayani	9	4600	1288
71	Thali	9	18613	5212

4.7 Time distribution of population of a node in a particular route

There are many nodes from which the vehicle travel to more than one route. So, the number of passengers in a particular route from a node was taken by calculating the average values in all routes from a node. The Table 8 shows the Travel Demand of Passengers at different interval of time at each node of study.

Table 8: Time distribution of population of a particular route

Node no.	Node name	Number of route from a place	Population of a particular route	6 am -9 am	9 am- 12 pm	12 pm- 3 pm	3 pm- 6 pm	6 pm - 9 pm
1	Baluwatar	2	2577	354	805	322	902	193
2	Narayan gopal chowk	7	636	79	164	111	222	58
3	Teaching Hospital	2	2227	278	575	389	779	204
4	Basundhara	5	891	111	230	155	311	81
5	Sukedhara	7	864	72	259	187	288	57
6	Dhumbarahi	7	864	72	259	187	288	57
7	Chapalkarkhana	7	864	72	259	187	288	57
8	Gopikrishna	6	1647	247	432	308	535	123
9	Chabhhil	7	1412	211	370	264	458	105
10	Tilganga	5	411	72	108	66	108	56
11	Airport	5	411	72	108	66	108	56
12	Gaushala	5	3094	386	812	541	1005	348
13	Tripureshwor	4	284	36	74	56	83	31
14	Bijulibazar	6	189	24	49	37	55	21

Node no.	Node name	Number of route from a place	Population of a particular route	6 am -9 am	9 am-12 pm	12 pm-3 pm	3 pm-6 pm	6 pm - 9 pm
15	Babarmahal	6	189	24	49	37	55	21
16	Maitighar	6	189	24	49	37	55	21
17	Bhadrakali	6	189	24	49	37	55	21
18	Shahid gate	1	1135	146	297	226	335	127
19	Teku	4	1270	174	365	254	412	63
20	Kuleshwor	4	1938	314	460	339	629	193
21	Kalimati	4	1938	314	460	339	629	193
22	Balkhu	7	1601	200	380	340	480	200
23	Kalanki	3	3736	466	887	793	1120	466
24	Swayambhu	3	6958	956	2000	1391	2261	347
25	Machhapokhari	3	2696	353	741	404	876	320
26	Balaju	3	2696	353	741	404	876	320
27	Banasthali	3	2696	353	741	404	876	320
28	Sitapaila	3	2696	353	741	404	876	320
29	Sundhara	7	503	106	100	94	119	81

Node no.	Node name	Number of route from a place	Population of a particular route	6 am -9 am	9 am- 12 pm	12 pm- 3 pm	3 pm- 6 pm	6 pm - 9 pm
30	Gongabu	4	2158	404	512	377	539	323
31	Samakhusi	5	1726	323	410	302	431	258
32	Ratapark	6	518	142	97	84	129	64
33	Putalisadak	4	777	213	145	126	194	97
34	Anamnagar	2	3192	518	797	558	1117	199
35	Singhdurbar	6	1064	172	265	186	372	66
36	Dillibazar	2	4923	553	1476	984	1415	492
37	Naya baneshwor	8	1056	96	307	202	299	149
38	Shatinagar gate	8	1056	96	307	202	299	149
39	Purano Baneswor	2	4223	387	1231	809	1196	598
40	Tinkune	8	731	80	219	120	233	76
41	Koteshwor	9	650	71	194	107	207	68
42	Sinamangal	5	1170	128	350	192	374	122
43	Garighau	5	1170	128	350	192	374	122
44	Jadibuti	4	1462	160	438	241	467	153

Node no.	Node name	Number of route from a place	Population of a particular route	6 am -9 am	9 am-12 pm	12 pm-3 pm	3 pm-6 pm	6 pm - 9 pm
45	Lagankhel	1	1227	76	368	291	398	92
46	Ekantakuna	3	409	25	122	97	132	30
47	Gwarko	3	1003	87	325	225	313	50
48	Balkumripol	4	1092	122	341	191	382	54
49	Satdobato	4	1328	165	331	298	464	66
50	Lokanthali	4	1366	204	478	170	443	68
51	Radhe-Radhe	2	878	148	290	137	257	43
52	Sankhadhar Chwok	3	586	98	193	91	171	29
53	Gothaghar	4	439	74	145	68	128	21
54	Kosaltar	4	439	74	145	68	128	21
55	jagati	2	1283	128	416	208	416	112
56	Chyamasingh	1	3154	394	985	473	1143	157
57	Srijananagr	2	2023	303	657	328	606	126
58	Suryabinayak	2	856	107	256	160	267	64
59	Sallaghari	2	856	107	256	160	267	64

Node no.	Node name	Number of route from a place	Population of a particular route	6 am -9 am	9 am- 12 pm	12 pm- 3 pm	3 pm- 6 pm	6 pm - 9 pm
60	Chobar	2	1395	174	453	313	366	87
61	Kirtipur	1	1866	349	559	233	536	186
62	Tu gate	4	466	81	93	110	122	58
63	Jorpati	2	5365	670	1609	1139	1542	402
64	Chalnakhel	2	740	110	240	138	212	36
65	Sesnarayan	2	739	101	258	92	240	46
66	Chaemale	2	404	50	126	70	121	35
67	Dakshinkali	2	622	93	140	124	186	77
68	Sisneri	1	808	100	252	141	242	70
69	Sankhu	1	1207	181	377	196	392	60
70	Indrayani	2	644	88	217	88	217	32
71	Thali	2	2606	293	716	618	749	228

4.8 Transportation cost

Generally, Transportation cost is the sum of fuel cost, capital cost & O&M (operation and maintenance cost). The following steps are followed for the calculation of transportation cost of a vehicle in a route of our model.

- ✓ For capital cost of a vehicle, the following process is adopted:
    1. Annualized cost of a vehicle is calculated from the formulae of PV of annuity i.e. PV of annuity = A* $\sum_{n=1}^{n=20} \frac{1}{(1+r)^n}$
    2. Where, PV of annuity is capital cost of vehicle, n = life period , r = discount rate, A= annualized cost
    3. Approximately value of capital cost is taken, For Bus, it is 32 lakh, For Mini bus, it is 29 lakh & For Micro bus, it is 26 lakh.
    4. Life period n = 20 years & Discount rate =10% is taken
- ✓ For O& M cost of a vehicle, O & M cost = 10 % of Capital cost is taken
- ✓ For fuel cost , the average fuel efficiency in km/ltr is taken as :
    1. For bus , it is 3.5 km/ltr
    2. For Mini bus, it is 4 km/ltr
    3. For Micro bus, it is 6.2 km/ltr

    (Bajracharya & Bhattarai, 2016)

The Table 9 shows transportation cost of a vehicle in different routes of study.

Table 9: Transportation cost of a vehicle in a route

Route	Type of vehicle	Capital cost (NRs)	Annuity cost (NRs)	Approx Capital Cost per day (NRs)	Approx Capital Cost per hr (NRs)	O & M cost per day (NRs)	Approx O&M Cost per hr (NRs)	Travelled distance (km)	Fuel consumped (litre)	Total Fuel cost (NRs)	Capital & O & M (NRs)	Total Transportation cost of a vehicle (NRs)
Route1: Kirtipur-Ratnapark-Reverse	Bus	3,200,000	**375,871**	1,253	**84**	**125**	**8**	176.4	50	4712.4	1378.19293	6091
Route 2: Gopikrishna-Balkumaripool-Reverse	Bus	3,200,000	**375,871**	1,253	**84**	**125**	**8**	155.2	44	4146.0571	1378.19293	5524
Route 3:Kathmandu Bus park-Ratnapark-Reverse	Bus	3,200,000	**375,871**	1,253	**84**	**125**	**8**	140.96	40	3765.6457	1378.19293	5144
Route 4:Chyamasingh -Ratnapark-Reverse	Bus	3,200,000	**375,871**	1,253	**84**	**125**	**8**	139.36	40	3722.9029	1378.19293	5101
Route 5: Lagankhel-Ring RoadRound Trip	Bus	3,200,000	**375,871**	1,253	**84**	**125**	**8**	125.2	36	3344.6286	1378.19293	4723

Route	Type of vehicle	Capital cost (NRs)	Annuity cost (NRs)	Approx Capital Cost per day (NRs)	Approx Capital Cost per hr (NRs)	O & M cost per day (NRs)	Approx O&M Cost per hr (NRs)	Travelled distance (km)	Fuel consumped (litre)	Total Fuel cost (NRs)	Capital & O & M (NRs)	Total Transportation cost of a vehicle (NRs)
Route 6: RingRoad Right-Reverse	Bus	3,200,000	**375,871**	1,253	**84**	**125**	**8**	116.4	33	3109.5429	1378.19293	4488
Route 7: RingRoad left-Reverse	Bus	3,200,000	**375,871**	1,253	**84**	**125**	**8**	116.4	33	3109.5429	1378.19293	4488
Route 8:Old bus park-Dakshinkali-Reverse	Bus	3,200,000	**375,871**	1,253	**84**	**125**	**8.4**	144.4	41	3857.5429	1378.19293	5236
Route 9: Sankhu-Ratnapark-Reverse	Mini bus	2,900,000	**340,633**	1,135	**76**	**114**	**8**	146.8	37	3431.45	1,248.99	4680
Route 9: Sankhu-Ratnapark-Reverse (Optimized scenario)	Bus	3,200,000	**375,871**	1,253	**84**	**125**	**8**	146.8	42	3921.6571	1378.19293	5300
Route 10 Madhyapur Thimi-Ratnpark-Reverse	Micro Bus	2,600,000	**305,395**	1,018	**68**	**102**	**7**	154.98	25	2337.1937	1,119.78	3457

Route	Type of vehicle	Capital cost (NRs)	Annuity cost (NRs)	Approx Capital Cost per day (NRs)	Approx Capital Cost per hr (NRs)	O & M cost per day (NRs)	Approx O&M Cost per hr (NRs)	Travelled distance (km)	Fuel consumped (litre)	Total Fuel cost (NRs)	Capital & O & M (NRs)	Total Transportation cost of a vehicle (NRs)
Route 10 Madhyapur Thimi-Ratnpark-Reverse (Optimized scenario)	Bus	3,200,000	**375,871**	1,253	84	**125**	**8**	154.98	44	4140.18	1,378.19	5518

4.9 Transportation Model

Transportation model used is a linear programming model. The model tends to optimize the required number of vehicles needed in a particular route in a day by finding out the number of vehicles needed at different time intervals in a day depending upon the average passengers' demand at such time intervals. Optimization is done on the basis of least cost method by fulfilling the travel demand at different interval of time in a day.

Table 10 :Different source nodes & destination nodes of Route 1

	From		To	
Route 1:Kirtipur-Ratnapark-Reverse	61	Kirtipur	62	TU.gate
	62	TU.gate	22	Balkhu
	22	Balkhu	20	Kuleshwor
	20	Kuleshwor	21	Kalimati
	21	Kalimati	19	Teku
	19	Teku	13	Tripureshwor
	13	Tripureshwor	29	Sundhara
	29	Sundhara	32	Ratnapark
	32	Ratnapark	29	Sundhara
	29	Sundhara	13	Tripureshwor
	13	Tripureshwor	19	Teku
	19	Teku	21	Kalimati
	21	Kalimati	20	Kuleshwor
	20	Kuleshwor	22	Balkhu
	22	Balkhu	62	TU.gate
	62	TU.gate	61	Kirtipur

4.9.1. Model Development

The following parameter are defined in our model.

- S_1, S_2, S_3.........S_i denotes the different source nodes of Route of study .For eg: In Route 1 as shown above in Table 10, S_1= Kirtipur, S_2 =TU gate , S_3 = Balkhu…. & i denote the number of source node in a particular route.
- D_1, D_2, D_3 ....D_j denotes the different destination nodes of Route of our study. For eg: In Route 1 as shown in Table 10, D_1=TU gate, D_2=Balkhu, D_3=Kuleshwor & j denotes the number of destination node in a particular route.

- Also, the representation between source node and destination node can be expressed as: $S_n = D_{n-1}$ where n=1,2,3,….
- S_iD_j represent routes linking source node S_i to destination node D_j where (i =1,2,3,……m , j=1,2,3……..m where m denotes the number of source node or destination node in a certain route.
- T_1 ,T_2, T_3 ,T_4 & T_5 represents the time interval of 3 hrs such that T_1 = 6 am-9 am,T_2 = 9 am – 12 pm,T_3 =12 pm – 3 pm , T_4= 3 pm – 6 pm , T_5 = 6 pm – 9 pm.
- **Matrix A** represents the travel demand of different source nodes of a particular Route of our study in a different interval of time in day.

$$A=\begin{bmatrix} S_1 \\ S_2 \\ S_3 \\ .. \\ .. \\ S_m \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{1n} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{2n} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{3n} \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ a_{m1} & a_{m2} & a_{m3} & a_{m4} & a_{mn} \end{bmatrix}$$

Where, the first row elements such as a_{11}, a_{12} , a_{13}…………….. a_{1n} represent the travel demand of first source node S_1 among different source node in the particular route of our study in a time interval T_1 ,T_2, T_3 ,T_4 & T_5 respectively. Similarly, The travel demand for others source nodes such as S_2 , S_3.........S_m are represented in a similar way.

- **Matrix B** represents the travel demand of different destination nodes of a particular Route of our study in a different interval of time in day.

$$B=\begin{bmatrix} D_1 \\ D_2 \\ D_3 \\ .. \\ .. \\ D_m \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} & b_{1n} \\ b_{21} & b_{22} & b_{23} & b_{24} & b_{2n} \\ b_{31} & b_{32} & b_{33} & b_{34} & b_{3n} \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ b_{m1} & b_{m2} & b_{m3} & b_{m4} & b_{mn} \end{bmatrix}$$

Where, the first row elements such as b_{11}, b_{12} , b_{13}…………….. b_{1n} represent the travel demand of first destination node D_1 among different destination nodes in the particular route of our study in a time interval T_1, T_2, T_3 ,T_4 & T_5 respectively. Similarly, The travel demand for others destination nodes such as D_2 , D_3.........D_m are represented in a similar way.

- **Matrix R** represents the average travel demand between different source node and destination node of a particular route at different interval of time in a day.

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{1n} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{2n} \\ r_{31} & r_{32} & r_{33} & r_{34} & r_{3n} \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ r_{m1} & r_{m2} & r_{m3} & r_{m4} & r_{mn} \end{bmatrix}$$

Where the first row elements such as r_{11} , r_{12} , r_{13}........r_{1n} represents the average travel demand between S_1D_1 at different interval of time such as T_1 ,T_2, T_3 ,T_4 & T_5 respectively. Similarly, Other different row elements upto mth row elements are represented in a similar way for S_2D_2 .... S_m D_m.

Mathematically,

For 1st row elements, $r_{1n} = \frac{a_{1n}+b_{1n}}{2}$ …………………(2) where n=1,2….5

For 2nd row elements, $r_{2n} = \frac{a_{2n}+b_{2n}}{2}$ ………………… (3) where n=1,2….5

………….. ………………… …………………….. …………………

For mth row elements, $r_{mn} = \frac{a_{mn}+b_{mn}}{2}$ ………………..(4) where n=1,2…..5

- **Matrix E** show the Theoretical calculation of required vehicles according to average travel demand of different source node & destination node of particular route in a different time interval of a day.

$$E = \begin{bmatrix} e_{11} & e_{12} & e_{13} & e_{14} & e_{1n} \\ e_{21} & e_{22} & e_{23} & e_{24} & e_{2n} \\ e_{31} & e_{32} & e_{33} & e_{34} & e_{3n} \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ e_{m1} & e_{m2} & e_{m3} & e_{m4} & e_{mn} \end{bmatrix}$$

Where , the first row elements such as e_{11} , e_{12} , e_{13}………..e_{1n} represent the theoretical calculation at time interval such as T_1 ,T_2, T_3 ,T_4 & T_5 respectively for route S_1D_1. Other different row elements upto mth row elements are represented in a similar way for S_2D_2 .... S_m D_m.

Mathematically,

For 1st row elements, $e_{1n} = \frac{r_{1n}}{Occupancy\ of\ a\ bus}$ ……………………… (5)

For 2nd row elements, $e_{2n} = \frac{r_{2n}}{Occupancy\ of\ a\ bus}$……………………….(6)

For mth row elements, $e_{mn} = \frac{r_{mn}}{Occupancy\ of\ a\ bus}$………………………(7)

Where n = 1,2,3,4 ,5

- **Matrix X** represents the optimum number of required vehicles between different source node & destination node of a particular route in a different interval of time in a day.

$$X=\begin{bmatrix} x_{11} & x_{12} & x_{13} & x_{14} & x_{1n} \\ x_{21} & x_{22} & x_{23} & x_{24} & x_{2n} \\ x_{31} & x_{32} & x_{33} & x_{34} & x_{3n} \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ x_{m1} & x_{m2} & x_{m3} & x_{m4} & x_{mn} \end{bmatrix}$$

Where, the first row elements such as : x_{11}, x_{12}......... x_{1n} represents the optimum number of required vehicles at time interval such as: such as T_1 ,T_2, T_3 ,T_4 & T_5 respectively in a day for route S_1D_1. Other different row elements upto mth row elements are represented in a similar way for S_2D_2 .... $S_m D_m$.

- **Matrix C** represents the transportation cost between different source node and destination node such as: S_1D_1, S_2D_2................. S_mD_m at different interval of time in a day.

$$C=\begin{bmatrix} c_{11} & c_{12} & c_{13} & c_{14} & c_{1n} \\ c_{21} & c_{22} & c_{23} & c_{24} & c_{2n} \\ c_{31} & c_{32} & c_{33} & c_{34} & x_{3n} \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ c_{m1} & c_{m2} & c_{m3} & c_{m4} & c_{mn} \end{bmatrix}$$

Where, the first-row elements such as: c_{11} , c_{12}............c_{1n} represents the transportation cost of a bus travelling through route S_1D_1 at different interval of time such as : T_1 ,T_2, T_3 ,T_4 & T_5 respectively in a day. Other different row elements from 2nd row upto mth row elements are represented in a similar way for S_2D_2 .... $S_m D_m$.

Mathematically,

For first Row elements,

$C_{1n}=C_{11}= C_{12} = C_{13}=C_{14}= C_{15}$ ....(8)

$C_{1n}=\sum(Total\ fuel\ cost\ )_{SmDm} + (Total\ capital\ \&\ O\ \&\ M\ cost)_T$ .... (9)

Where,

S_mD_m = S_1D_1 for 1st row elements & m=2,3…… for 2nd row elements, 3rd row elements respectively & the representation followed for other row elements upto mth row elements in a similar way.

T = Time period =T_1, T_2, T_3, ,T_4 & T_5 for row elements C_{11}, C_{12} , C_{13}, C_{14}, C_{15} respectively.

Similarly, for 2nd row elements upto mth row elements , the equation no (8) & (9) are modified accordingly in a similar way.

Objective Function:

Let, X_1 represents the total sum of transportation cost of a bus travelling through route S_1D_1 at time period T_1 ,T_2, T_3 ,T_4 & T_5

i.e. $X_1 = x_{11}c_{11} + x_{12}c_{12} + x_{13}c_{13} + x_{14}c_{14} + x_{15}c_{15} = x_{1n}c_{1n}$ where n= 1,2,3,4,5

$= (\sum_{n=1}^{n=5} x_{1n}\, c_{1n})$……………………………………………….(10)

Similarly, X_2 , X_3 ……….. X_m represents the transportation cost for route S_2D_2 , S_3D_3…. $S_m D_m$. respectively

Objective function is represented as:

- Minimize [($\sum_{n=1}^{n=5} x_{1n}\, c_{1n}$)+ ($\sum_{n=1}^{n=5} x_{2n}\, c_{2n}$)+………. ($\sum_{n=1}^{n=5} x_{mn}\, c_{mn}$)]

Decision variable is represented as:

- The decision variable is all the elements of Matrix X such as:

  x_{1n} where n=1,2,3,4,5 for 1st row elements

  x_{2n} where n=1,2,3,4,5 for 2nd row elements

  …………………

  …………………

  x_{mn} where n=1,2,3,4,5 for mth row elements

Constraints used in model are:

- (x_{1n} , x_{2n} ………….. x_{mn}) ≥ 0.
- $x_{1n} \geq e_{1n}$

  $x_{2n} \geq e_{2n}$

  …………….

  …………….

  $x_{mn} \geq e_{mn}$
- where n=1,2,3,4, & 5 & m=mth row of matrix

The following Figure 3 shows time distribution of population in a particular route. The flow of passengers or population in peak hour time such as 9 am-12 pm and 3 pm-6 pm is very high in comparison of other interval of time in different routes of study.

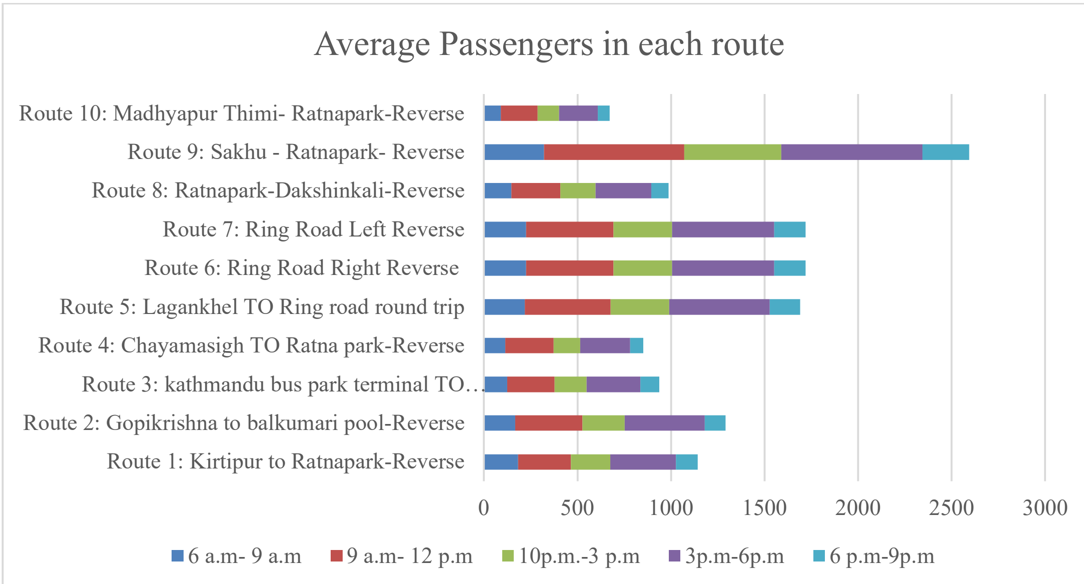


Figure 3:Average Passengers travel demand in each route

4.10. Result Analysis & Finding

4.10.1 Transportation Optimization Result

The present number of vehicle plying on the route is more in the Route 1, Route 2, Route 3, Route 4, Route 5, Route 6, Route 7, Route 8 & route 10 than the optimized number of vehicle as shown in Figure 4. This clearly shows that the requirement of number of vehicles is less according to the travel demands of passengers. The lesser number of vehicles signifies the low transportation cost, low energy consumption & low environment emissions. The requirement of vehicles is more in the route 9 than the number of running vehicles at that route as shown in Figure 4. This shows that the running number of vehicles at the present scenario are not enough to satisfy the travel demand of passengers. The effective population at nodes such as Jorpati, Chabhil, Dillibazar pipalbot, Purano baneswor are also found to be high which means the flow of passengers form these nodes are high.

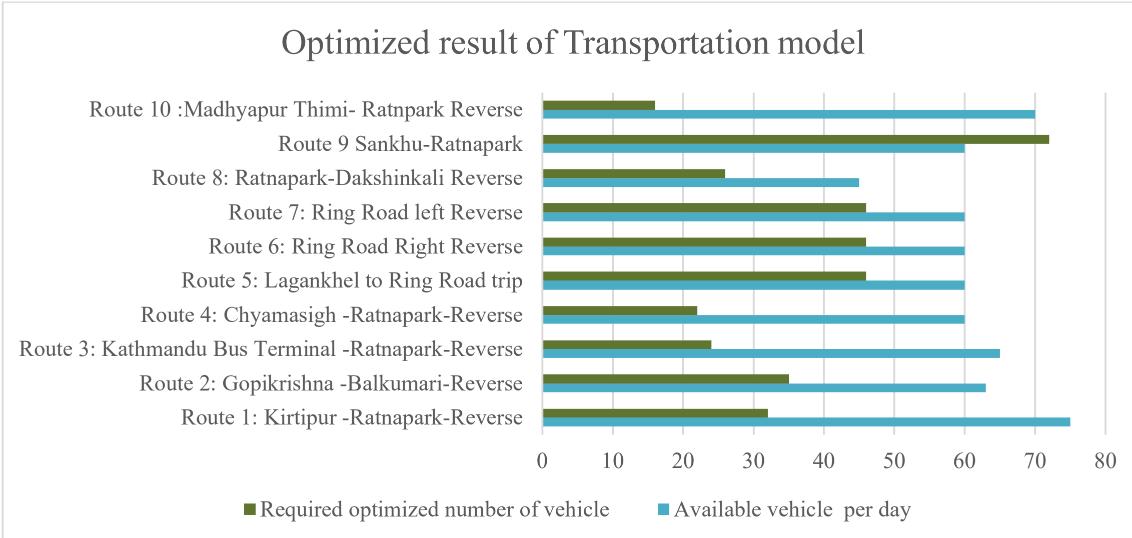


Figure 4:Optimization result of Transportation model

Also, the total number of vehicles plying on the route at present scenario is 618 & the number of vehicles required at optimized scenario decrease by 41% to 365.This clearly shows that the 253 number of vehicles can be reduced at optimized scenario which is positive result of optimization model as shown in Table 11.

Table 11: Optimization result of number of bus required at each route

Route Name	Available vehicle per day	Required optimized number of vehicle	Addition/Deduction needed
Route 1	75	32	43
Route 2	63	35	28
Route 3	65	24	41
Route 4	60	22	38
Route 5	60	46	14
Route 6	60	46	14
Route 7	60	46	14
Route 8	45	26	19
Route 9	60	72	-12
Route 10	70	16	54

Route Name	Available vehicle per day	Required optimized number of vehicle	Addition/Deduction needed
Total	618	365	253

Optimization of number of vehicles needed at different time slots:

The number of passengers utilizing the public transport is not same throughout the day Maximum number of passengers use public transport during peak hours which is between 9 to 12 pm, 3 pm to 6 pm. Similarly, at nodes where there is college, maximum people use public transport from 6 am to 9 am. So, the optimization is done to determine the number of vehicles required between different time slots of 3 hours in each route as shown in Figure 5.

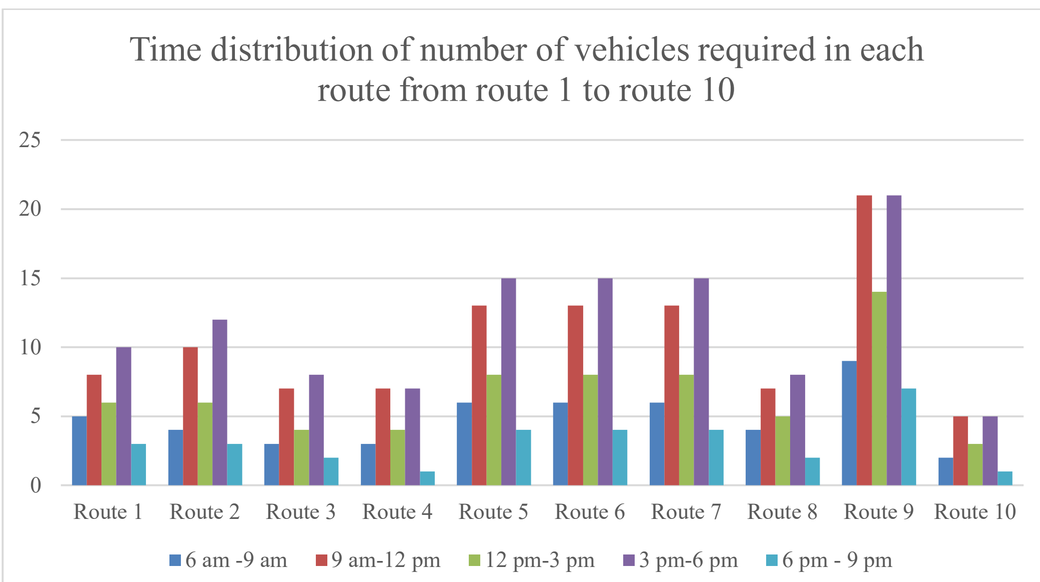


Figure 5: Time distribution of number of vehicles (buses) required from Route 1 to Route 10.

4.10.2 Comparison between the transportation cost of present scenario & optimized scenario

In the section 4.8, the transportation cost of a vehicle in a certain route From Route 1 to Route 10 is calculated. In the present scenario, the number of vehicles available per day is also know. Thus, the total transportation cost of all route is calculated. Similarly, optimized number of vehicles are known from the optimization model in all route. & the total transportation cost for all route is calculated. The transportation cost is more in Route 9 in the optimized scenario since the requirement of vehicles is more than the current operating vehicles at that particular route. Also, for Route 9 & for Route 10, in the optimized scenario, we have proposed bus in place of mini bus & micro bus respectively. Total transportation cost for all routes at present scenario is Rs. 30,25,558 for 618 number of vehicle & the total transportation cost for all routes at optimized scenario decrease by 39% to Rs.18,60,058 for 365 number of vehicles. The total saving is Rs.11,65,500 which is good. The Following Table 12 shows the comparison of total transportation cost between the present scenario and optimized scenario.

Table 12: Comparison of transportation cost between present scenario & optimized scenario

Description of Route	**Total Transportation cost at present scenario** (NRs)	**Total Transportation cost at optimised scenario** (NRs)	**Saving** (NRs)
Route1: Kirtipur-Ratnapark-Reverse	456,794	194,899	261,895
Route 2: Gopikrishna-Balkumaripool-Reverse	348,028	193,349	154,679
Route 3:Kathmandu Bus park-Ratnapark-Reverse	334,350	123,452	210,897
Route 4:Chyamasingh - Ratnapark-Reverse	306,066	112,224	193,842
Route 5: Lagankhel-Ring RoadRound Trip	283,369	217,250	66,120
Route 6: RingRoad Right-Reverse	269,264	206,436	62,828
Route 7: RingRoad left-Reverse	269,264	206,436	62,828
Route 8:Old bus park-Dakshinkali-Reverse	235,608	136,129	99,479
Route 9: Sankhu-Ratnapark-Reverse	280,826	381,589	(100,763)
Route 10 Madhyapur Thimi-Ratnpark-Reverse	241,988	88,294	153,694
TOTAL	3,025,558	1,860,058	1,165,500

4.10.3 Energy Consumption

Energy consumption of a vehicle is an amount of fuel consumed by it. It varies according to the fuel efficiency of a vehicle. The following Table 13 shows the amount of fuel consumed by a single vehicle in a particular route, it also shows the amount of fuel consumed by a bus in place of mini bus at Route 9 & in place of micro bus at Route 10 respectively.

Table 13: Energy consumption of a vehicle at present scenario at different route

Route name	Mode of vehicle	Trip distance(km)	No of Trip /day	Total distance travelled by a single vehicle (km)	Fuel consumed by a single vehicle (ltr)
Route 1: Kirtipur - Ratnapark-Reverse	Bus	25.2	7	176.4	50
Route 2: Gopikrishna -Balkumari-Reverse	Bus	38.8	4	155.2	44
Route 3: Kathmandu Bus Terminal - Ratnapark-Reverse	Bus	35.24	4	140.96	40
Route 4: Chyamasigh -Ratnapark-Reverse	Bus	34.84	4	139.36	40
Route 5: Lagankhel to Ring Road trip	Bus	31.3	4	125.2	36
Route 6: Ring Road Right Reverse	Bus	29.1	4	116.4	33
Route 7: Ring Road left Reverse	Bus	29.1	4	116.4	33

Route name	Mode of vehicle	Trip distance(km)	No of Trip /day	Total distance travelled by a single vehicle (km)	Fuel consumed by a single vehicle (ltr)
Route 8: Ratnapark-Dakshinkali Reverse	Bus	72.2	2	144.4	41
Route 9:Sankhu-Ratnapark-Reverse	Mini Bus	36.7	4	146.8	37
Route 9:Sankhu-Ratnapark-Reverse-Optimized	Bus	36.7	4	146.8	42
Route 10 :Madhyapur Thimi-Ratnpark Reverse	Micro Bus	22.14	7	154.98	25
Route 10 :Madhyapur Thimi-Ratnpark Reverse-Optimized	Bus	22.14	7	154.98	44

The following Table 14 shows the amount of energy consumption by vehicles at different routes in present scenario. The energy consumption is more in Route 1 and less in Route 10.

Table 14:Total energy consumption by vehicles at different routes in present scenario

	Present scenario Per day			
Route description	**Available vehicle per day**	**Total fuel required (ltr)**	**Total fuel required (kg)**	**Total energy consumed at present scenario (MJ)**
Route 1: Kirtipur - Ratnapark-Reverse	75	3780	3144.96	143,096
Route 2: Gopikrishna -Balkumari-Reverse	63	2794	2,324	105,755
Route 3: Kathmandu Bus Terminal - Ratnapark-Reverse	65	2618	2,178	99,101
Route 4: Chyamasigh -Ratnapark-Reverse	60	2389	1,988	90,439
Route 5: Lagankhel to Ring Road trip	60	2146	1,786	81,249
Route 6: Ring Road Right Reverse	60	1995	1,660	75,538
Route 7: Ring Road left Reverse	60	1995	1,660	75,538
Route 8: Ratnapark-Dakshinkali Reverse	45	1857	1,545	70,281

	Present scenario Per day			
Route description	**Available vehicle per day**	**Total fuel required (ltr)**	**Total fuel required (kg)**	**Total energy consumed at present scenario (MJ)**
Route 9 Sankhu-Ratnapark-Reverse	60	2202	1,832	83,359
Route 10 :Madhyapur Thimi-Ratnpark Reverse	70	1750	1,456	66,239
Total				890,594

The following Table 15 shows the amount of energy consumption by vehicles at different routes in optimized scenario. The energy consumption is more in Route 1 and less in Route 10.

Table 15 :Total energy consumption by vehicles at different route in optimized scenario

	Optimized scenario per day			
Route description	**Required optimized number of vehicle**	**Total fuel required (ltr)**	**Total fuel required (kg)**	**Total energy consumed at optimized scenario (MJ)**
Route 1: Kirtipur -Ratnapark-Reverse	32	1613	1342	61,054
Route 2: Gopikrishna -Balkumari-Reverse	35	1552	1291	58,753

	Optimized scenario per day			
Route description	**Required optimized number of vehicle**	**Total fuel required (ltr)**	**Total fuel required (kg)**	**Total energy consumed at optimized scenario (MJ)**
Route 3: Kathmandu Bus Terminal - Ratnapark-Reverse	24	967	804	36,591
Route 4: Chyamasigh -Ratnapark-Reverse	22	876	729	33,161
Route 5: Lagankhel to Ring Road trip	46	1645	1369	62,291
Route 6: Ring Road Right Reverse	46	1530	1273	57,912
Route 7: Ring Road left Reverse	46	1530	1273	57,912
Route 8: Ratnapark-Dakshinkali Reverse	26	1073	892	40,607
Route 9:Sankhu-Ratnapark-Reverse,Optimized	72	3020	2513	114,319
Route 10 :Madhyapur Thimi- Ratnpark Reverse,Optimized	16	708	589	26,820
			Total	549,420

The Following Table 16 shows the comparison of energy consumption at present scenario & optimized scenario. The saving of energy consumption is more in Route 1 whereas in Route 9, the energy consumption is more in optimized scenario & there is no saving of energy consumption at all. About 341 GJ of energy consumption can be saved which is equal to 38% of energy consumption at present scenario.

Table 16: Comparison of energy consumption at present scenario & optimized scenario

Route description	Total energy consumed at present scenario (MJ)	Total energy consumed at optimized scenario (MJ)	Saving in energy Consumption (MJ)
Route 1: Kirtipur - Ratnapark-Reverse	143,096	61,054	82,042
Route 2: Gopikrishna - Balkumari-Reverse	105,755	58,753	47,002
Route 3: Kathmandu Bus Terminal - Ratnapark-Reverse	99,101	36,591	62,510
Route 4: Chyamasigh - Ratnapark-Reverse	90,439	33,161	57,278
Route 5: Lagankhel to Ring Road trip	81,249	62,291	18,958
Route 6: Ring Road Right Reverse	75,538	57,912	17,625
Route 7: Ring Road left Reverse	75,538	57,912	17,625
Route 8: Ratnapark-Dakshinkali Reverse	70,281	40,607	29,674

Route description	Total energy consumed at present scenario (MJ)	Total energy consumed at optimized scenario (MJ)	Saving in energy Consumption (MJ)
Route 9: Sankhu-Ratnapark-Reverse	83,359	114,319	(30,960)
Route 10 :Madhyapur Thimi- Ratnpark Reverse	66,239	26,820	39,420
Total	890,594	549,420	341,174

4.10.4 Environment emissions

The environmental emissions of vehicles were calculated in terms of air pollutants gases such as CO_2, CH_4, N_2O, NMVOC, NO_X ,CO, SO_2 & also particulate matters such as $PM_{2.5}$.All the above mentioned GHG's emitting pollutants and particulate matters decrease by 57% , 44% , 66%, 62 %, 22%,20%, 20%, & 42 % in Route 1, Route 2, Route 3, Route 4, Route 5, Route 6, Route 7 &Route 8 respectively in optimized scenario. In case of Route 9, those gases & particulate matters under consideration except methane gas increases very high since we have considered bus to replace mini-bus & also the requirement of bus is high. Also, in case of route 10, air pollutants gases such as N_2O, NMVOC, NO_X, CO increases high in optimized scenario since micro-bus is replaced by bus in this route & also the emission factor of bus & mini-bus are very different for all those gases & particulate matters under consideration.

The emission factors of pollutants for different modes of vehicles vary accordingly as shown in Table 17.

Table 17: Emissions factor of pollutants for different modes of vehicles

Mode of vehicle	Pollutants	Type of Pollutants	Emission in g/kg of fuel	Mode of vehicle	Pollutants	Emission in g/kg of fuel
Bus	CO_2	Air Pollutant gases	3467	Mini /Micro Bus	CO_2	1875
	N_2O		0.23		N_2O	0.02
	CH_4		0.02		CH_4	0.59
	NO_x		55		NO_x	15.94
	CO		56.66		CO	14.14
	NMVOC		14.25		NMVOC	2.01
	SO_2		0.1		SO_2	0.1
	$PM_{2.5}$	PM	5.58		$PM_{2.5}$	6.94

(Sadavarte,2019)

The emissions of pollutants by vehicles at different routes for present scenario is shown in Table 18.

Table 18: Emissions of pollutants at present scenario in different routes

Route description	Mode of vehicle	Total fuel required (kg)	Pollutants	Emission in g/kg of fuel	Total emission at present scenario (grams)
Route 1: Kirtipur to Ratnapark-Reverse	Bus	3145	CO_2	3467	10,903,576
			CH_4	0.02	63
			N_2O	0.23	723
			NO_x	55	172,973
			CO	56.66	178,193
			NMVOC	14.25	44,816
			$PM_{2.5}$	5.58	17,549
			SO_2	0.1	314

Route description	Mode of vehicle	Total fuel required (kg)	Pollutants	Emission in g/kg of fuel	Total emission at present scenario (grams)
Route 2: Gopirishna to Balkumaripool-Reverse	Bus	2324	CO_2	3467	8,058,262
			CH_4	0.02	46
			N_2O	0.23	535
			NO_x	55	127,835
			CO	56.66	131,693
			NMVOC	14.25	33,121
			$PM_{2.5}$	5.58	12,969
			SO_2	0.1	232
Route 3: Kathmandu Bus Terminal - Ratnapark-Reverse	Bus	2,178	CO_2	3467	7,551,242
			CH_4	0.02	44
			N_2O	0.23	501
			NO_x	55	119,792
			CO	56.66	123,407
			NMVOC	14.25	31,037
			$PM_{2.5}$	5.58	12,153
			SO_2	0.1	218
Route 4: Chyamasigh - Ratnapark-Reverse	Bus	1,988	CO_2	3467	6,891,258
			CH_4	0.02	40
			N_2O	0.23	457
			NO_x	55	109,322
			CO	56.66	112,621
			NMVOC	14.25	28,324
			$PM_{2.5}$	5.58	11,091
			SO_2	0.1	199
Route 5: Lagankhel to Ring Road trip	Bus	1,786	CO_2	3467	6,190,963
			CH_4	0.02	36
			N_2O	0.23	411

Route description	Mode of vehicle	Total fuel required (kg)	Pollutants	Emission in g/kg of fuel	Total emission at present scenario (grams)
Route 5: Lagankhel to Ring Road trip			NO_x	55	98,213
			CO	56.66	101,177
			NMVOC	14.25	25,446
			$PM_{2.5}$	5.58	9,964
			SO_2	0.1	179
Route 6: Ring Road Right Reverse	Bus	1,660	CO_2	3467	5,755,815
			CH_4	0.02	33
			N_2O	0.23	382
			NO_x	55	91,309
			CO	56.66	94,065
			NMVOC	14.25	23,657
			$PM_{2.5}$	5.58	9,264
			SO_2	0.1	166
Route 7: Ring Road left Reverse	Bus	1,660	CO_2	3467	5,755,815
			CH_4	0.02	33
			N_2O	0.23	382
			NO_x	55	91,309
			CO	56.66	94,065
			NMVOC	14.25	23,657
			$PM_{2.5}$	5.58	9,264
			SO_2	0.1	166
Route 8: Ratnapark-Dakshinkali-Reverse	Bus	1,545	CO_2	3467	5,355,282
			CH_4	0.02	31
			N_2O	0.23	355
			NO_x	55	84,955
			CO	56.66	87,520
			NMVOC	14.25	22,011
			$PM_{2.5}$	5.58	8,619
			SO_2	0.1	154

Route description	Mode of vehicle	Total fuel required (kg)	Pollutants	Emission in g/kg of fuel	Total emission at present scenario (grams)
Route 9: Sankhu-Ratnapark-Reverse	Mini bus	1,832	CO_2	1875	3,435,000
			CH_4	0.59	1,081
			N_2O	0.02	37
			NO_x	15.94	29,202
			CO	14.14	25,904
			NMVOC	2.01	3,682
			$PM_{2.5}$	6.94	12,714
			SO_2	0.1	183
Route 10: Madhyapur Thimi- Ratnpark Reverse	Micro bus	1,560	CO_2	1875	2,925,000
			CH_4	0.59	920
			N_2O	0.02	31
			NO_x	15.94	24,866
			CO	14.14	22,058
			NMVOC	2.01	3,136
			$PM_{2.5}$	6.94	10,826
			SO_2	0.1	156

The emissions of pollutants by vehicles at different routes for optimized scenario is shown in Table 19.

Table 19: Emissions of pollutants at optimized scenario in different routes

Route description	Mode of vehicle	Total optimized fuel required (kg)	Pollutants	Emission in g/kg of fuel	Total emission at optimized scenario (grams)
Route 1: Kirtipur to Ratnapark-Reverse	Bus	1342	CO_2	3467	4,652,193
			CH_4	0.02	27
			N_2O	0.23	309
			NO_x	55	73,802
			CO	56.66	76,029
			NMVOC	14.25	19,121
			$PM_{2.5}$	5.58	7,488
			SO_2	0.1	134
Route 2: Gopirishna to Balkumaripool-Reverse	Bus	1291	CO_2	3467	4,475,897
			CH_4	0.02	26
			N_2O	0.23	297
			NO_x	55	71,005
			CO	56.66	73,148
			NMVOC	14.25	18,397
			$PM_{2.5}$	5.58	7,204
			SO_2	0.1	129
Route 3: Kathmandu Bus Terminal - Ratnapark-Reverse	Bus	737	CO_2	3467	2,555,805
			CH_4	0.02	15
			N_2O	0.23	170
			NO_x	55	40,545
			CO	56.66	41,769
			NMVOC	14.25	10,505
			$PM_{2.5}$	5.58	4,113
			SO_2	0.1	74

Route description	Mode of vehicle	Total optimized fuel required (kg)	Pollutants	Emission in g/kg of fuel	Total emission at optimized scenario (grams)
Route 4: Chyamasingh-Ratnapark-Reverse	Bus	762	CO_2	3467	2,641,649
			CH_4	0.02	15
			N_2O	0.23	175
			NO_x	55	41,907
			CO	56.66	43,172
			NMVOC	14.25	10,858
			$PM_{2.5}$	5.58	4,252
			SO_2	0.1	76
Route 5: Lagankhel to Ring Road trip	Bus	1399	CO_2	3467	4,849,587
			CH_4	0.02	28
			N_2O	0.23	322
			NO_x	55	76,933
			CO	56.66	79,255
			NMVOC	14.25	19,933
			$PM_{2.5}$	5.58	7,805
			SO_2	0.1	140
Route 6: Ring Road Right Reverse	Bus	1328	CO_2	3467	4,604,652
			CH_4	0.02	27
			N_2O	0.23	305
			NO_x	55	73,048
			CO	56.66	75,252
			NMVOC	14.25	18,926
			$PM_{2.5}$	5.58	7,411
			SO_2	0.1	133

Route description	Mode of vehicle	Total optimized fuel required (kg)	Pollutants	Emission in g/kg of fuel	Total emission at optimized scenario (grams)
Route 7: Ring Road Left Reverse	Bus	1328	CO_2	3467	4,604,652
			CH_4	0.02	27
			N_2O	0.23	305
			NO_x	55	73,048
			CO	56.66	75,252
			NMVOC	14.25	18,926
			$PM_{2.5}$	5.58	7,411
			SO_2	0.1	133
Route 8: Ratnapark-Dakshinkali Reverse	Bus	892	CO_2	3467	3,094,163
			CH_4	0.02	18
			N_2O	0.23	205
			NO_x	55	49,085
			CO	56.66	50,567
			NMVOC	14.25	12,718
			$PM_{2.5}$	5.58	4,980
			SO_2	0.1	89
Route 9: Sankhu-Ratnapark-Reverse	Bus	2513	CO_2	3467	8,712,571
			CH_4	0.02	50
			N_2O	0.23	578
			NO_x	55	138,215
			CO	56.66	142,387
			NMVOC	14.25	35,810
			$PM_{2.5}$	5.58	14,023
			SO_2	0.1	251

Route description	Mode of vehicle	Total optimized fuel required (kg)	Pollutants	Emission in g/kg of fuel	Total emission at optimized scenario (grams)
Route 10:Madhyapur Thimi-Ratnpark Reverse	Bus	589	CO_2	3467	2,042,063
			CH_4	0.02	12
			N_2O	0.23	135
			NO_x	55	32,395
			CO	56.66	33,373
			NMVOC	14.25	8,393
			$PM_{2.5}$	5.58	3,287
			SO_2	0.1	59

The Table 20 shows the comparison of environmental emissions between the present scenario & optimized scenario at different routes of study in terms of air pollutants and $PM_{2.5}$.

Table 20:Comparison of environment emissions between the present scenario & optimized scenario at different routes

Route description	Pollutants	Total emission at present scenario (grams)	Total emission at optimized scenario (grams)	% reduction in emission
Route 1: Kirtipur to Ratnapark-Reverse	CO_2	10,903,576	4,652,193	57%
	CH_4	63	27	57%
	N_2O	723	309	57%
	NO_x	172,973	73,802	57%
	CO	178,193	76,029	57%
	NMVOC	44,816	19,121	57%
	$PM_{2.5}$	17,549	7,488	57%
	SO_2	314	134	57%

Route description	**Pollutants**	**Total emission at present scenario (grams)**	**Total emission at optimized scenario (grams)**	**% reduction in emission**
Route 2: Gopirishna to Balkumaripool-Reverse	CO_2	8,058,262	4,475,897	44%
	CH_4	46	26	44%
	N_2O	535	297	44%
	NO_x	127,835	71,005	44%
	CO	131,693	73,148	44%
	NMVOC	33,121	18,397	44%
	$PM_{2.5}$	12,969	7,204	44%
	SO_2	232	129	44%
Route 3: Kathmandu Bus Terminal - Ratnapark-Reverse	CO_2	7,551,242	2,555,805	66%
	CH_4	44	15	66%
	N_2O	501	170	66%
	NO_x	119,792	40,545	66%
	CO	123,407	41,769	66%
	NMVOC	31,037	10,505	66%
	$PM_{2.5}$	12,153	4,113	66%
	SO_2	218	74	66%
Route 4: Chyamasigh - Ratnapark-Reverse	CO_2	6,891,258	2,641,649	62%
	CH_4	40	15	62%
	N_2O	457	175	62%
	NO_x	109,322	41,907	62%
	CO	112,621	43,172	62%
	NMVOC	28,324	10,858	62%
	$PM_{2.5}$	11,091	4,252	62%
	SO_2	199	76	62%
Route 5: Lagankhel to Ring Road trip	CO_2	6,190,963	4,849,587	22%
	CH_4	36	28	22%
	N_2O	411	322	22%
	NO_x	98,213	76,933	22%
	CO	101,177	79,255	22%
	NMVOC	25,446	19,933	22%

Route description	**Pollutants**	**Total emission at present scenario (grams)**	**Total emission at optimized scenario (grams)**	**% reduction in emission**
Route 5: Lagankhel to Ring Road trip	$PM_{2.5}$	9,964	7,805	22%
	SO_2	179	140	22%
Route 6: Ring Road Right Reverse	CO_2	5,755,815	4,604,652	20%
	CH_4	33	27	20%
	N_2O	382	305	20%
	NO_x	91,309	73,048	20%
	CO	94,065	75,252	20%
	NMVOC	23,657	18,926	20%
	$PM_{2.5}$	9,264	7,411	20%
	SO_2	166	133	20%
Route 7: Ring Road left Reverse	CO_2	5,755,815	4,604,652	20%
	CH_4	33	27	20%
	N_2O	382	305	20%
	NO_x	91,309	73,048	20%
	CO	94,065	75,252	20%
	NMVOC	23,657	18,926	20%
	$PM_{2.5}$	9,264	7,411	20%
	SO_2	166	133	20%
Route 8: Ratnapark-Dakshinkali Reverse	CO_2	5,355,282	3,094,163	42%
	CH_4	31	18	42%
	N_2O	355	205	42%
	NO_x	84,955	49,085	42%
	CO	87,520	50,567	42%
	NMVOC	22,011	12,718	42%
	$PM_{2.5}$	8,619	4,980	42%
	SO_2	154	89	42%

Route description	Pollutants	Total emission at present scenario (grams)	Total emission at optimized scenario (grams)	% reduction in emission
Route 9: Sankhu-Ratnapark-Reverse	CO_2	3,435,000	8,712,571	-154%
	CH_4	1,081	50	95%
	N_2O	37	578	-1477%
	NO_x	29,202	138,215	-373%
	CO	25,904	142,387	-450%
	NMVOC	3,682	35,810	-872%
	$PM_{2.5}$	12,714	14,023	-10%
	SO_2	183	251	-37%
Route 10:Madhyapur Thimi-Ratnpark Reverse	CO_2	2,925,000	2,042,063	30%
	CH_4	920	12	99%
	N_2O	31	135	-334%
	NO_x	24,866	32,395	-30%
	CO	22,058	33,373	-51%
	NMVOC	3,136	8,393	-168%
	$PM_{2.5}$	10,826	3,287	70%
	SO_2	156	59	62%

Shakya et al. (2013) has done similar type of research work regarding the Transportation Network of Pokhara Sub-Metropolitan City. The Study was done on to optimize the requirement of bus distribution in different Sixteen routes of Pokhara Sub-Metropolitan City based upon the distribution of passenger in different time duration. The optimization of distribution of Bus is done by using Premium solver in the Microsoft Excel spreadsheet platform. The result clearly shows that Out of 251 buses available from the Pokhara Bus Entrepreneurs Association, only 234 buses were required which further show the fact that the distribution of bus in some route was inadequate whereas in some route, the distribution of bus exceed the maximum number of required bus. In the same way, this thesis research work under the similar type of Transportation Optimization Model has shown that Out of 618 vehicles available at present scenario, about 41% of vehicles can be reduced at the optimized scenario. These facts justify & validate the results of Optimization Model used in thesis work.

Similarly, Bajracharya & Bhattarai has done research work regarding the Road Transportation Energy Demand and Environment Emission of Kathmandu Valley. They have used the modeling tool, long -range Energy Alternative Planning System (LEAPS) to develop the bottom-up model to estimate the energy demand and environmental emissions in the Kathmandu Valley for the period 2016-2030 AD. Under the alternative scenarios of Public Bus Penetration, about 18% of energy demand can be reduced in 2030 AD. Also, the emissions of local air pollutants such as: CO_2, CO, HC, NO_X reduced by 36%, 34%, 36%, & 22% respectively & PM_{10} by 30% in 2030 AD. In the same way, this thesis research work has also shown that About 38% of energy consumption can be saved in optimum scenario also the emissions of air pollutants gases & $PM_{2.5}$ can also be reduced significantly optimized scenario. These facts justify & validate the results regarding the energy consumption and environmental emissions.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The total number of vehicles plying on the route at present scenario is 618 & the number of vehicles required at optimized scenario is reduced by 41% to 365. This clearly shows that 253 number of vehicles can be reduced at optimized scenario. Comparison with present scenario shows the saving of Rs.11,65,000 in a optimized scenario which is equal to 39% of transportation cost at present scenario Also, About 341 GJ of consumption of energy can be saved in optimized scenario which is equal to 38% of energy consumption at present scenario. From the view of environmental emissions, local air pollutant gases & particulate matters $PM_{2.5}$ decreases by 57% , 44% , 66%, 62 %, 22%,20%, 20%, & 42 % in Route 1, Route 2, Route 3 , Route 4 ,Route 5, Route 6, Route 7 & Route 8 respectively in optimized scenario. In case of Route 9, those gases & particulate matters under consideration except methane gas increases very high. Also, in case of Route 10, the local air pollutants such as: N_2O, NMVOC, NO_X, CO increases high in optimized scenario.

5.2 Recommendations

- The optimization model is only performed for ten routes where travel demands is more in my study. Such works can also be performed for other routes also in future for determining the optimum number of vehicles required at other routes among 163 routes.
- This type of optimization model can be also applied on other cities of our country where there is more travel demand to find out the required optimum number of vehicles.
- Node such as; Jorpati has more flow of passengers. Hence, Department of Transport Management can allocate more buses upto this node.

5.3 Limitations

- The data regarding the public route of Kathmandu Valley was taken from Nepal Yatayat Mahasangh, Balkumari which contains about 160 routes of public transport route of valley. The research is done from the same data to calculate the Top Ten routes of valley. Other data regarding the Public transport route is so limited. Hence, the study regarding the route was only done from the available data from Nepal Yatayat Mahasangh.

- The study only covers the modes of public transportation such as : Bus, Mini-Bus, Micro-Bus & 3-wheeler tempo such as Gas & Electric.
- The study does not cover other modes of public transportation such as : Taxi & also other online public transportation (Ride sharing apps) such as : Tootle & Pathao.
- Microsoft Excel Solver Tools is only useful for solving low volume of simple input variables.

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Annex A. Travel demand of Routes of Kathmandu Valley

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
1	Kirtipur-Balkhu-Kuleswor-Kalimati-Tripureshwor-NAC-Ratnapark-Old bus park-Reverse	Bus	80	75	35.27	7	12.6	139,986,630	Kirtipur yatayat committee
2	Gopikrishna-Teaching Hospital-Baluwatar-JayaNepal-Putalisadak-Anamnagar-Naya Baneswor-Koteswor-Balkumaripol-Reverse	Bus	69	63	35.27	4	19.4	103,456,786	Nepal yatayat mini bus committee
3	Kathmandu bus park terminal-Chabhil-Gaushala-Naya Baneswor- Maitighar-Singhadurbar-Old Buspark-Reverse[3]	Bus	119	65	35.27	4	17.62	96,947,354	Madhya Upatyaka Bus Entrepreneurs Associations
4	Chayamasigh-Koteswor-Singhdurbar-Ratnapark-Old Bus park[7]	Bus	82	60	35.27	4	17.42	88,474,090	Madhya Upatyaka Bus Entrepreneurs Associations
5	Langankhel-Ring Road Round Trip-Reverse	Bus	86	60	35.27	4	31.3	79,484,472	Lalitpur Mini bus Associations
6	Ring Road Right-Reverse	Bus	60	60	35.27	4	29.1	73,897,704	Upatyaka Swayambhu Bus sewa committee
7	Ring Road Left-Reverse	Bus	60	60	35.27	4	29.1	73,897,704	Upatyaka Swayambhu Bus sewa committee
8	Old bus park-Tripureswor-Kalimati-Balkhu-Dakshinkali-Sisneri-Reverse	Bus	55	45	35.27	2	36.1	68,755,338	Dakshinkali Bus sewa committee

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
9	Sakhu-Indrabati-Thali-Jorpati-Chabhil-Purano Baneswor-Putali Sadak-Old Bus Park-Reverse	Mini Bus	60	60	21.79	4	18.35	57,577,896	Sakhu Bus Enterpreneurs Associations
10	Madhyapur Thimi-Koteswor-Baneswor-Singhdurbar-NAC-Ratnapark	Micro Bus	74	70	17.05	7	11.05	55,390,335	Thimi Mini Bus sewa samiti
11	Sundarijal-Gokarna-Boudha-Chabhil-Old Baneswor-Putali Sadak-Bagbazar-Old Bus Park-Tripureswor-Kalanki-Swayambhu-Kathmandu Bus Park Terminal-Reverse	Bus	40	31	35.27	3	27.9	54,909,041	City yatayat sewa committee
12	Tinchuli-Chabhil-Gaushala-Old Baneswor-Maitidevi-Putalisadak-NTB-NAC-Gayneswor-Reverse	Electric Tempo	80	60	11.07	10	13.3	53,003,160	Nepal safa paribahan Enterpreneurs Associations
13	D.Ring Road Round Trip	Mini Bus	85	75	21.79	4	27	52,949,700	Sada Yatayat P .ltd
14	Chayamasingh-Thimi-Koteswor-Gwarko-Balkhu-Kalanki-Reverse[6]	Bus	36	28	35.27	4	21.3	50,484,067	Madhya Upatyaka Bus Entrepreneurs Associations
15	Kathmandu Bus park Terminal-Narayan Gopal Chowk-Chabhil-Guashala-Koteswor-Naya Thimi-Jagati-Kamal Binayak	Bus	108	60	35.27	2	19.6	49,773,024	Bhaktapur Mini Bus Committee

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
16	NAC- Jamal-Sorhakhutte-Nayabazar- Balaju Chowk-Boharatar	Micro Bus	90	70	17.05	10	6.7	47,978,700	Balaju Micro bus service
17	Sakhu-Indrabati-Thali-Jorpati-Chabhil-Airport-Koteswor-Satdobato-Reverse	Micro Bus	55	55	17.05	3	28.3	47,768,985	Sakhu Bus Enterpreneurs Associations
18	Budanilkantha-Jamal-Shahidgate-Jamal-Reverse	Micro Bus	70	60	17.05	7	10.8	46,403,280	Budanilkantha mini bus entrepreneurs associations
19	Kalanki-Kalimati-Tripureswor-Thapathali-Naya Baneswor-Tinkune-Koteswor-Reverse	Micro Bus	56	50	17.05	7	11.7	41,891,850	Shree kalanki Sarbajanik Gas Micro bus Coordination Committee
20	G. Ring Road Round Trip	Micro Bus	90	75	17.05	4	27	41,431,500	Lalitpur Van Enterpreneurs Association
21	Thankot-Kalanki-Ratnapark-Old Bus Park-Shahidgate-Tripureswor-Reverse	Mini Bus	66	40	21.79	5	30.6	40,006,440	Thankot Mini bus sewa committee
22	Medical college- Jorpati-Mitrapark-Putalisadak-Ratopool-Dillibazar-Shahidgate-Ratnapark-Jamal- Krishnapauroti-Gyaneswor-Mitrapark-Jorpati-Medical College	Micro Bus	62	40	17.05	7	27.65	39,600,330	Jorpati Micro Bus Enterpreneurs Association

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
23	A.Lagankhel-Koteswor-New Baneswor-Maitighar-Lagankhel	Electric Tempo	155	90	11.07	5	13.2	39,453,480	Nepal Safa paribahan Entrepreneur associations
24	Kamalbinayak-Dudha Pokhari-Sallaghari-Naya Thimi-Koteswor- Naya Baneswor-Singha durbar-Putali Sadak-Bagbazar-Bhaktapur Bus park (Bagbazar)	Bus	59	35	35.27	3	17.6	39,107,376	Bhaktapur Mini Bus Committee
25	Jorpati-Ratopool-Ratnapark-Old Bus Park-Reverse	Bus	65	40	35.27	4	11.1	37,583,712	City yatayat sewa committee
26	Gurjudhara-Kalanki-Thapathali-Singhdurbar-Shahidgate-Thapathali-Reverse	Micro Bus	50	45	17.05	7	11.3	36,413,685	Gurjudhara Micro bus committee
27	H. Jorpati-Chabhil-Ring Road Round Trip	Bus	65	35	35.27	3	31.5	34,996,658	City yatayat sewa committee
28	Pepsicola-Jadibuti-Koteswor-Thapathali-Kalimati-Balkhu-Ekantakuna-Jawalakhel-Kopundole-Thapathali-Naya Baneswor-Koteswor-Jadibuti-Papsikola	Bus	36	32	35.27	3	34.1	34,637,962	Nepal yatayat mini bus committee
29	F.Ring Road Round Trip	Micro Bus	41	31	17.05	4	27	34,250,040	Upatyaka micro bus committee

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
30	Jorpati-Chabhil-Narayan Gopal Chowk-Maharaiganj-Kalanki-Reverse	Micro Bus	30	30	17.05	7	15.9	34,157,970	Valley Yatayat Enterpreneurs Associations
31	Ratnapark-Jamal-Nayabazar-Balaju-Mankakhel-Reverse	Bus	16	16	35.27	8	12.25	33,182,016	Balaju Mini bus service
32	Sakhu-Indrabati-Thali-Jorpati-Chabhil-Naya Baneswor-Reverse	Micro Bus	45	40	17.05	3	26.3	32,285,880	Sakhu Bus Enterpreneurs Associations
33	Gothatar-Pepsicola-Jadibuti-Koteswor-NayaBaneswor-Maitighar-Sinhadurbar-Shahidgate- Tripureswor-Thapathali-Maitighar-Naya Baneswor-Koteswor-Jadibuti-Pepsicola-Gothatar	Bus	27	22	35.27	4	33.75	31,425,570	Nepal yatayat mini bus committee
34	B.Lagankhel-Jawalakhel-Kopundole-Singhdurbar-NAC-Ratnapark-Singhdurbar-Reverse	Micro Bus	40	40	17.05	8	9.55	31,262,880	Lalitpur Van Enterpreneurs Association
35	Kapan-Chabhil-Gaushala-Ratopol-Maitidevi-Singhdurbar-Thapathali-Tripureswor-NAC-Jamal-Durbarmarg-Kamalpokhari Mitrapark-Ratopol-Gaushala-Chabhil-Kapan	Mini Bus	22	22	21.79	4	26.7	30,718,670	Kapan Baglamukhi Yatayat Enterpreneur

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
36	B. Kalanki-Kalimati-Tripureswor-Sundhara-NAC-Ratnapark-Reverse	Micro Bus	40	40	17.05	11	6.8	30,608,160	Shree kalanki sarbajanik gas micro bus coordination committee
37	Narayantar-Jorpati-Bouddha-Chabhil-Gaushala-Dillibazar-Putalisadak-Ghantaghar-Ratnapark	Micro Bus	54	50	17.05	6	9.96	30,567,240	Nepal micro bus entrepreneurs associations
38	**A. Lagankhel-Satdobato-Godabari-Reverse**	Micro Bus	40	40	17.05	9	8.2	30,198,960	Upatyaka Micro bus committee
39	Narayan Tar-Chabhil-Ratopool-Maitidevi-Dillibazar-Putalisadak-Ghantaghar-Ratnapark B-Reverse	Micro Bus	46	40	17.05	7	10.46	29,961,624	Nepal micro bus entrepreneurs associations
40	Macha Pokhari- Teaching Hospital-Jamal- Shahidgate-Ratnapark (Bhotahity side)-Jamal-Reverse	Micro Bus	45	35	17.05	7	11.15	27,945,803	Buddhanilkantha Micro bus Committee
41	A. lagankhel-Jawakhel-Kopundole-Singhdurbar-NAC-Ratnapark-Singhadurbar -Reverse	Micro Bus	41	41	17.05	7	9.5	27,892,095	Upatyaka Micro bus committee

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
42	A.Kalanki-Chakrapath-Satdobato-Lagankhel-Reverse	Micro Bus	40	40	17.05	3	22.7	27,866,520	Yatayat Entrepreneurs Associations
43	Kapan-Chabhil-Dillibazar-Ratnapark-Reverse	Micro Bus	35	35	17.05	10	7.7	27,569,850	Nepal micro bus entrepreneurs associations
44	Old bus park-Shahidgate-Tripureswor-Kalimati-Kalanki-Sitapaila-Bhimdhunga-Reverse	Bus	22	22	35.27	4	14.65	27,282,050	Upatyaka Swayambhu Bus sewa committee
45	Dudhpati-Sanothimi-Pepsicola-Koteswor-Chabhil	Bus	35	25	35.27	3	16.8	26,664,120	Madhyapur Bus sewa Committee
46	B. Hattigauda-Bansbari-Marajganj-Lazimpat-Lainchaur-Jamal-NAC-Reverse	Electric Tempo	66	60	11.07	7	9.4	26,222,616	Nepal Safa paribahan Entrepreneur associations
47	Khumaltar-Satdobato-Lagankhel-RatnaparkReverse	Micro Bus	60	45	17.05	8	7.1	26,147,880	Lalitpur Mini bus Associations
48	Kirtipur-Balkhu-Teku-Tripureswor-Thanpathali-Singhdurbar-Shahidgate-Tripureswor-Reverse	Micro Bus	26	26	17.05	7	13.05	24,297,273	Kirtipur Micro bus entrepreneurs associations
49	Swayambhu-Dallu-Sorakhutte-NAC-Sorakhutte- Naya Bazar-Banasthali-Swayambhu	Micro Bus	26	26	17.05	7	12.9	24,017,994	Balaju Micro bus sewa committee

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
50	Old bus park- Babarmahal-New Baneswar-Tinkune-Koteswor-Mulpani-NEC-Reverse[4]	Bus	20	16	35.27	4	17.1	23,159,693	Madhya Upatyaka Bus Entrepreneurs Associations
51	New Buspark, Machapokhari, Balaju Chowk, Vanasthali, Sano Bharyang, Thulo Bharyang, Halchowk, Sowyambhu, Sitapaila, Bafal , Kalanki, Khasibazar, Tyangla Fant Chowk,T .U. Gate, Balkhu, Naya Bato, Dhobighat, Patipa Chowk, Nakhu Chowk, Ekantakuna, Yatayat Office,Thasikhel, Mahalaxmithan, Tikhidewal, Satdobato, B & B Hospital, Gwarko Chowk, Balkumari Chowk, Kotwshwor, Tinkune, Gairigaun, Sinamangal, Airport Gate, International Terminal, Airport (Internal)	Bus	12	12	35.27	3	28.8	21,940,762	Sajha Yatayat
52	Old bus park-Tripureswor-Thapathali-Maitighar-Koteshwor-Thimi-Sallaghari-Suryabinayak-Chayamasingh- Tathali-Nala- Reverse[5]	Bus	18	16	35.27	3	21.4	21,737,606	Madhya Upatyaka Bus Entrepreneurs Associations

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
53	Ratnapark-Jamal-Nayabazar-Balaju-Golddhunga-Reverse	Bus	16	16	35.27	8	7.95	21,534,451	Balaju Mini bus service
54	Shova Bhagabati-Lainchaur-Jamal-Gyaneswor-Maitidevi-Old Baneswor-Bhimsengola-Sinamangal-Koteswor-Gwarko-Reverse-Maitidevi-Dillibazar-Putali Sadak-Ghantaghar-Jamal-Shova Bhagabati Reverse	Gas Tempo	45	45	11.07	4	17.55	20,982,078	New Annapurna tempo enterpreneurs associations
55	Balkhu-Kalanki-Swayambhu-Maharajganj -Chakrapath-Teaching Hospital- Kantipath-RatnaPark(B)-Reverse	Mini Bus	30	25	21.79	3	21.2	20,787,660	Kantipur Yatayat sewa committee
56	Dudhpokhari-Sanothimi-Pepsicola-Jadibuti-Koteswor-Naya Baneswor-Maitighar-Putalisadak-Bhaktapur Bus Park (Bagbazar)- Ratnapark Chwok--Reverse	Bus	30	21	35.27	3	15.5	20,664,693	Madhyapur Bus sewa Committee
57	Budanilkantha-Ratnapark-Reverse	Micro Bus	25	25	17.05	7	11.4	20,408,850	Budanilkantha Public Micro bus entrepreneurs associations

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
58	Patandhoka-Thapathali-Singhadurbar-Shahidgate-Ratanapark-Jamal-Lainchaur-Dhobichaur-Tukucha-Garighara-Tangal-Naxal-Jaynepal Hall-Jamal-Ghantaghar-NEA-Old bus park-Shahidgate-Tripureshwor-Thapathali-Patandhoka	Mini Bus	41	41	21.79	3	25.18	20,246,004	Lalitpur Bus Enterpreneurs Association
59	Kathmandu Bus Park Terminal-Kalanki-Tnpureswor-Jamal-Sano Gaucharan-Chabhil-Gopikrishna-Kapan-Reverse	Mini Bus	35	35	21.79	2	22.05	20,179,719	Samyukta Yatayat Operators Associations
60	Ratnapark-Jamal-Nayabazar-Balaju-Dharmasthali-Reverse	Bus	16	16	35.27	7	8.45	20,027,717	Balaju Mini bus service
61	Matatirtha-Satungal-Kalanki-Kalimati-Jamal-Ratnapark-Singhadurbar-Koteswor-Satdobato-Balkhu-Kalanki-Matatirtha	Mini Bus	60	40	21.79	3	12.6	19,767,888	Matatirtha Rajdhani Transport
62	Kapan-Chabhil-Mitrapark-Sano Gaucharan-Durbar Marg-Shahidgate-Jamal-Reverse	Bus	17	17	35.27	6	9.15	19,750,495	Bagamati Anchal yatayat enterpreneurs
63	**B. Lagankhel-Satdobato-Godabari-Reverse**	Micro Bus	26	26	17.05	9	8.2	19,629,324	Lalitpur Van Enterpreneurs Association

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
64	Ratnapark-Samakhusi-Tokha-Reverse	Micro Bus	40	34	17.05	10	5.6	19,477,920	BuddhaNilkantha Public Micro bus committee
65	Koteswor-New Baneswor-Maitighar-Kalanki-Naikaap-Reverse	Gas Tempo	48	48	11.07	5	12.2	19,447,776	Gas Yatayat Enterpreneurs Associations
66	Ratnapark-Jamal-Nayabazar-Balaju-Phutung-Reverse	Bus	16	16	35.27	8	7.15	19,367,462	Balaju Mini bus service
67	New Buspark, Gongabu Chowk, Samakhusi Chowk, Basundhara, Narayangopal Chowk, Teaching Hospital, Panipokhari, Lajimpat, Lainchaur, Jamal, Old Buspark, Sahidgate, Tripureshowr, Thapathali, Kupondol, Krishnagalli, Pulchowk, Jawalakhel, Kumaripati, Lagankhel	Bus	12	12	35.27	4	19	19,299,744	Sajha Yatayat
68	Ratnapark-Jawalakhel-Ekantakuna-Bungmati-Reverse	Bus	20	20	35.27	4	11.3	19,130,448	Lalitpur Mini bus Associations

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
69	Golphutar-Mandikhatar-Dhumbarahi-Gopikrishna Cinema Hall- Chabhil-Mitrapark- Siphal-Kalopool- Sano Gaucharan-Naxal-Jay Nepal Cinema hall- Durbar Marg-Old Bus Park- Shahid gate-Tripureswor- Teku-Kalanki-Naikaap-Reverse	Mini Bus	35	35	21.79	3	13.8	18,944,226	Janata Yatayat Sewa Committee
70	Lagankhel-Satdobato-Chapagaun-Reverse	Bus	35	25	35.27	4	8.9	18,834,180	Lalitpur Van Enterpreneurs Association
71	Lagankhel-Chapagaun-Lagankhel	Bus	35	25	35.27	4	8.7	18,410,940	Lalitpur Mini bus Associations
72	Khokana -Ekantakuna-Lagankhel-Reverse	Bus	40	35	35.27	4	6.1	18,072,348	Lalitpur Mini bus Associations

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
73	Sowyambhu, Sitapaila, Kalanki, Rabibhawan, Soltimode, Kalimati, Teku, Tripureshowr, N.A.C., Ratnapark, Bhrikutimandap, Sahidgate, Tripureshowr, Thapathali, Maitighar, Babarmahal, Bijulibazar, New Baneshowr, Minbhawan, Tinkune, Koteshowr, Jadibudi, Lokanthali, Kausaltar, Gathaaghar, TB Hospital, Thimi Bazar, Shyama Shyam Dham, Srijana Nagar, Sallaghari, Katunjechowk, Chundebi, Ghalate,Suryavinayak	Bus	10	10	35.27	3	28.3	17,966,538	Sajha Yatayat
74	Naya Basti-Chabhil-Ratopool-Matidev Chowk-Dilli Bazar-Shahidgate-Jamal-Gyaneswor-Ratopool-Reverse	Micro Bus	20	20	17.05	6	14.5	17,800,200	Jorpati Micro Bus Enterpreneurs Association
75	B. Lagankhel-Koteswor-New Baneswor-Maitighar-Lagankhel	Gas Tempo	40	40	11.07	5	13.2	17,534,880	Gas yatayat entrepreneur associatons/self employment transport entrepreneirs associatons

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
76	Tinkune-Sinamangal-Bhimsengola-Dillibazar-Ghantaghar-Ratnapark B-through Gyaneswor Reverse	Gas Tempo	39	39	11.07	7	9.65	17,498,017	New Annapurna tempo enterpreneurs associations
77	Lagankhel-Satdobato-Chapaguan-Lele- Reverse	Bus	22	19	35.27	3	14.4	17,369,770	Lalitpur Mini bus Associations
78	Kharibot-Pashupati Gaurighat-Mitrapark-Kalopol-Sano Gaucharan-NAC-Ratnapark- Jamal-Sano Gaucharan- Reverse	Micro Bus	17	17	17.05	7	14.15	17,225,786	Bishalnagar Sarbajanik Micro Association
79	**Kaushaltar-Koteswor-New Baneswor-Tnpureswor-Teku-Kalanki-Reverse**	Mini Bus	28	28	21.79	4	11.7	17,132,170	Bagamati anchal gas tempo enterprenuers associations
80	Aarubari-Chuchepati-Chabhil-Naya Baneswor-old bus park-Reverse[9]	Bus	20	15	35.27	4	13.45	17,077,734	Madhya Upatyaka Bus Entrepreneurs Associations
81	Ratnapark-Jamal-Nayabazar-Balaju-Mansingh-Reverse	Bus	16	16	35.27	8	5.95	16,116,979	Balaju Mini bus service
82	Lagankhel-Satdobato-Godabari-Reverse	Micro Bus	35	25	17.05	7	8.9	15,933,225	Lalitpur Mini bus Associations
83	Jorpati-Gaushala-Matidevi-Putali Sadak- Ghantaghar-Ratnapark-Jamal-Durbar Marg- Kamalpokhari-Gaushala-Chabhil-Jorpati	Micro Bus	35	35	17.05	4	22	15,754,200	Valley Yatayat Enterpreneurs Associations

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
84	Balaju Bipass-Baisa Dhara-Balaju-SorahaKhutte-Jarnal-Ratnapark Chowk-Shahidgate-Jamal-Reverse	Micro bus	36	30	17.05	6	8.55	15,743,970	Nepal Rastriya micro bus association
85	Mahadevsthan-Koteswor-Ratnapark-Reverse	Micro Bus	20	20	17.05	8	9.6	15,713,280	Nepal micro bus entrepreneurs associations
86	Narayansthan, Chapali Gaun, Ghumti, Italitar, Ganesh Chowk, Hattigauda, Especial Chowk, Golfutar, Neuro Hospital, Gangalal Hospital, Sallaghari, Narayangopal Chowk, Teaching Hospital, Panipokhari, Lajimpat, Lainchaur, Jamal, Old Buspark, Sahidgate, Tripureshowr, Thapathali, Kupondol, Krishnagalli, Pulchowk, Jawalakhel, Kumaripati, Lagankhel	Bus	12	12	35.27	3	20.6	15,693,739	Sajha Yatayat
87	Bagbazar Bus Park-Singhadurbar-Koteswor-Sallaghari-Nagarkot-Reverse	Mini Bus	26	20	21.79	2	30	15,688,800	Uttar Purbi Yatayat enterpreneur associations

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
88	Dhapasi-Nature Club-Teaching Hospital-Lazimpat-Lainchaur-Jamal-Ghantaghar- Ratnapark Chowk-NAC-Jamal-Reverse	Micro Bus	20	20	17.05	8	9.4	15,385,920	Basundhara Public Micro Bus Enterpreneurs Association
89	Lagankhel-Singhdurbar-NAC-Shahidgate-Tripureswor-Teku-Paropakar-Dallu-Reverse to Tripurswor-Thapathali-Lagankhel	Gas Tempo	35	35	11.07	3	22	15,343,020	Gas Yatayat Enterpreneurs Associations
90	Kapan-Gopikrishna-Chabhil-Bhatkekopol-Haadi Gaun-Ghantaghar-NEA-Shahidgate-NAC-Bus Ratnapark-Putalisadak-JayNepal Cinema hall-Naxal—Haadigaun-Reverse	Micro Bus	18	18	17.05	7	11.85	15,274,413	Bishalnagar Sarbajanik Micro Association
91	Kalopol-NAC-Kalopol	Gas Tempo	41	41	11.07	7	8	15,250,032	Bagamati anchal gas tempo enterprenuers associations
92	Sinamangal-Kharibot-Shantinagar GATE -New baneswor-Maitighar-Singh durbar-NAC-Ratnapark-Reverse	Micro Bus	16	16	17.05	4	23.1	15,124,032	Dakshinkali clean tempo & micro bus enterprenerus associations

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
93	Kapan-Sukedhara-Pipalbot-Haadigaun-Ghantaghar-NAC-Ratnapark-Putalisadak-JayNepal Cinema hall-Naxal Haadigaun-Reverse	Micro Bus	16	16	17.05	7	12.9	14,780,304	Bishalnagar Sarbajanik Micro Association
94	Golphutar-Dhumbarahi-Pipalbot-Bishalnagar-Naxal-NAC-Jamal-Naxal-Reverse	Micro Bus	15	15	17.05	6	16	14,731,200	Bishalnagar Sarbajanik Micro Association
95	J. Kapan-Gopikrishna Cinema Hall-Ring Road Round Trip	Micro Bus	25	25	17.05	4	28.5	14,577,750	Nepal micro yatayat P .ltd
96	Sitapaila-Chauni Museum-Tahachal Campus-Tankeswor/Bishnumati-KalimatiPool-Teku-Tripureswor-NAC-Shahidgate-Reverse	Electric Tempo	50	35	11.07	7	8.84	14,385,244	Nepal safa paribahan Enterpreneurs Associations
97	Bhaktapur Bus park (Bagbazar)- Singhdurbar-Bhadrakali-Maitighar-Baneswor-Koteswor-Naya Thimi-Dudha Pokhari (Bhaktapur)	Bus	30	15	35.27	3	15.1	14,379,579	Bhaktapur Mini Bus Committee
98	Balkhu-Kuleswor-Kalimati-Tripureswor-Shahidgate-NAC-Ratnapark-Reverse	Micro Bus	19	19	17.05	11	6.7	14,325,069	Dakshinkali clean tempo & micro bus enterprenerus associations

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
99	Mohanpokhari-Narayan Gopal Chowk-Teaching Hospital-Lazimpat-Lainchaur-Jamal-Ghantaghar-Ratnapark Chowk-Shahidgate-NAC-Jamal-Reverse	Micro Bus	22	20	17.05	8	8.75	14,322,000	Basundhara Public Micro Bus Enterpreneurs Association
100	Saibu-Ekantakuna-Jawalakhel-Singhdurbar-Ratnapark-Reverse	Bus	28	12	35.27	5	10.85	13,776,462	Lalitpur Mini bus Associations
101	Gothatar-Pepsicola-Koteswor-New Baneswor-Maitighar-Putali Sadak-Ratnapark-Singh Durbar-Reverse	Gas Tempo	21	21	11.07	6	16.3	13,641,340	Gas yatayat entrepreneurs associations
102	Kathmandu Bus Park Terminal-Samakhushi-Gongabu-Chakrapath-Lazimpat-Ratnapark- Old Bus Park-Singhdurbar-Maitighar-Naya Baneswor-Tinkune-Gaushala-Chabhil-Naya Bus Park	Mini Bus	33	25	21.79	3	13.8	13,531,590	Kantipur Yatayat sewa committee
103	Sinamangal-Bhimsengola-Battis Putali- Maitidevei Chowk-Dilli Bazar-Putali Sadak- Shahidgate-NAC-Reverse	Electric Tempo	35	35	11.07	7	8.1	13,181,049	Nepal safa paribahan Enterpreneurs Associations

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
104	Saraswotikhel-SanoThimi-Gathaghar-Koteswor-Naya Baneswor-Maitighar-Putalisadak-Bhaktapur Bus Park(Bagbazar)-Ratnapark Chowk-Reverse	Bus	16	13	35.27	3	15.9	13,122,556	Madhyapur Bus sewa Committee
105	Old Baneswor-Anamnagar-Putali Sadak-NTB-NAC-Reverse	Electric Tempo	76	50	11.07	7	5.6	13,018,320	Nepal safa paribahan Enterpreneurs Associations
106	Lagankhel-Jawalakhel-Pulchowk-Dhobighat-Sanepa-Kalimati-Paropakar(Tamsipakha)-Reverse	Electric Tempo	26	26	11.07	8	9.3	12,848,285	Nepal safa paribahan Enterpreneurs Associations
107	Lagankhel-Satdobato-Koteswor-Sallaghari-Dudhpokhari	Bus	30	17	35.27	3	11.9	12,843,218	Bhaktapur Mini Bus Committee
108	Gothatar-Pepsicola-Koteswor-New Baneswor-Maitighar-Putali Sadak-Ratnapark-Singh Durbar-Reverse	Mini Bus	20	20	21.79	3	16.3	12,786,372	
109	Nepaltar-Phutung-Dhapasi-Balaju-Gangabu-Basudhara Chowk-Reverse	Micro Bus	19	15	17.05	5	16.3	12,506,175	Basundhara Public Micro Bus Enterpreneurs Association
110	Lagankhel-Balkhu-Kirtipur-Reverse	Mini Bus	13	13	21.79	7	10.5	12,492,207	Lalitpur Mini bus Associations

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
111	A. Hattigauda-Ratnapark-Hattigauda	Gas Tempo	35	35	11.07	3	17.6	12,274,416	Gas yatayat entrepreneur associatons/self employment transport entrepreneirs associatons
112	Lagankhel-Ekantakuna-Jawalakhel-Bungmati-Reverse	Bus	12	12	35.27	5	9.6	12,189,312	Lalitpur Mini bus Associations
113	Greenland Chowk-Basundhara-Narayan Gopal Chowk-Teacing Hospital-Lazimpat-Lainchaur-Jamal-Ratnapark-Jamal-Reverse	Micro Bus	22	17	17.05	8	8.55	11,895,444	Basundhara Public Micro Bus Enterpreneurs Association
114	Chappal Karkhana-Chandol-Bishalnagar-Naxal- Ratopol-NAC-Reverse	Micro Bus	17	17	17.05	7	9.6	11,686,752	Bishalnagar Sarbajanik Micro Association
115	**Kaushaltar-Koteswor-New Baneswor-Tnpureswor-Teku-Kalanki-Reverse**	Gas Tempo	30	30	11.07	5	11.7	11,656,710	Bagamati anchal gas tempo enterprenuers associations
116	Sudal-Chyamasingh-Koteswor-Singh Durbar-Ratnapark-Reverse	Bus	12	9	35.27	3	20.3	11,598,892	Madhya Upatyaka Bus Entrepreneurs Associations
117	Kathmandu Bus park terminal-Balaju-Nayabazar-Jamal-Ratnapark-Reverse	Micro Bus	25	25	17.05	11	3.9	10,971,675	Balaju Mini bus service

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
118	A.Kalanki-Ratnapark-Kalanki	Gas Tempo	35	30	11.07	5	10.8	10,760,040	Gas yatayat entrepreneur associatons
119	A. Lagankhel-Gwarko-Luvu-Reverse	Bus	30	25	35.27	3	6.7	10,633,905	Lalitpur Mini bus Associations
120	Jorpati-Shakhu-Village Area	Mini Bus	25	20	21.79	4	9.8	10,250,016	Aama ghaylmo yatayat ltd
121	Nakkhu Chowk-Balkhu-Kalimati-Tripureswor-Shahidgate-NAC-Ratnapark-Reverse	Micro Bus	19	17	17.05	6	9.3	9,704,178	Dakshinkali clean tempo & micro bus enterprenerus associations
122	Gwarko-Mangal Bazar-Pulchowk-Kupondole-Tripureswor-Sundhara-NAC-Reverse	Electric Tempo	18	18	11.07	9	8.95	9,630,236	Nepal safa paribahan Enterpreneurs Associations
123	Nakhibot-Lagankhel-Thapathali-Singhdurbar-NAC-Old Bus-Reverse	Mini Bus	20	18	21.79	4	9.9	9,319,147	Lalitpur Mini bus Associations
124	Dudhpokhari-Sallaghari-Pepsicola-Jadibuti-Koteswor-Satdobato-Satdobato-Lagankhel-Reverse	Bus	15	11	35.27	3	13.2	9,218,167	Madhyapur Bus sewa Committee
125	Lagankhel-Satdobato-Dhapakhel-Reverse	Bus	28	20	35.27	4	5.2	8,803,392	Lalitpur Mini bus Associations
126	Mangal Bazar-Pulchowk-Kopundole-Thapathali-Tripureswor-NAC-	Electric Tempo	19	19	11.07	5	13.9	8,770,761	Nepal safa paribahan Enterpreneurs Associations

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
	JamakNaxal-Baluwatar-Reverse								
127	Gongabu-Kantipath-Ratnapark-Reverse	Micro Bus	15	15	17.05	12	4.75	8,746,650	Gongabu micro bus entrepreneurs committee
128	B. Mangal Bazar-Pulchowk-Kopundole- Thapathali-Tripureswor-NAC-Reverse	Gas Tempo	22	22	11.07	7	8.3	8,489,804	Gas yatayat entrepreneur association
129	Lagankhel-Satdobato-Sunakothi	Gas Tempo	30	30	11.07	8	5.2	8,289,216	Gas Yatayat Enterpreneurs Associations
130	Shankmul-Naya Baneswor-Old Baneswor- Gaushala-Chabhil-Jorpati-Reverse	Electric Tempo	26	26	11.07	4	12	8,289,216	Nepal safa paribahan Enterpreneurs Associations
131	Sahanshah-Samakhushi-Lainchaur-Jamal-Shahidgate-Jamal-Reverse	Micro bus	16	16	17.05	6	8.3	8,151,264	Samakhusi yatayat enterpreneurs association
132	Changunarayan-Bagbazar	Bus	12	10	35.27	2	17.4	7,364,376	Bhaktapur Mini Bus Committee
133	Kathmandu Bus park terminal-Chabhil-Gaushala-Koteswor-Surya Binayak-Kharipati	Bus	10	8	35.27	2	21.4	7,245,869	Bhaktapur Mini Bus Committee
134	Doleswar-Gongabu	Bus	10	6	35.27	2	27.4	6,958,066	Bhaktapur Mini Bus Committee

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
135	Dakshinkali-Balkhu-Satdobato-Lagankhel-Reverse	Bus	8	7	35.27	2	22.8	6,754,910	Lalitpur Mini bus Associations
136	Manmaiju-Samakhushi-Lainchaur-Jamal-Shahidgate-Jamal-Reverse	Micro bus	11	11	17.05	6	9.7	6,549,246	Samakhusi yatayat enterpreneurs association
137	NAC-Jamal-Gyaneswor-Maitidevi-Old Baneswor-Gaushala-Chabhil-Bouddha-Jorpati-Reverse	Gas Tempo	16	16	11.07	5	12.2	6,482,592	Gas Yatayat Enterpreneurs Associations/self employment transport entrepreneurs associations
138	Bagdole-Sanepa-Kopundole-Thapathali-Singhdurbar-NAC-Reverse	Electric Tempo	16	16	11.07	7	8.7	6,471,965	Nepal safa paribahan Enterpreneurs Associations
139	Khokana-Jawalakhel-Lagankhel-Reverse	Bus	12	12	35.27	4	6.3	6,399,389	Lalitpur Mini bus Associations
140	Doleswar-Kalanki	Bus	10	6	35.27	2	21.9	5,561,374	Bhaktapur Mini Bus Committee
141	Lagankhel-Satdobato-Gotikhel-Reverse	Mini Bus	6	6	21.79	2	33.3	5,224,370	Lalitpur Mini bus Associations
142	Old bus park-Kalanki-Dhugeadda-Naikap-Dahachowk-Reverse	Mini Bus	10	10	21.79	3	13.25	5,196,915	Dahachowk Yatayat sewa committee

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
143	Shankmul-New Baneswor-Maitighar-Ratnapark-Reverse	Micro Bus	9	9	17.05	11	5	5,063,850	Dakshinkali clean tempo & micro bus enterprenerus associations
144	Dipjyoti-Samakhushi-Lainchaur-Jamal-Shahidgate-Jamal-Reverse	Micro bus	9	9	17.05	6	9	4,971,780	Samakhusi yatayat enterpreneurs association
145	B. Kalanki-Chakrapath-Satdobato-Lagankhel-Reverse	Micro Bus	7	7	17.05	3	22.7	4,876,641	kalanki micro bus entrepreneur committee
146	Lagankhel-Jwalakhel-Bhaisepati-Reverse	Bus	10	9	35.27	5	4.6	4,380,534	Lalitpur Mini bus Associations
147	Ratnapark-Sinhadurbar-Kopundole-Jawalakhel-Lagankhel-Kusunti-Ranibuchowk-Reverse	Micro Bus	8	8	17.05	5	10.1	4,132,920	Lalitpur Van Enterpreneurs Association
148	Taudaha-Kirtipur-Balkhu-atnapark-Reverse	Gas Tempo	10	10	11.07	4	13.3	3,533,544	Gas Yatayat Enterpreneurs Associations
149	Sirutar-Balkot-Kaushaltar-Koteswor-Maitighar-NAC-Ratnapark-Old Bus park--Reverse	Bus	10	8	35.27	2	10.3	3,487,498	Bhaktapur Mini Bus Committee
150	Lagankhel-Satdobato-Godamchaur-Reverse	Bus	7	6	35.27	3	8.7	3,313,969	Lalitpur Mini bus Associations
151	Lagankhel-Satdobato-Damaitar	Bus	6	5	35.27	4	7	2,962,680	Lalitpur Mini bus Associations

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
152	Lagankhel-Gwarko-Tikathali	Gas Tempo	12	12	11.07	9	4.1	2,941,078	Gas Yatayat Enterpreneurs Associations
153	Lagankhel-Satdobato-Badhikhel-Reverse	Bus	6	4	35.27	3	10.7	2,717,201	Lalitpur Mini bus Associations
154	Chaughare-Bhardev-Lagankhel	Bus	2	2	35.27	2	27.6	2,336,285	Lalitpur Mini bus Associations
155	A.Mangal Bazar-Puichowk-Kopundole- Thapathali-Tripureswor-NAC-Reverse	Electric Tempo	5	5	11.07	7	8.3	1,929,501	Gas yatayat entrepreneur associatons
156	Imadole-Gwarko-Sundhara-Saugal Tole-Mangal Bazar-Pulchowk-Thapathali-Tripureswor- Ratnapark-Reverse	Electric Tempo	6	6	11.07	4	12.04	1,919,272	Nepal safa paribahan Enterpreneurs Associations
157	Lagankhel-Satdobato-Chapaguan-Manidada-Reverse	Bus	5	3	35.27	3	9.1	1,733,168	Lalitpur Mini bus Associations
158	Lagankhel-Chapagaun-Bajrabarahi	Micro Bus	9	6	17.05	3	8.8	1,620,432	Lalitpur Mini bus Associations
159	Harisiddhi-Lagankhel--Reverse	Bus	6	4	35.27	4	4	1,354,368	Lalitpur Mini bus Associations
160	Lagankhel-Jawalakhel-Bungrnati-Phasidole-Reverse	Bus	3	3	35.27	2	10	1,269,720	Lalitpur Mini bus Associations
161	Lagankhel-Champhi-Tika Thali-Reverse	Mini Bus	8	6	21.79	3	5	1,176,660	Lalitpur Mini bus Associations
162	Lagankhel-Gwarko-Shankdevi-Reverse	Bus	6	3	35.27	2	6.8	863,410	Lalitpur Mini bus Associations

S.N.	Route Description	Vehicle Type	Vehicle Nos	Available vehicles / day	Average Occupancy	Trip/day	Distance(Half Trip) in km	Passengers km / year	Associations
163	Lagankhel-Gwarko-Manedovan-Reverse	Bus	4	2	35.27	2	7	592,536	Lalitpur Mini bus Associations

ANNEX B: Calculation of weighted average occupancy

		Peak	Normal	Off Hrs		
Modes of vehicles	Occupancy	Occupancy 1	Occupancy 2	Occupancy 3	Weighted Average	Weighted
Bus	25	40	25	15	27.66667	0.255
Bus	35	50	35	21	37.13333	0.342
Bus	42	57	42	25.2	43.76	0.403
				Total	108.56	
Weighted Average occupancy for Bus		35.27				
		Peak	Normal	Off Hrs		
Modes of vehicles	Occupancy	Occupancy 1	Occupancy 2	Occupancy 3	Weighted Average	Weighted
Mini Bus	24	39	25	15	27.4	0.277
Mini Bus	22	37	35	21	33.66667	0.340
Mini Bus	20	35	42	25.2	37.89333	0.383
				Total	98.96	
Weighted Average occupancy for Mini Bus		21.79				
		Peak	Normal	Off Hrs		
Modes of vehicles	Occupancy	Occupancy 1	Occupancy 2	Occupancy 3	Weighted Average	Weighted
Micro BUS	18	33	18	10.8	21.04	0.524
Micro BUS	16	31	16	9.6	19.14667	0.476
				Total	40.18667	
Weighted Average occupancy for Micro bus		17.05				

		Peak	Normal	Off Hrs		
Modes of vehicles	Occupancy	Occupancy 1	Occupancy 2	Occupancy 3	Weighted Average	Weighted
Tempo	10	25	10	6	13.46667	0.467
Tempo	12	27	12	7.2	15.36	0.533
				Total	28.82667	
Weighted Average occupancy for Tempo, Gas & Electric		11.07				

	From	To	Total hrs	Weighted
Operating hrs of vehicles	6:00 AM	9:00 PM	15	
Peak hrs	9:00 AM	11:00 AM	2	
	4:00 PM	6:00 PM	2	
		Total	4	0.27
Normal hrs	7:00 AM	9:00 AM	2	
	11:00 AM	4:00 PM	5	
	6:00 PM	8:00 PM	2	
		Total	9	0.60
Off hrs	6:00 AM	7:00 AM	1	
	8:00 PM	9:00 PM	1	
		Total	2	0.13

Modes of Vehicles	Weighted Average Occupancy rate
Bus	35.27
Mini Bus	21.79
Micro Bus	17.05
Tempo	11.07

ANNEX C: Questionnaire of the survey for determining the flow of passengers in the Public Transportation during the various time of day

Node name :………………………..

1. What is the approximate number of flow of passengers during the entire full day in a given node?.............................
2. What is the approximate number of flow of passengers during the various time interval of day in a certain node?

Time Intervals	**Approximate number of flow of passengers**	**Approximate number of flow of passengers in terms of percentage**
6 am-9 am		
9 am-12 pm		
12 pm-3 pm		
3 pm-6 pm		
6 pm – 9 pm		