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Modeling Optimal Mode Share of Paratransits using VISSIM for Congested One-Way Traffic Urban Roads

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Abstract: In most small and mid-sized cities of developing countries, paratransits form the basic mode of shared transport that people use for their daily commuting. These paratransits include autos (motorized three wheelers) and taxis or cabs. These small transit systems usually carry about 5 to 6 passengers and ply on fixed short routes ranging from 3 to 8 kms. In India, with increase in population and travel demand, there has been a huge increase in the number of paratransit vehicles, particularly autos in recent years and is contributing to congestion and related problems. This work attempts optimize the share of paratransits by minimizing travel time, delay and queue length and maximizing travel speed using VISSIM. It was observed that a share of 10 to 20% of paratransit in total traffic yields minimum travel time and delay.

Keywords: Paratransit, Optimal Mode Share, Travel speed and delay

1. INTRODUCTION

In most small to medium cities of developing countries, paratransits like shared autos (motorized three-wheelers) and e-rickshaws form a major part of public transport. Most people use paratransits for their daily commuting as they provide better accessibility compared to conventional public transport modes. The paratransit system is dynamic and do not follow fixed schedule. Madhu (2013) defined paratransit vehicles as small flexible shared mode used for short distance commuting. They usually carry 4 to 6 passengers and ply on fixed short routes ranging from 3 to 8 kms.

In small and medium old congested cities maneuvering of big transit vehicles is difficult. Many researchers have discussed the importance of paratransits in providing an efficient public transportation system where mass transit like metro and bus is not available or not feasible due to infrastructure restrictions. Tangphaisankun et al. (2009) attempted to find the perception of commuters about paratransits and their service quality and emphasized on using paratransits as feeder for mass transit system primarily to increase mass transit patronage in Taiwan. Jaiswal & Sharma (2012) explained how autos and other paratransit modes play a vital role in public transport system in old congested cities with the case of the city of Bhopal in India. Gaurkar (2013) emphasized the importance of proper planning and optimization of the paratransits using case study of Surat, India. He explained how increased number of autos and personal vehicles on main roads cause several traffic problems like traffic collisions, congestions and reduction in travel speeds.

Mass transit systems have much higher capacity and designated stops. They have fixed schedule and optimization of their travel time and number of stops is common. Various

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researchers have studied optimal routing problems of such mass transit systems and have suggested many methods to address them. Xiong and Schneider (1993) proposed a cumulative Genetic Algorithm (GA) method to choose alternative routes and they found this method more effective than the conventional GA method. They also emphasized on using neural networks for passenger trip assignment. Constantin and Florian (1995) used non-linear, non-convex mixed integer programming model to minimize the total travel time and waiting time under fleet size constraints and tested the model in urban context in Stockholm, Winnipeg and Portland. Lu (2001) developed an algorithm for dynamic and stochastic routing optimization based on Travelling Salesman Problem (TSP). In his research, he examined the probabilistic TSP, the dynamic TSP and the dynamic travelling repairman problem. Chakroborty and Dwivedi (2002) also proposed a Genetic algorithm based method in which they heuristically determined a set of routes. Yu et al. (2005) developed an ant colony based optimization model for network design of bus that tries to achieve minimum transfers and maximum passenger flow with minimum direct route length constraint that is beneficial for both passengers and transit companies. Nallusamy et al. (2009) studied and developed an algorithm to generate optimized routes for multiple routing problems using a clustering method. Xie et al. (2014) considered vehicle routing problem as a typical non-linear combination problem. They recommended using Max-Min Ant algorithm to solve TSP problem as it provides better solutions in terms of cost savings compared to other algorithms.

Lin et al., (2013) in his work used VISSIM software to simulate and analyze the road network of CBD in Beijing, China. Four different traffic organization measures were compared in this study without considering the effect of pedestrians. Fatima and Kumar (2014) used VISSIM to simulate the existing condition of traffic and optimize the routes of the public bus in Bardoli, Gujrat, India. They also determined the optimal stops and developed a model using VISSIM to prepare the schedule for the bus. Kaur and Varmora, (2015) suggested VISSIM as an effective tool for in heterogeneous multimodal traffic modeling and evaluation of network system performance.

In the city of Patna, India where this study is based, there has been an increase in population and travel demand in recent years, and number of paratransits in form of motorized three-wheelers (autos and e-rickshaws) plying on the roads have increased substantially over past few years. The paratransits stop at any point along the route for boarding and de-boarding of passengers, which creates congestion and traffic slowdown. Fu (2002) discussed the problems related to scheduling paratransit operations. Greater proportion of paratransits in a link causes increase in delay and travel trime in that link. The present work attempts to suggest optimum percentage share of paratransit as percentage of total traffic volume, assuming that the paratransits have random stops, in order to have minimum travel time and delay. The optimal share is obtained by optimizing travel time, delay, average travel speed and queue length due to random stops using VISSIM.

2. METHODOLOGY

In order to determine the optimum proportion of paratransits, initially traffic and network data was collected and mapped in the VISSIM model. Then the model was calibrated using base network traffic data. Finally the effect of proportion of paratransits on delay, travel time, travel speed and queue length was studied by simulation.

A busy area of Patna, which has the maximum share of paratransit was selected for the study. The existing road network of the area was first traced over the satellite maps provided by Open Street Map (Mapnik) and Aerial Map (Bing) to prepare the VISSIM model. The number of lanes, width of lane, lane additions and drops, the road intersections and the other road geometry were marked from the map. Additional details like posted speed limits, reduced speed areas etc. were incorporated into VISSIM road network to better reflect field conditions. The existing established routes of paratransits in the area was surveyed to obtain geometric features in detail and was incorporated in the VISSIM model. The geometric features include road width, road length, turnings and number of lanes. The travel demand of the routes, the traffic volumes of the routes, and the alternate possible routes were also observed and incorporated in the model. The study area and VISSIM model constructed by identifying the geometric features of each route are shown in Figure 1.

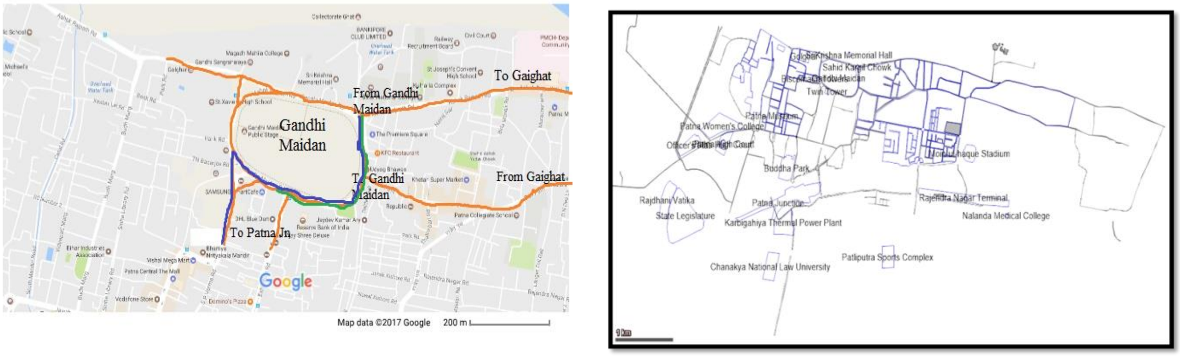

Figure 1. Study Area and VISSIM model Network

Traffic volume and traffic composition data for each route was collected and used in the initial VISSIM model for model calibration. The default VISSIM input parameters do not represent the existing conditions of the study area and therefore were required to be adjusted to replicate reality. This was the purpose of calibration. Traffic data was extracted from the field survey, traffic videos and traveling along the route with GPS. These data were then processed to obtain the traffic volume and compositions on the study routes, the journey travel time, maximum, average and minimum speeds and the acceleration deceleration data. The traffic volume, composition, and different driver behavior parameters were used to achieve realistic queuing and congested traffic conditions for the VISSIM model. The data extracted were also analyzed to determine the nature of speed distribution, reduced speed areas, speed limits, traffic flow to be assigned to each routes and route decisions. For the current study, default vehicle types were changed according to the existing traffic composition. Volumes of the different class of vehicles are input at every access of the road network from traffic survey using traffic video data during the calibration process. Pedestrians were not considered as a factor in this work. The main reason for this was that pedestrians have little influence on the traffic in the study area and the main purpose of this study was to evaluate the network performance due to presence of paratransits.

The desired speed of a vehicle class at any location is defined by its distribution instead of a fixed value to reflect the real stochastic nature of traffic. For any vehicle type, the speed distribution is an important parameter that significantly influences the road capacity and the achievable travel speeds. GPS data was used to determine the speed distribution around the study area. This speed distribution was used to calibrate the VISSIM network model. Speed limits and reduced speed areas were used to generate the required speed distributions.

After the above initial calibrations the VISSIM road network was simulated under two situations, firstly using initial survey traffic stream composition for calibration and secondly using different paratransit proportions.

In the first case, the simulation was done and the various parameters like speed of the vehicle, acceleration of the vehicle and traffic flow in the network were analyzed. These parameters are matched with actual values obtained from the field observations. This was done by introducing speed areas and changing the vehicle inputs on the routes linked to the study routes. When the speed, acceleration and traffic flow on the study routes match the actual values, then the network is said to be calibrated. In this study, the maximum speed, minimum speed, average speed and the traffic flows were considered for calibration. The paratransits were taken to have random intermediate stops. After the calibration was done, the VISSIM network was simulated to determine the congestion points. These congestion points were located by the use of queue counters in the VISSIM network. These queue counters gave the length of queues, maximum queue length and number of stops as the result.

To estimate the optimal proportion of paratransits, the proportion of paratransits as percentage of total volume is varied as 0, 10, 20, 30 and 40% of total volume. Then the network was analyzed for queue results, travel speed, acceleration, travel time, delay. After the completion of simulation of VISSIM road network with different proportions, the results were compared and the proportion which produced minimum queue length, minimum number of queue stops, more travel speed, minimum travel time and delay was identified as the optimal proportion.

3. DATA

In this study, data of road network details like road with, shoulder width, curves and traffic details like traffic composition, speed, delay etc. were used. Four routes namely Gaighat-Gandhi Maidan (A), Gandhi Maidan- Gaighat(B), Gandhi Maidan-Patna Jn(C) and Patna Jn - Gandhi Maidan (D) were considered for the study. The links have one directional traffic movement. The traffic volumes on each of the four routes vary. The traffic volume and demand was obtained from primary survey. Traffic volume and composition data was collected on all links by traffic video survey. To collect video data, a video camera was set-up at the study location in such a manner that each route originating from it get captured in the video. The main reason for using this method was to minimize the human errors and overcome the difficulties in collecting traffic information.

The travel speed, travel distance, travel time and acceleration was obtained by travelling along the route with GPS device tracking the information. These data were used to determine the distributions of speed and acceleration on the routes followed by the paratransits. The speed frequency distribution obtained is shown in Figure 2.

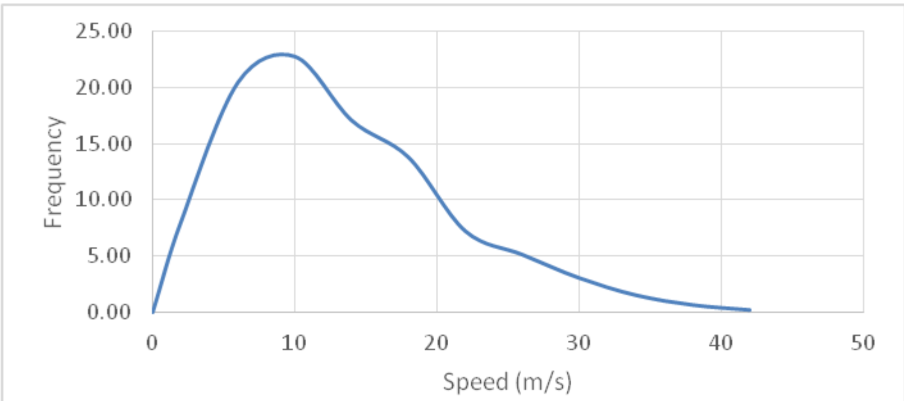

Figure 2. Speed Frequency Distribution Curve around the Study Area in Patna

The geometric details of the road network and the actual road widths are obtained from field.

4. ANALYSIS AND RESULTS

The simulation of traffic with varying proportion of paratransits in four routes namely Gaighat-Gandhi Maidan (A), Gandhi Maidan- Gaighat(B), Gandhi Maidan-Patna Jn(C) and Patna Jn - Gandhi Maidan (D) is simulated using VISSIM 7.0. The actual link properties and total traffic volumes obtained from survey was kept constant while simulation. Only the proportion of paratransits was varied and replaced by passenger cars. The VISSIM road network model was first calibrated using average speed, acceleration and traffic volume as calibration parameters. The network model prepared in VISSIM was initially simulated using the default parameters and then these parameters were varied to get the existing traffic conditions.

The simulation results for each of the compositions were analyzed and the proportion, which gave the best results for evaluation parameters, was considered as the optimum proportion. Simulation results for evaluation of Queue Length is analyzed and shown in Table 1 and Figure 3. Traffic Queue Length is the distance that vehicles queuing in front of the queue counters/detection lines. In VISSIM queue lengths are measures with the help of queue counters.

Table 1 Queue Length indices of different routes

	A	B	C	D
40%	205	25	149	128
30%	193	21	136	14
20%	118	17	124	12
10%	47	16	147	23
0%	180	17		

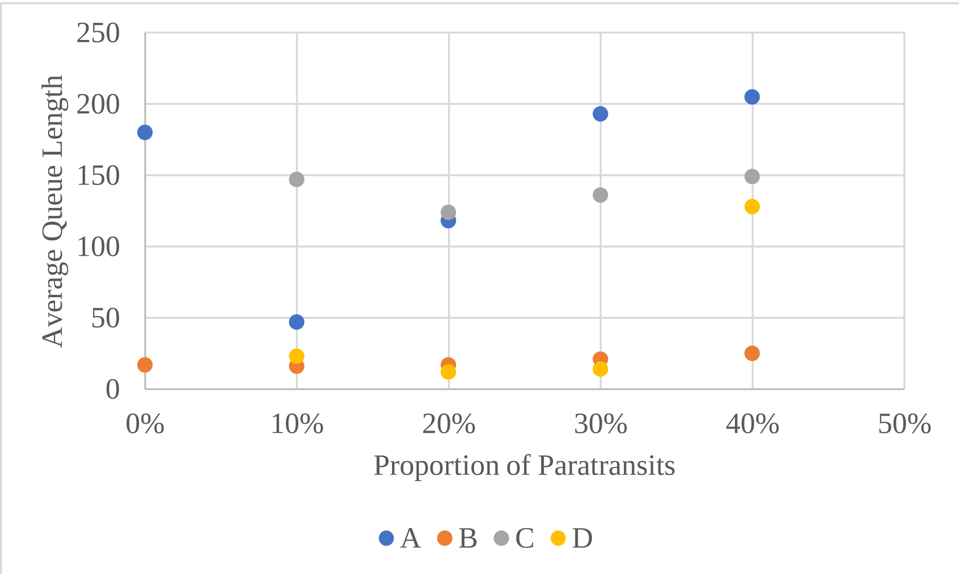

Figure 3. Variation of Average queue length with paratransit proportions

It is evident from Figure 3 that the average queue length is minimum at 20% paratransits for three out of four cases. The average travel time is a simple and robust network performance measure which denotes the time taken to travel from origin to destination while delay means the time loss for vehicles from the origin to destination compared with free moving traffic. In VISSIM, travel time and delay are measured by using same detector called travel time section. The travel time for each route and proportion is shown in Table 2 and Figure 4. The delay and travel speeds for different routes and proportions also obtained. The travel delay for each route and proportion is shown in Table 3 and Figure 5. The travel speed for each route and proportion is shown in Table 4 and Figure 6.

Table 2 Average Travel Time (minutes)

	A	B	C	D
40%	50.74	24.39	16.36	12.66
30%	43.14	22.26	13.65	12.31
20%	41.23	19.56	13.35	7.31
10%	28.83	16.83	13.80	9.20
0%	37.85	20		

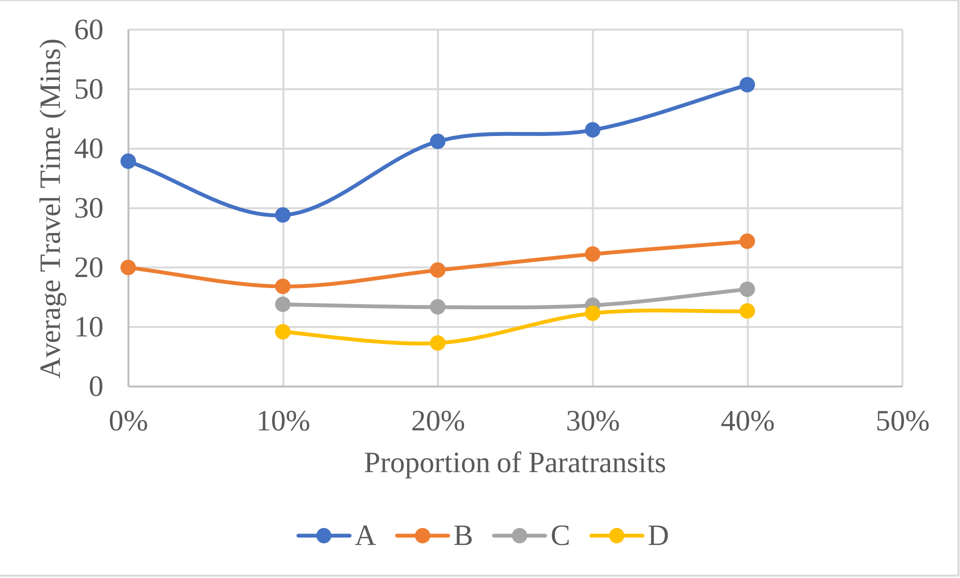

Figure 4. Variation of Average travel time with paratransit proportions

Table 3 Average Delay (minutes) for different paratransit proportions

	A	B	C	D
40%	20.85	16.42	3.8	20.85
30%	19.17	13.91	3.71	19.17
20%	16.15	9.26	1.32	16.15
10%	18.46	7.3	1.85	18.46
0%	24.17	12.364		24.17

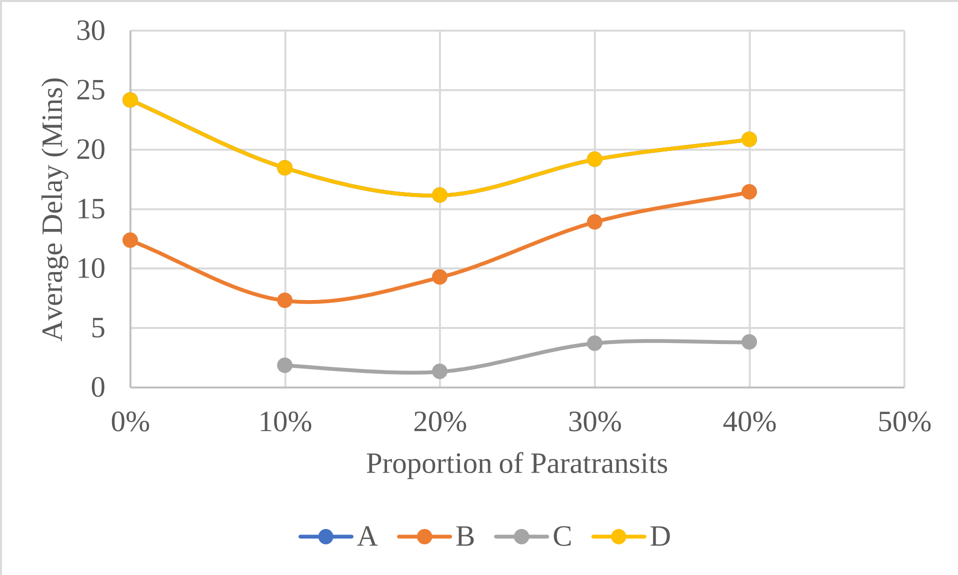

Figure 5. Variation of Average Delay with paratransit proportion

Table 4 Travel Speed (Km/hr) for different paratransit proportions

	A	B	C	D
40%	6.09	30.55	30.70	30.39
30%	13.36	32.31	30.92	30.78
20%	24.41	33.86	31.38	31.24
10%	24.57	32.93	30.58	30.35
0%	17.73	32.29		

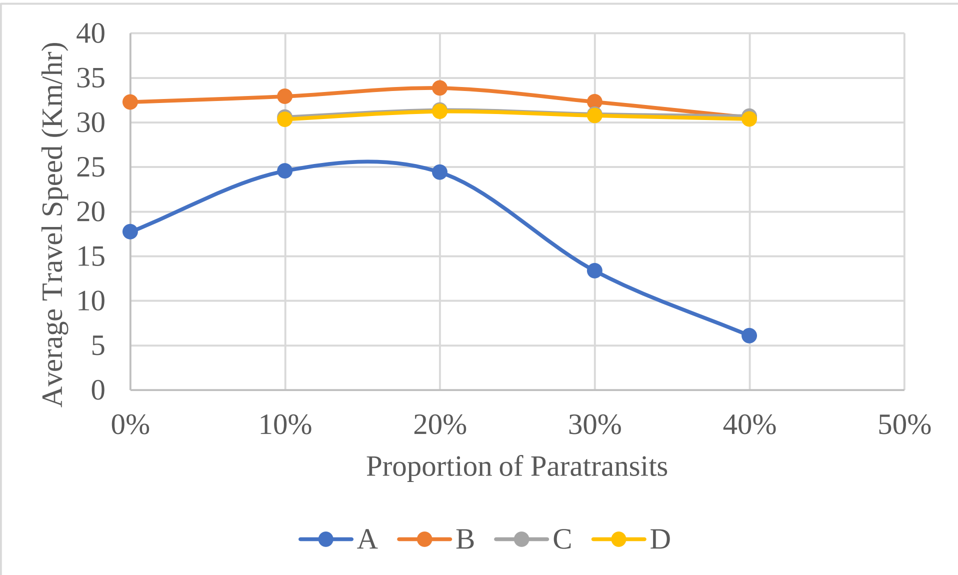

Figure 6. Variation of Average Travel Speed with paratransit proportion

It can be observed from the study of variation of proportion of paratransits with travel time, delay and travel speed that proportion of paratransit has significant role in performance of traffic stream. The proportion between 10 to 20 percent paratransit yield maximum travel speed and minimum average delay and travel times. The average queue lengths do not have significant variation with proportion of paratransits in traffic. Thus it may be advisable to keep the proportions of paratransit between 10 to 20 % by traffic volume in a stream to have optimum operating speeds and travel times for a given traffic volume. Presence of 10 to 20% paratransit vehicles improves speed and travel time over presence of no paratransits as it occupies less space than passenger cars which have similar capacity of riders.

5. CONCLUSIONS

The current work attempted to study the effect of paratransit proportions on travel time, travel speed, delay and queue length. The study was conducted in four routes of a busy network of Patna, India namely Gandhi Maidan to Gaighat, Gaighat to Gandhi Maidan, Gandhi Maidan to Patna Jn. and Patna Jn. to Gandhi Maidan. The proportion of paratransits were taken as 0%, 10%, 20%, 30% and 40% of total traffic obtained in peak hour survey. The traffic composition and volume obtained is taken for simulation by replacing paratransit proportions fully with passenger cars for the 0% case and then replacing 10% to 40% passenger cars by paratransits accordingly.

The variations of average queue length, travel time, travel speed and delay was plotted for varying proportions of paratransits. It was observed that average queue length is not much affected with increase of paratransit proportions. But the average travel speed, delay and travel time significantly vary with proportion of paratransit in traffic stream. It could be observed that 10 to 20 % of paratransit in the stream yields best travel times and speeds. The increase of paratransit proportion over 20% cause significant delay and reduction in travel speeds. This present work can be used as a guide for deciding optimal number of paratransits in a traffic stream.

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