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PUBLIC TRANSPORTATION ENERGY PLANNING BY NETWORK ANALYSIS-A CASE STUDY OF KATHMANDU VALLEY

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Abstract

This paper is an attempt to find out the required optimum number of vehicles in the Top Ten Routes of Kathmandu Valley which was found from the 163 number of routes of our study on the basis of total travel demand measured in passenger-km per year. The transportation optimization model has been prepared on the Microsoft-Excel Spreadsheet & the optimization of distribution of vehicles is done by using Premium Solver. The results clearly show that the requirement of buses at some routes was less than the available buses plying on the route & the requirement of buses at some routes was more than the available buses plying on the route. The optimization is done on the basis of least cost methods fulfilling the travel demands of flow of passengers at different interval of time in a day at each route of our study. More number of required vehicles in the optimized scenario in the route means more transportation cost, more energy consumption & more environmental emissions than the present scenario & Lesser number of required vehicles in the optimized scenario in the route means lesser transportation cost, lesser energy consumption & lesser environmental emissions than the present scenario.

Keywords: *Travel demand, Transportation optimization model, Energy demand, Environmental Emission*

1. Introduction

Rapid population growth, urban sprawl, and increasing motorization in Kathmandu valley are creating complexity of traffic congestion, poor public transport system, pedestrian and vehicular conflict, and poor air quality. With the present trend of growth, the 2.6 million population of the valley from 2011 is slated to touch 4 million by the end of 2020[1].Vehicle population is growing at the rate of 12% annually in the valley[1].The composition of motorcycle is highest with 73.2% among registered vehicles in Kathmandu valley followed by car/ jeep/ van with share of 18.5%. Public transport constitutes only 2.5% of total passenger vehicles in Kathmandu valley [2]. Public vehicles operate at more than 200 routes in Kathmandu valley which is exclusively provided by the private sector. 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 [3]. Public transport is far better than private transportation from the viewpoints of reducing vehicle numbers, saving energy and meeting travel demand. However, the existing PT modes are not serving well, not sufficient, inefficient, overcrowded since those vehicles are poorly assigned to routes. Currently, routes are assigned by the Department of Transport Management through a complex and unscientific process and assignment of routes is not done until the vehicles are imported.

2. Literature Review

2.1 Transportation 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,…

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

A typical transportation problem is shown in Table 1 below.

Table 1: 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.

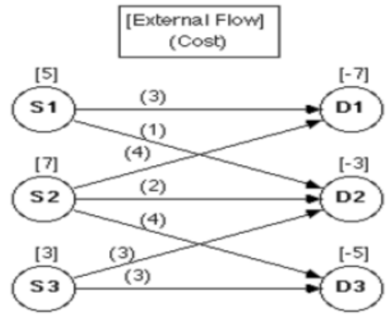

Figure 1: Network Flow Diagram

The circles in fig 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.

2.2 Past research done on Transportation sector problem

In paper [4], Shakya et al. performed transportation network analysis of Pokhara Sub-Metropolitan City. The required optimum number of vehicles running at different routes of Pokhara under Pokhara Bus Entrepreneurs' Association was found out by preparing the Transportation Optimization Model in the Microsoft Excel spreadsheet using premium Solver. The result clearly shows that Out of 251 buses available from the Pokhara Bus Entrepreneur's 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 paper [5], Jaramillo et al. developed a multi-objectives optimization model for the route optimization of urban public transportation based on operation research technique. They have used Software GAMS 22.7 and its solver CPLEX. In paper [6], Uddin.et al. performed the Minimization of a transportation cost by developing an efficient network model and found that the shortest route using the Network Model provides the effective minimum transportation. In paper [7], Bale et al. discusses the various routing problems in road transportation system and focused on route optimization and its techniques. The techniques were categorized as hard and soft computing; presenting their general strengths and weaknesses. Emphases were on Agent Based Soft Engineering (ABSE) which is the recent approach in solving route optimization problem. There are few projects going on within the valley such as: Urban Transport Improvement for Kathmandu valley & Kathmandu Sustainable Urban Transport Project (KSUTP) [8]. The KSUTP has proposed a three-tier hierarchy of public transport routes based on the demand and width of the road structures. The project has proposed 8 primary routes, 16 secondary routes and 40 tertiary routes plus two in historic areas. It has envisaged to operate higher capacity mass transit service with 12-18 m articulated buses with dedicated bus-lanes, 9-10 m buses in secondary routes providing feeder service to primary routes and low occupancy vehicles such as tempos, microbus and minibus in tertiary routes.

Similarly, there are many studies done in the past relating to energy demand and environmental emissions from transportation sector in the Kathmandu Valley. lastly, the research work regarding the efficient planning and management of public vehicles route in Kathmandu valley are rare & this research paper deals with route optimization of public vehicles route by finding out the required optimum number of vehicles based upon the travel demand of passengers in different intervals of time in a day.

3. Research Methodology

Research methodology follows commonly followed steps in research. The steps followed in this study are problem identification, literature review, case study, data collection, modeling, analysis, evaluation, and findings, conclusion and recommendation. The problem identification was the first step which deals with the identification of problems related to transport sector. The areas of our study were identified and the past research work relating to the same field was studied. & for this, different past research works, journal papers, conference papers, current projects relating to transportation problem was studied.

A case study of public transportation routes of Kathmandu valley was taken for study area.

3.1. Data collection

- The list of public routes of Kathmandu valley was taken from the Nepal Yatayat Mahasangha, Balkumari. The number of routes available was 163.
- To calculate the Travel demand of route, the number of vehicles, number of vehicle available on the day, Number of Trip performed by vehicle, distance of route was necessary. The data regarding number of vehicles, number of vehicle available on the day, Number of Trip performed by vehicle 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-node available of the model.

3.2. Model development

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.

The following parameter are defined in our model.

- S_1, S_2 ,S_3.........S_i denotes the different source nodes of Route of our study .For eg: In Route 1, 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, D_1=TU gate , D_2=Balkhu, D_3=Kuleshwor & j denotes the number of destination node in a particular route.
- S_iDj 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_5represents 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_1among 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_1among 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_1at different interval of time such as T_1,T_2, T_3, T_4&T_5 respectively. Similarly, Other different row elements uptomth row elements are represented in a similar way for S_2D_2 ………… S_mD_m.

Mathematically,

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

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

………….. ………………… …………………….. …………………

For mth row elements, $r_{mn} =\frac{a_{mn}+b_{mn}}{2}$………………..(3) 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 uptom[th] row elements are represented in a similar way for S_2D_2 .... S_mD_m.

Mathematically,

For 1[st] row elements, $e_{1n}=\frac{r_{1n}}{Occupancy\ of\ a\ bus}$ ………………………(4)

For 2[nd] row elements, $e_{2n}= \frac{r_{2n}}{Occupancy\ of\ a\ bus}$………………………(5)

For m[th]row elements, $e_{mn}= \frac{r_{mn}}{Occupancy\ of\ a\ bus}$………………………(6)

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 uptom[th] row elements are represented in a similar way for S_2D_2 .... S_mD_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_1at 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 2[nd] row uptom[th] row elements are represented in a similar way for S_2D_2 .... S_mD_m.

Mathematically,

For first Row elements,

$C_{1n}= C_{11} = C_{12}= C_{13}=C_{14}=C_{15}$……………………………………………………(7)

$C_{1n}= \sum\ (Total\ fuel\ cost\ )_{SmDm} + (Total\ capital\ \&\ O\ \&\ M\ cost)_{T}$…………………(8)

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 m th 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 m th row elements, the equation no (7) & (8) 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

$= \left(\sum_{n=1}^{n=5} x_{1n}\, c_{1n}\right)$……………………………………………….(9)

Similarly, X_2, X_3…………X_m represents the transportation cost for route S_2D_2, S_3D_3…. S_mD_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 m th 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 = m th row of matrix

4. Results and Discussions

4.1. Top Ten Routes of Kathmandu Valley.

The Top Ten Routes of Kathmandu Valley was calculated from the travel demand of each route in pass-km/year. Travel demand is calculated from the following equation:

The Formula for Travel demand in a certain route is: Available vehicle/day * Average Occupancy*Trip/day* Distance *2

The list of Top Ten Routes in order of decreasing order of travel demand are as follows:

Route1: Kirtipur-Balkhu-Kuleswor-Kalimati-Tripureshwor-NAC-Ratnapark-Old bus park-Reverse

Route 2: Gopikrishna - Teaching hospital- Baluwatar-JayaNepal-Putalisadak-Anamnagar-NayaBaneshwor-Koteshwor-Balkumaripol-Reverse

Route 3: Kathmandu bus park terminal-Chabhil-Gaushala-NayaBaneswor- Maitighar-Singhadurbar-Old Buspark-Reverse

Route 4: Chayamasigh-Koteswor-Singhdurbar-Ratnapark-Old Bus park-Reverse

Route 5: Lagankhel-RingRoad Round trip-Reverse

Route 6: Ring Road Right -Reverse

Route 7: Ring Road Left-Reverse

Route 8: Old bus park-Tripureswor-Kalimati-Balkhu-Dakshinkali-Sisneri-Reverse

Route 9: Sakhu-Indrabati-Thali-Jorpati-Chabhil-PuranoBaneswor-PutaliSadak-Old Bus Park-Reverse

Route 10: MadhyapurThimi-Koteswor-Baneswor-Singhdurbar-NAC-Ratnapark-Reverse

4.2 Average Passengers in each route

The vehicles are supposed to be operate from 6 am to 9 pm. The 15 hrs operational time period is divided into 5 time slots from 6 am-9am, 9 am-12 pm, 12 pm – 3 pm, 3 pm -6 pm & 6 pm – 9 pm. The distribution of passenger at peak office hours from 9 am-12pm& 3 pm-6 pm are very high. The average flow of passengers at different time intervals in a day in a certain route are as follows:

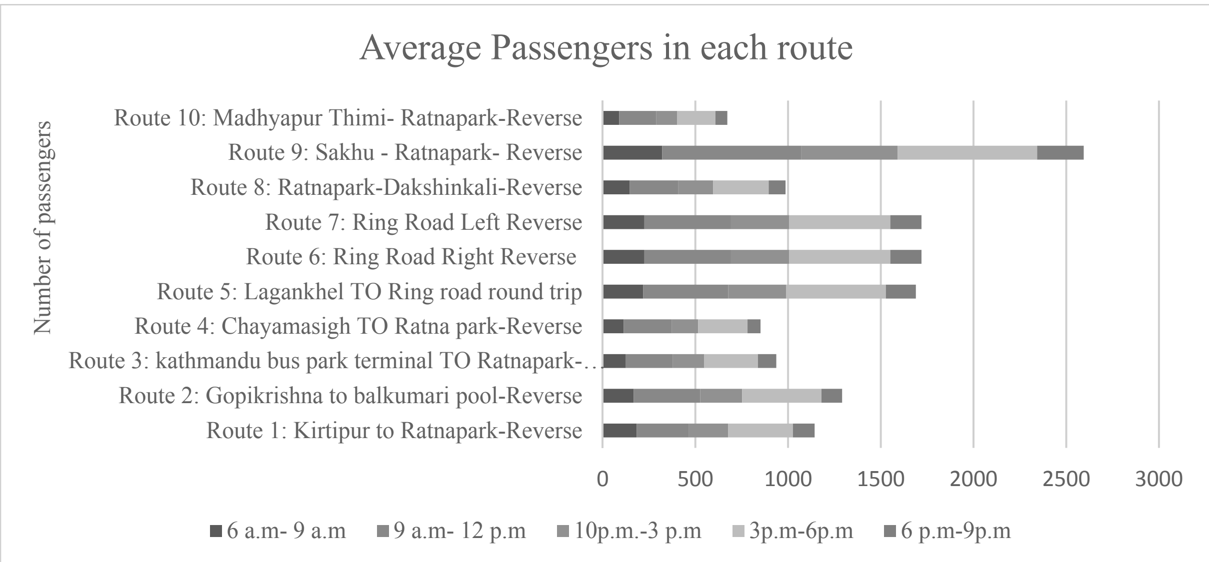

Figure 2: Average passengers flow in each route

4.3. Optimization of number of vehicles needed at different time slots:

The optimization is done to determine the number of vehicles required between different time slots in a day according to the travel demand of passengers.

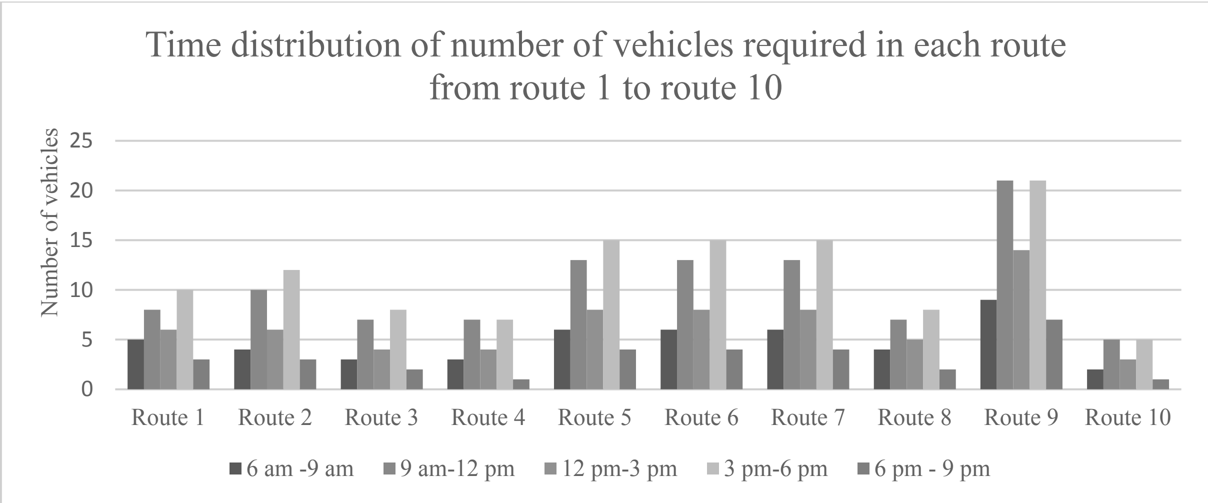

Figure 3: Time distribution of number of vehicles required in each route

4.4. 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 This clearly shows that the requirement of number of vehicles is less according to the travel demands of passengers . The requirement of vehicles is more in the route 9 than the number of running vehicles at that route. This shows that the running number of vehicles at the present scenario are not enough to satisfy the travel demand of passengers

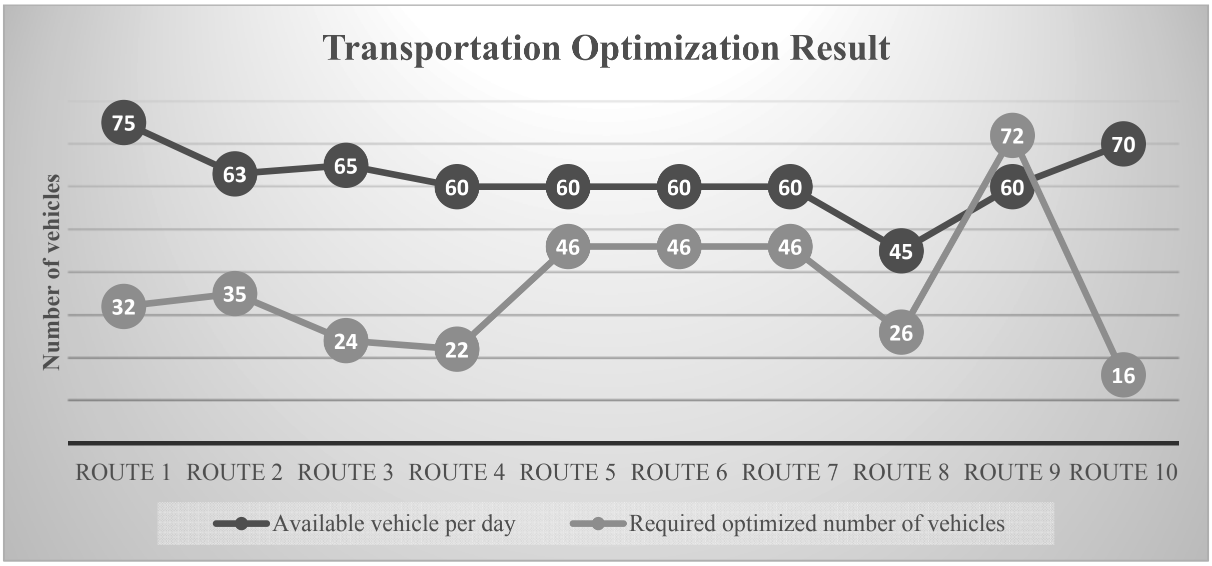

Figure 4: Optimized result of Transportation Model

Also, the total number of vehicles plying on the route at present scenario is 618 & the number of vehicles required at optimized scenario is 365.This clearly shows that the 253 number of vehicles can be reduced at optimized scenario which is positive result of optimization model.

4.5. Comparison of Transportation cost between the present scenario & optimized scenario.

The transportation cost of a vehicle in a certain route From Route 1 to Route 10 was 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 is Rs.18,60,058 for 365 number of vehicles. The total saving in a day is Rs.11,65,500 which is good.

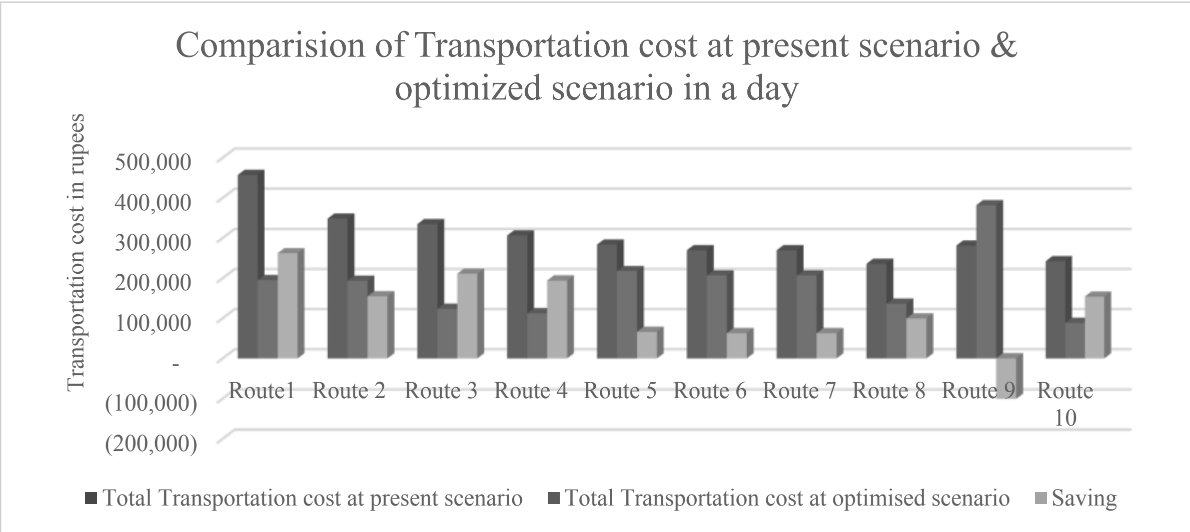

Figure 5: Comparisons of transportation cost at present scenario & optimized scenario.

4.6 Comparisons of Energy Consumption at present scenario & optimized scenario in day.

Energy consumed by a single vehicle at a particular route was calculated. It depends upon the vehicle kilometre travelled (VKT) & fuel efficiency (ltr/km). The number of vehicles in a certain route at the present scenario is also known & the required number of vehicles in a particular route at the optimized scenario is also found out. The total energy Consumptions by vehicles at different routes is 890,594 MJ at present scenario which is reduced to 549,420 MJ at optimized scenario. The amount of energy consumption that can be saved is 341,174 MJ.

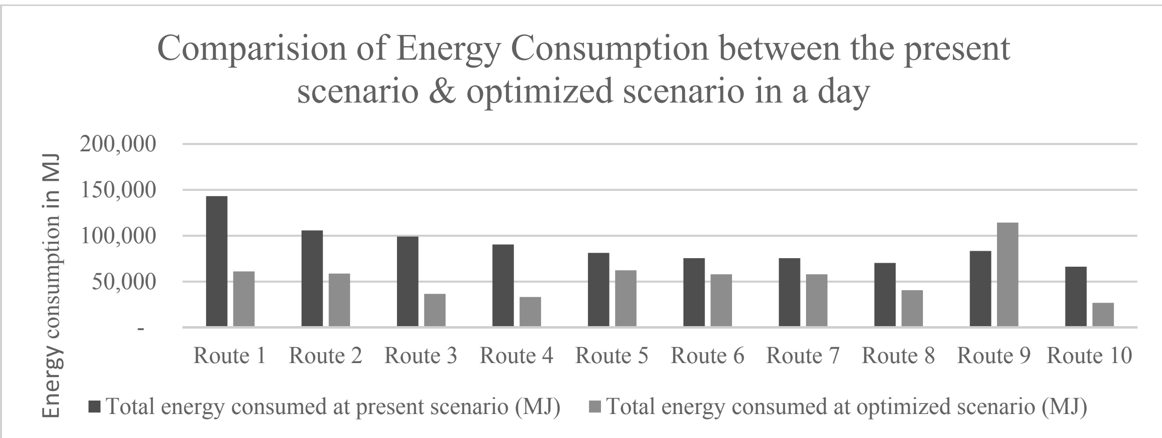

Figure 6: Comparison of energy consumption between the present scenario & optimized scenario

4.7 Environmental emissions

The environmental emissions of vehicles were calculated in terms of direct GHG's emitting pollutants such as CO_2, CH_4, N_2O, indirect GHG's emitting pollutants such as 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, the direct GHG's emitting pollutants except CO_2&CH_4 i.e. N_2O gas increases high in optimized scenario & also, the indirect GHG's emitting pollutants such as NMVOC,NO_X,CO increases high in optimized scenario since we have considered bus to replace micro-bus in this route & also the emission factor of bus & mini-bus are very different for all those gases & particulate matters under consideration.

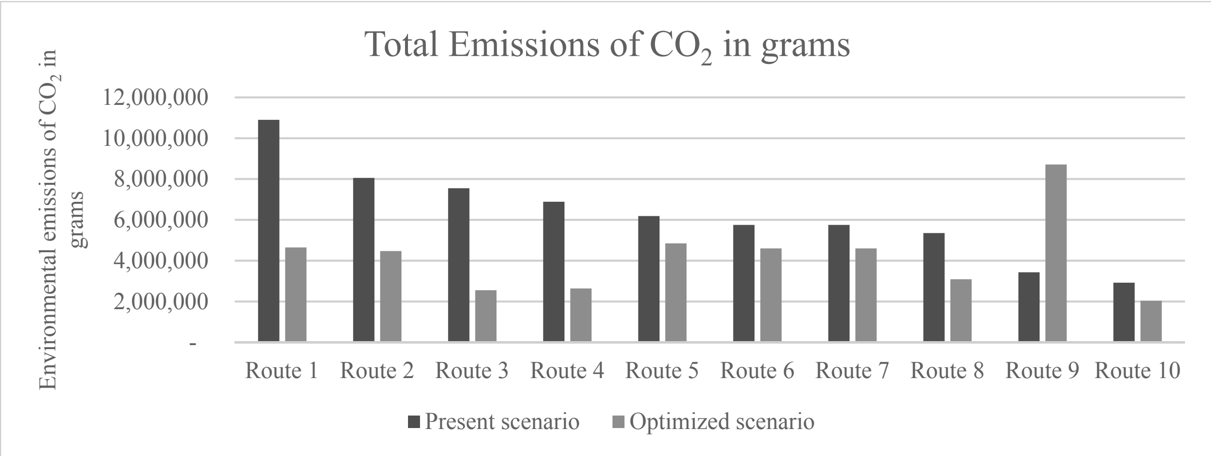

Figure 7: Total emissions of CO_2 in grams

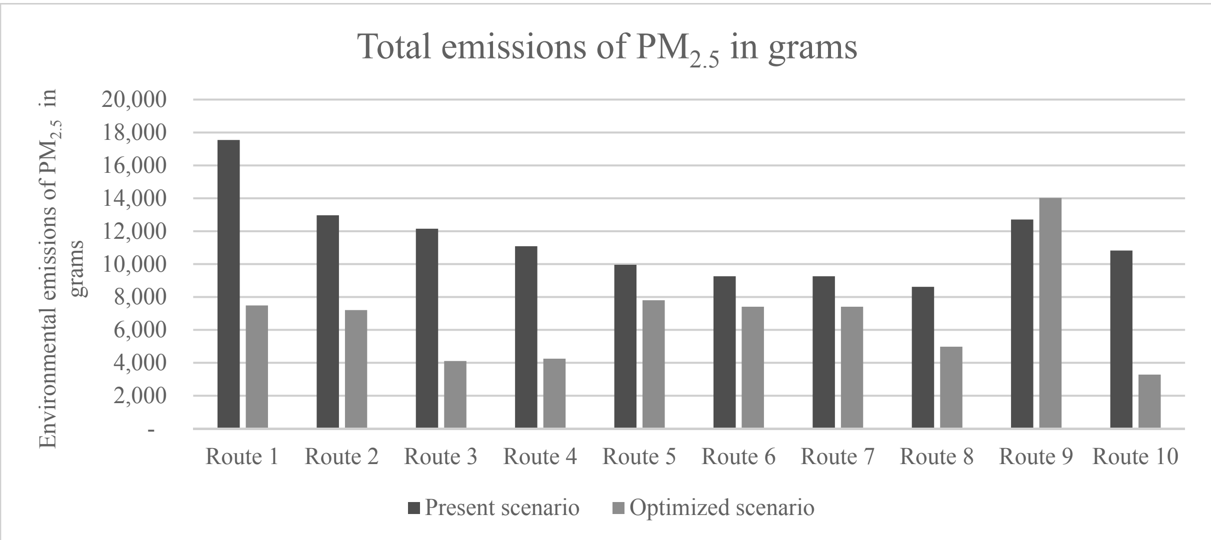

Figure 8: Total emissions of $PM_{2.5}$ in grams

5. Conclusion

This research paper is all about the energy planning of public transportation of Kathmandu Valley with the help of Network Analysis of Operation Research tool. Mainly the top ten routes among 163 routes of our study was chosen where the travel demand was high. The required optimum number of vehicles was found out at those routes using Microsoft -Excel premium Solver tools which shows that the optimum requirement of buses at all routes except route 9 was less than the available buses plying on the road at those routes. In route 9 from Sankhu to Ratnapark, the requirement of buses was high since the travel demand was high & also the nodes of this route such as : Jorpati,Chabhil,Dillibazarpipalbot, PuranoBaneshwor has more flow of passengers. The optimization was done on the basis of least cost method fulfilling the travel demand of passengers at different intervals of time in day. Comparisonwith present scenario shows the saving of Rs.11,65,000 in transportation cost in day in optimized scenario. Also, About 341 GJ of consumption of energy can be saved in optimized scenario as comparision with present scenario. From the view of environmental emissions, the GHG's emitting 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 direct GHG's emitting pollutants except CO_2&CH_4 i.e. N_2O gas increases high in optimized scenario & also, the indirect GHG's emitting pollutants such as NMVOC,NO_X,CO increases high in optimized scenario.

6. Recommendation

- Microsoft-Excel Solver tool is used for optimization of transportation model in my study. Other optimization tools such as GAMS can be used for the same purpose in future research work in related fields.
- 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 of my study.
- 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.

7. Limitation

- The data regarding the public route of Kathmandu Valley was taken from Nepal YatayatMahasangh, 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 YatayatMahasangh.
- 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.

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