European Transport \ Trasporti Europei (2015) Issue 58, Paper n° 1, ISSN 1825-3997

Microscopic simulation to evaluate the traffic congestion mitigation strategies on urban arterials

Amudapuram Mohan Rao[1], K. Ramachandra Rao[2*]

[1]*Senior Scientist, CSIR-Central Road Research Institute, Delhi-Mathura Road, New Delhi -110 025, India,amrao_crri@yahoo.co.in*

[2*]*Associate Professor, Department of Civil Engineering and Transportation Research and Injury Prevention Programme (TRIPP), IIT Delhi, HauzKhas, New Delhi-110 016, India.*

Abstract

Traffic congestion mitigation has many facets. Simulation modelling is of the useful tools for evaluating the congestion mitigation strategies and improvements. In the present study, VISSIM was selected as the simulation tool for microscopic modelling and evaluation. A comprehensive set of possible mitigation scenarios were identified after reviewing the existing literature and practices. Ring road in the Delhi's National Capital Territory was chosen for the case study. Several mitigation scenarios were developed. For evaluating these scenarios the Performance Measures chosen include; (a) Traffic volumes (b) Average speeds (c) Network performance (d) Individual link performance (e) Travel delay (f) Travel time (g) Change in Congestion Index. These performance measures were compared with the base case. It was observed that the traffic management option performs better vis-à-vis other alternatives. This study also suggests a methodology for measurement of micro level traffic characteristics in the congested corridors/locations.

Key Words: Micro simulation, calibration VISSIM, traffic congestion mitigation, urban arterials

1. Introduction

Microscopic simulation is a tool, which can be used for evaluating the congestion mitigation alternate and their performance before implementing for the existing traffic conditions. Further, these simulation models helpcapture the traffic characteristics such as speed, flow and density at macro level and also helps to capture the behaviour of driver for different traffic situations under prevailing road conditions.

* Corresponding author: K. Ramachandra Rao (rrkalaga@civil.iitd.ac.in)

Capturing the macro level data one can study the system behaviour in detailed manner.For the current study, the simulation is carried out using VISSIM software. 'VISSIM is the stochastic traffic simulator that uses the psycho-physical driver behaviour model' developed by R. Wiedemann (1974)**.**The VISSIM software evaluates the system performance by considering the driver perceptual model, vehicle behaviour model of each traffic mode. The driver behavioural model includes reaction time and response time based on this time driver can decide the lane changing behaviour for increasing the speed of their vehicles (Fellendorfand Vortisch2010).

Urban congestion mitigation alternatives are somewhat difficult to evaluate before field implementation even on a trial basis. And at times these may be costly too. Thus a tool or model to test these alternatives is needed. There are some studies that have applied simulation for testing the congestion mitigation strategies for freeways (Daganzo2012; Halkias et al. 2012). Further there are too few studies are done for evaluation of urban congestion mitigation strategies (Zhang et al. 2009). In the present study an attempt has been made to evaluate the congestion mitigation alternatives which can be implemented through road agencies.Simulation application for evaluating the congestion mitigation alternatives for urban arterials is studied by taking a case study of New Delhi, capital city of India. A section of major urban arterial (Inner Ring Road) is considered for the analysis.

Thus the objectives of the study can be out set as follows:

- Formulation of alternatives for congestion mitigation
- Selection of performance evaluation parameters
- Evaluation of mitigation alternates
- Suggestion for congestion mitigation

Rest of the paper is organised as follows; Section 2 describes the available literature on similar study. Section 3 describes the description of study area and model development. Section 4 discusses driver behaviour models in VISSIM model calibration. Later section 5 focuses on development of mitigation scenarios. Section 6 explains the evaluation of the mitigation scenarios. Lastly the Section 7 gives the summary and conclusions of the study.

2. Literature Review

The quality of the outputs depends on the simulation models used in the development of the simulator. There are two main components which influence the quality. They are car-following and lane changing models (Dia and Rakha2005). Gao and Rakha (2008) in their work explained briefly about five widely-used microscopic traffic simulation models such as AIMSUN2, VISSIM, PARAMICS, CORSIM and INTEGRATION.The simulator VISSIM has a capability to produce all traffic engineering parameters at the same time it is capability of modelling different type of vehicles for all class of roads under different traffic control situations (Moenet al. 2000).

The existing simulation models cannot be applied directly as they require calibration with the site specific data for making them relevant to the case study.There are a number of traffic simulation studies whose primary focus is on calibration. Further, some of these studies have considered single parameter for calibrating the simulation software.The calibration based on single parameter fails to recognize the traffic parameters. The accuracy of the outputs in one parameter does not ensure the quality of the other parameter. Hence there are some studies taken multi parameters for calibration and these studies are summarized in Table 1. In this study a multi-criteria parameter calibration was proposed.

3. Study area and data analysis

The study area chosen for this study National Capital Territory (NCT) of Delhi has an area of 1,484 km^2.The Inner Ring Road is 55 km long road that connects many important locations. In this study a section about 10.0km Inner Ring road section taken, this section is facing regular congestion problems. The simulation model for the collected traffic flow, travel speed, flyovers, routing and geometric characteristics of actual conditions for a corridor of 10 km on inner ring road of Delhi was developed. The Figure 1 shows the study section.

3.1 Data preparation for Simulation

Network Coding: The road network coded as links and connectors in VISSIM. Links should be created to represent road segments that carry them through movements and general geometry and curvature of the roadway. Links are connected by connectors, the connectors have additional characteristics that affect driver behaviour, specifically lane changing, so it is important when coding to take this into consideration and eliminate the excessive use of connectors (Crowe2009).

Vehicle Inputs: The vehicular attributes such as acceleration/deceleration, length, width etc. as per the Indian vehicle fleet conditions are coded in 15 minutes intervals. The inputs for public transportation vehicles such as frequencydwell time distributions, location of bus stops and bus routes are carefully coded in VISSIM. The road way capacity is influenced by the speed distribution and desired speed should be considered carefully (PTV VISSIM, 2011). The traffic composition and desired speed distribution for all types of vehicles are coded in to thesimulation software. The traffic composition and a typical speed distribution for three wheelers are shown in Figure 2.

Signal Control Coding and PT inputs: Four fixed time signalized junctions are there in the study area. Signal cycle time survey is conducted at all these signals using stopwatch, the signal time are noted at least ten cycle times and the average signal time taken for coding, signal times and signal phases are incorporated in to VISSIM inputs. Public Transportation (PT) inputs such as frequency and dwell time inputs are prepared.

Table 1: Simulation calibration studies by various criteria

Study	Type of optimization	Model	Network Type	Measure of Performance	Results of best parameter estimate
Hourdakis et al. (200)	Heuristic search	AIMSUM	Freeway	Volume	8.84 % (RMSPE)
Park and Qi (2005)	Genetic algorithm	VISSIM	Freeway Interchange	travel time	12.6 % (RSPE)
Kim et al. (2005)	Genetic algorithm	VISSIM	Freeway network	travel time	1 % (MAER)
Ma and Abdulhai (2007)	Genetic algorithm	PARAMICS	Arterial network	Flows	46.09 % (GRE)
		Multi criteria' parameter calibration			
Toledo et al. (2004)	Iterative averaging	MITSIMLab	Freeway	Speed and Density	4.6 % (MAER for speed)
Balakrishna et al. (2007)	Simultaneous Perturbation Stochastic Approximation (SPSA)	MITSIMLab	Freeway	Volume (Counts)	22 to 65 % (RMSPE)
Ma et al. (2002)	SPSA	PARAMICS	Freeway	Link capacity and critical occupancy	0.70 % (Sum of GEH)
Duong et al. (2010)	Genetic Algorithm	VISSIM	Freeway	Volume and Speed	1.9 % (RMSPE Speed); 10.5 % (RMSPE Volume)
Weinan and Jain (2009)	NSGA II	VISSIM	Freeway	Volume and Speed	1.0 (Volume Fitness) and 0.97 (Speed Fitness)
Toledo et al. (2004)	Iterative averaging	MITSIMLab	Freeway	Speed and Density	4.6 % (MAER for speed)
Balakrishna et al. (2007)	Simultaneous Perturbation Stochastic Approximation (SPSA)	MITSIMLab	Freeway	Volume (Counts)	22 to 65 % (RMSPE)

Note: RMSPE: Root mean square percentage error, GRE: Global relative error and MAER: Mean absolute error ratio

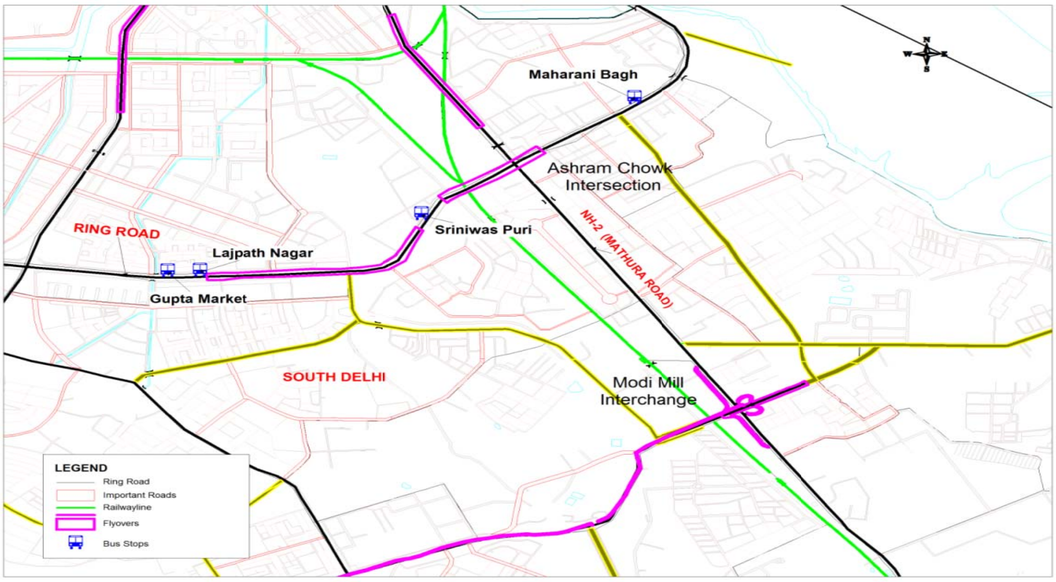


Figure 1: Details of the Study corridor

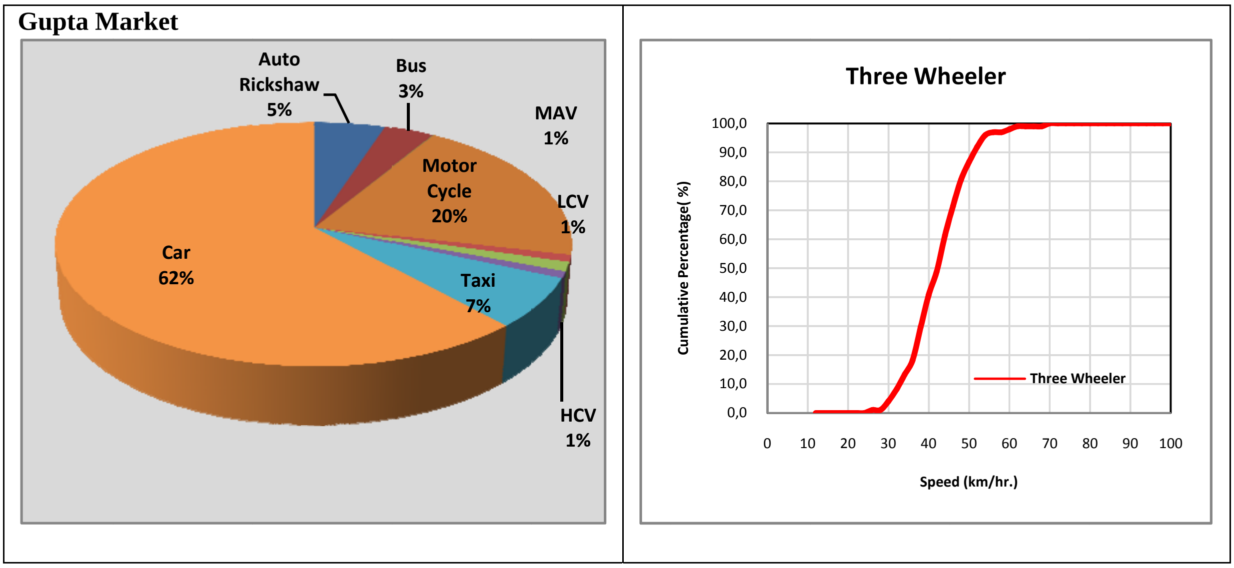


Figure2: Typical Traffic composition and three wheelers desired speed distribution

4. Driving Behaviour Models in VISSIM and calibration

Driving behaviour in VISSIM consists of two behavioural models: car following and lane changing models. The parameters within these models can be adjusted during either the initial coding process or the calibration process. However, changes to these parameters should be made by experienced professional with caution. The car-following and the driver behaviour models requires a strong mathematical representation to capture the real world scenario. The car-following models characterizes following vehicles which follows the lead vehicle. The models types developed in VISSIM are discrete, stochastic models captures the interactions among the vehicles(Wiedemann 1974).

- Wiedemann 99 Model (Freeway Traffic)
- Wiedemann 74 Model (Arterial / Urban Traffic)

For freeway links and connectors, the Wiedemann 99 model should be selected for car following model. For most arterial links and connectors, the Wiedemann 74 car following model should be applied. The study belong to urban arterial, hence Wiedemann 74 model was selected.

4.1 VISSIM Model Calibration

The default car following parameter set for the VISSIM Wiedemann 74 model is a good starting point but it may need to be calibrated to better match with real-world conditions, especially when trying to match flow rates, speeds and travel times to achieve real-world conditions.The methodology used for the calibration of the VISSIM model is explained in theFigure 3.

4.2 Calibration Goals

Before starting the calibration process, one should frame the calibration goals based on the study type and the availability of data. Calibration objective was to match the simulation data with the field observed data. It may be noted that there is now well set procedure for calibration individual should device the procedure for calibration and validation for complex transportation networks. In this study the calibration process used to achieve adequate reliability/validity of the model by establishing suitable parameter values so that the model replicates local traffic conditions as closely as possible. The calibration parameters are selected after the literature review (Table 1), the choice of parameter values can be specific to the project. The calibration goals selected for this study are as follows:

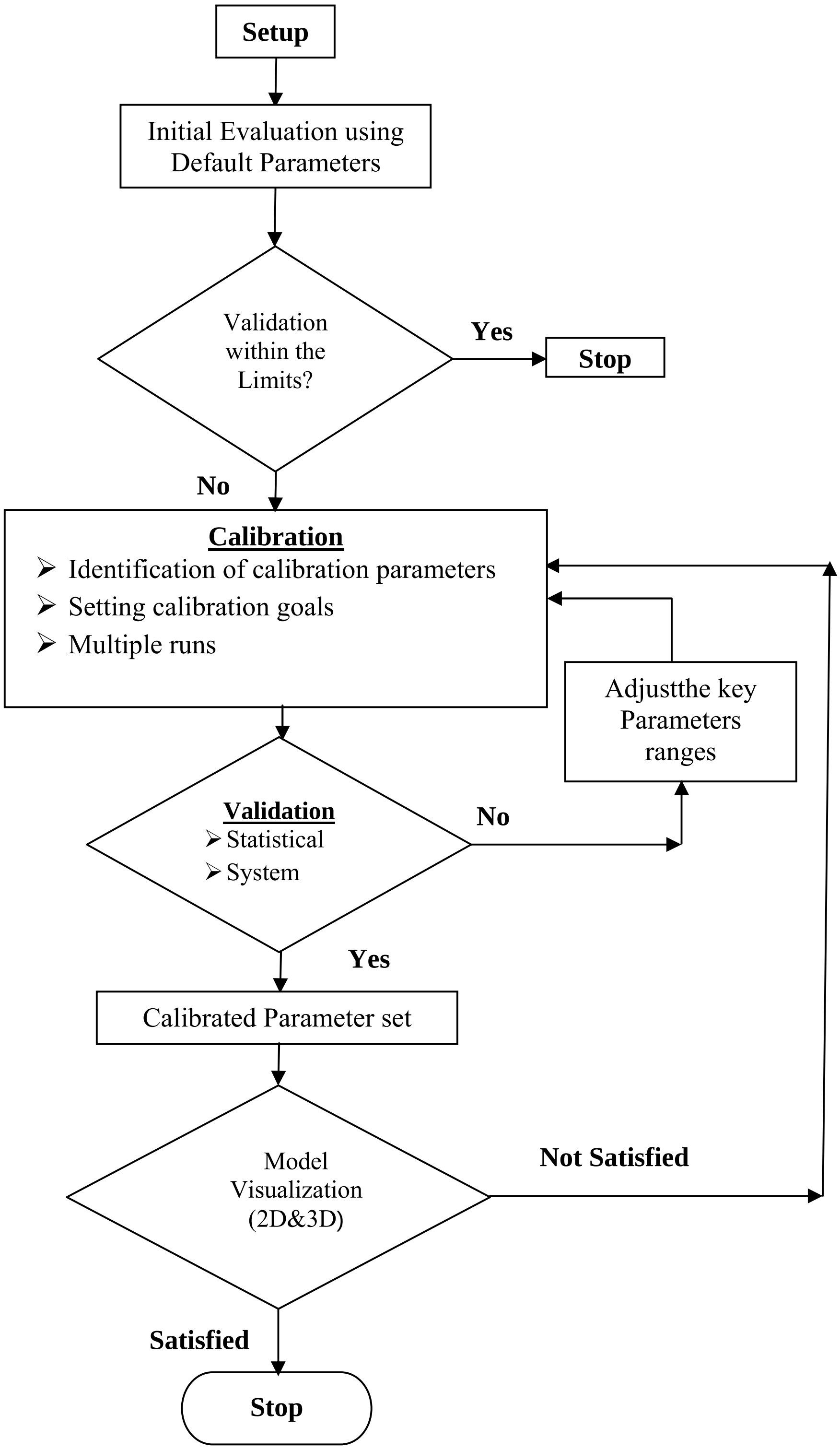


Figure 3: VISSIM Calibration Methodology flow chart

- Goal 1 Vehicle Speeds
- Goal 2 Travel Times
- Goal 3 Traffic Volumes
- Goal 4 Visual Observation

Goal 1 - Vehicle Speeds: Modelled average speeds of all the vehicles to be within the acceptable range of observed speeds on the study corridor. The allowable error in the speed should be within 10 percent.
Goal 2 - Travel Times: Travel time is good measure to know the performance of traffic; hence the goal was formed as the average travel time on at least 75% of sections under study,withinerror tolerance of 20%.
Goal 3 -Traffic Volumes: Link flows versus observed flows to meet criteria arethat, the link volumes for more than 85 percent of cases to have a GEH statistic less than five.
Goal 4 -Visual Observation: In the simulation in addition to the technical parameters (speed, volume etc.) it is equally important to see behaviour of the vehicles by visually for full simulation time. The visual observation of the of the simulation gives fair idea about utilization of the lanes at the merging and diverging and routing decisions at different routes and at bus stops. Sometimes at merging the vehicles over run each other this type of behaviour observed in visual observation several times in 2D and 3D.

4.3 Calibration Results

The study corridor is simulated using the default parameters of the VISSIM and the outputs of the traffic flows at various points with respect to the actual volumes are observed. VISSIM output and the actual field observation are quite different. Therefore, it is decided to conduct the calibration and validation procedure (Park and Qi 2005).

Volume/Density

The first measure of proof of calibration is how closely field volumes match simulation output volumes. A simple percentage difference is not a fair comparison of the wide range of link volumes or turning movement volumes possible in the model. For example, a 10 percent tolerance would allow a road link with 4,000 vehicles per hour (vph) to vary by 400 vph, but a turning movement with 30 vph at an intersection could vary by only 3 vph to meet the criteria.The best universal measure to compare simulation inputs and outputs is the GEH formula. The GEH is a formula proposed by Geoffrey E. Havers, in the 1970s which is extensively used in traffic modelling for comparing the modelled and actual values. GEH formula is not statistical test; it is a empirical formula that has been using from many years for traffic analysis purposes. This continuous volume tolerance formula was developed to overcome the wide range in volume data.

The formula for the GEH statistic is:

$$GEH = \sqrt{\frac{2(M-C)^2}{(M+C)}} \quad (1)$$

Where M is the output traffic volume from the Simulation Model (vph) and C is the real world Input traffic volume (vph)

GEH statistics shall be calculated for all mainline links and flyovers and for all intersection turns at study intersections identified in the scope of work. In addition, the GEH statistic must be calculated for all traffic volumes at all entry and exit locations in the calibration area of the model. The GEH values gives as an indication of a goodness of fit and the ranges of GEH values are given below;

- GEH<5 Traffic Flows values considered as good fit
- 5<GEH<10 Traffic Flows values may require further investigation
- GEH > 10 Traffic Flows values cannot be considered to be a good fit

The actual volumes collected from field and simulated volumes along with the GEH statistics are presented in Table 2.

Table 2: GEH statistics for traffic volume

Name of location	Actual volume (vph)	VISSIM output (vph)	GEH
Gupta Market (Lajpath Nagar)	8975	8911	0.7
SrinivasaPuri	9765	9635	1.3
Maharani Bagh Bus Stop	11354	11218	1.2
Lajpath Nagar Flyover	4765	4494	3.9
Ashram flyover	5117	5129	1.43
Mother dairy	10583	10132	4.4
Before DND Flyover	11874	8344	35.0

The GEH statistics shows 86 percentage of sections are less than 5, this results shows good fit. One section (Before DND flyover) have more GEH values, this point is end point of the simulation section. All the vehicles are not crossed the exit point at the end of simulation may be the reason for higher values.

Speed

The speed values are calibrated by changing different driver behaviour parameters in the model, some critical locations are identified. The calibration process is carried out until stream speed observed in the field equal to the simulation speed. Table 3 gives the percentage error observed and comparison of simulated and actual speeds.

Table 3: Comparison of simulated and actual Speeds

Location	Actual Speed (km/h)	Simulated Speed (km/h)	Percentage Error
Gupta Market	32	32	0.5
Maharani Bagh	22	20	10.6

Travel Time

The Travel time data collected using the VBOX GPS for different type of vehicles such as car, bus, two wheeler and three wheelers covering different days, all peak and nonpeak hours. The data is analyzed using the performance software (hardware (GPS) specific). All the runs data is exported in to GIS software and extracted the data pertaining to the study section, the data is further analyzed to section level and the study corridor is divided in to four sections.The travel times are calculated for different modes for each section. The results from simulation runs are compared with the field data. The percentage errors observed are presented in Table 4 for car mode, collected for two runs.

Table 4: Percentage error in travel times

S. No.	Section name	Error (%)	
		Run1	Run2
1	Mool Chand – Lajpathnagar Flyover	-5.5	19.3
2	Lajpathnagar Flyover	-79.0	-2.3
3	Link Between 2 Flyovers	20.1	45.5
4	Ashram Flyover end - DND Flyover Start	-0.6	8.2

Minimum Number of Simulation Runs

The average results of multiple runs is necessary due to the random nature of micro simulation, but in order to ensure that the value reported is a true statistical representation of the average, the following formula for a 95 percent confidence interval shall be applied:

$$N = \left(2 * t_{0.025,N-1}\frac{S}{R}\right)^2 \quad (2)$$

Where;

- R = 95-percent confidence interval for the true mean
- $t_{0.025,N-1}$Student's t-statistic for two-sided error of 2.5 percent (total 5 percent with N-1 degree of freedom
- S = Standard deviation of about the mean for selected parameter (Measurement of Effective Ness (MOE))
- N= Number of required simulation runs

It is not practical to test the statistical significance of the average of every data output. For simplicity, this calculation should only be conducted for one or two measures of effectiveness that are deemed most important to the outcome of the project, in this study traffic flow and speed are tested by multiple runs. This calculation is only required for base model scenarios.

5. Development of Mitigation Scenarios

Urban traffic congestion mitigation measures encompass a set of strategies and techniques to reduce the impact of congestion and improve the overall commute. Several mitigation strategies are available for mitigation of congestion, using these strategies we can reduce the traffic congestion on road users (OECD 2004). There are many possible combinations to mitigate congestion; there is no single solution for congestion these solutions differ to place to place and site to site. The mitigation strategy selected should have the following criteria.

- Proven effectiveness in any studies for congestion reduction
- The techniques and the combinations Untested
- The solution should be easy for implementation
- It should consider the minimum infrastructure modifications
- It should interact and complement with other congestion mitigation programmes

In this study, different types of strategies were developed and tested using VISSIM. Further an attempt has been made to find which of these the proposed congestion mitigation alternates have the highest likelihood of reducing the traffic congestion on the urban arterials considered. The simulation model based on the data such as traffic flow, traffic speed and road characteristics for a corridor of 10 km on inner ring road of Delhi was developed (Figure 1). The set of scenarios that were developed/tested for the study are as follows:

- Scenario 1: Base Case (Do Nothing)
- Scenario 2: Traffic Management
- Scenario 3: Elevated Road Construction
- Scenario 4: Shifting of the Bus Stops
- Scenario 5 Dedicated Bus Lanes

The details of the each scenario are explained in detail

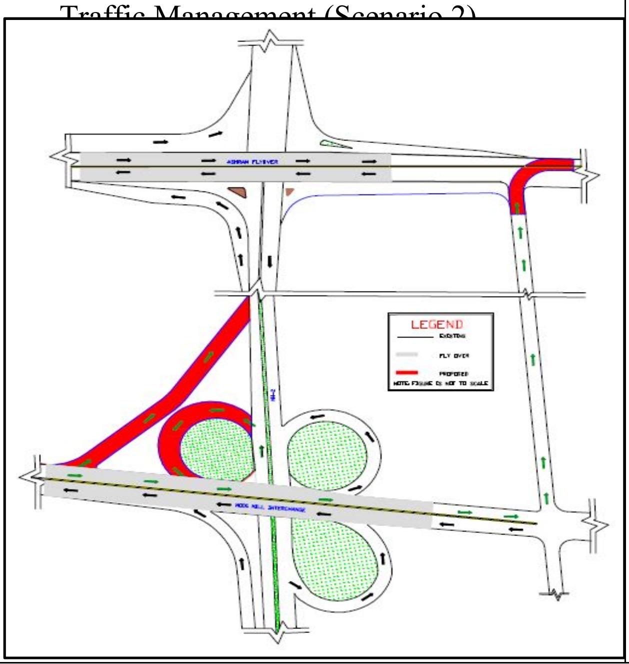
Scenario 1: Base Case (Do Nothing): Base case represents the existing conditions; the base case network consists of approximately 10.0 km long, three bus stops, two flyovers and five signalized intersections.

Scenario 2: Traffic Management: Traffic management (i.e. one way routes, diverting traffic one route to other route, signal control etc.) is the option for mitigation of traffic congestion through this technique we can effectively utilize the available road space. Delhi has 22 percentage of area is covered by roads, which is highest in India. To utilize the roads with less utilized the traffic is diverted to the less intensity alternate roads.

The study road (Ring Road) and the National Highway 2 (NH-2) cross each other at Ashram intersection (Figure 1).the major turning movement at this intersection is right (i.e., Mathura to

Rajghat), the right turning movement is merged with the Ring Road traffic which is a major cause of the congestion. Hence it is proposed to restrict the right turning movement at this junction. Further, this traffic is diverted to an existing Modimill cloverleaf interchange (Figure 4), NH-2 (Mathura Road) traffic intending to go right (Rajghat) side at Ashram Intersection will take right turn at Modimill interchange and travel from New Friends colony road (alternate road) and merge with Ring Road traffic at after Maharanibagh Bus Stop through underground subway. The traffic diversion plan details are shown in Figur 4.

Traffic Management (Scenario 2)



Shifting of Bus Stops (Scenario 4)

Figure 4: Traffic Congestion Mitigation Scenarios

Scenario 3: Elevated Road Construction: There are 17 flyovers on Ring Road (50.0km) most of these flyovers are facing the congestion problems, about 30% of the Ring Road is elevated now. If the entire road (remaining 70%) is elevated the traffic congestion problem facing at the exiting flyover which are constructed isolated manner may reduce. In this scenario it is proposed to construct an elevated road width equal to the existing flyovers for entire corridor. Under the elevated road can be used by the traffic coming from other roads and the buses can use this road. The vehicle inputs are divided into two parts one for elevated road and other for under elevated road, from the traffic surveythe share of traffic observed on flyover is 65% and remaining traffic is under flyover, the same proportion is entered into VISSIM.

Scenario 4: Shifting of the Bus Stops: The locations of the bus stops are creating many congestion problems on the road considered. The location of the bus stops moved to appropriate nearby locations towards the intersection, the congestion created by the buses can be reduced to certain level (Venglar et al. 2001). The three bus stops on the study corridor, i) Lajpath Nagar ii) Sriniwaspuri and iii) Maharanibagh these are facing congestion problem almost every day.

Hence under these scenarios, it is proposed to shift the bus stops to under flyover sections. It is proposed to shift Lajpath Nagar bus stop to the junction nearby which is 500 m from the existing bus stop location. Also the Srinivasapuri bus stop can be moved little away from the existing location(200 m before the existing location). Maharanibaghbus stop is also to be shifted near to Ashram intersection (Figure 4, shifting of bus stops).

Scenario 5 Dedicated Bus Lanes: The use of the private mode is the root cause of the traffic congestion, by providing the good public transportation system such as bus can be introduced. The success of any bus rapid transit system is dependent on making the bus transport mode faster.In order to attract more people to use the bus is necessary to introduce certain bus priority strategies (Papageorgiou et al. 2009). These may involve minor changes in the current road infrastructure with the addition of bus lanes as well as changes in the traffic management schemes with the introduction of extra traffic lights for signal pre-emption at road intersections for buses. In this scenario a dedicated bus lane is provided from exiting lanes only (Vedagiri and Jain2012;Mulley2011). A lane of 3.5 m width is considered as dedicated bus lane on extreme left side of the carriageway and the composition of buses from the traffic stream is removed and the new composition for the traffic is considered and inputs are given in VISSIM accordingly.

6. Evaluation of Mitigation Scenarios

Five testing scenarios were developed for study corridor. Every scenario was at least five runs were made and the outputs were prepared for each run. After completing the simulation and the outputs were analysed outside the simulation and the average of all the five scenarios simulations runsare used for further analysis (Lownes and Machemehl2006).

6.1 Selection of Performance Measures

The evaluations of different scenarios are carried out by selecting appropriatePerformance Measure (PMs). PMs vary case to case, present study deals with traffic congestion; hence PMs used properly reflect the traffic congestion characteristics(Wheelerand Figliozzi 2011). The PMs chosen for this study are listed below:

- Traffic volumes
- Average speed of all modes
- Network performance
- Individual link performance
- Travel delay
- Travel time

6.2 Scenario Outputs

The outputs collected from data collection points, travel time sections, network parameters and link evaluation parameters as pre identified performance parameters and then analyzed in Microsoft Excel. With these aggregate level data, graphs and tables were prepared for each scenario and presented in Figure 5. They are discussed in detail in the subsequent sections:

6.3 Base Case (Do Nothing)

The base case is the do nothing case, this scenario consists existing conditions. The corridor of length 10.0 km consists of four bus stops, two flyovers and four fixed time signals with lot of merging and diverging sections.

6.4 Scenario 2 (Traffic management)

The spot speed at Guptamarket and Srinivaspuri is marginally decreased and the speed at Maharanibagh is drastically increased almost double. The speed is increased to 37.89% at network level. The average, stopped and total delays of this option is decreased to 37.89%,59.14% and 38.63%.The density (veh/km) at individual link level is decreased to 11.04%. The travel time decreased on Srinivasapuri 3.1% and travel time on Ashram flyover end to DND flyover entry is decreased to 22.1% due to traffic impositions and traffic delay also decreased on this sections. The network performance is very well in this option and the spot speed at Maharanibagh is also increased considerably.

By diverting the traffic to low intensity road the network performance (delays, density and travel time) is increased very much and the speed at critical location increased, it shows this scenarios is mitigating the traffic congestion well with less cost because traffic diversion does not require much money.

6.5 Scenario 3 (Elevated Road)

The spot speed at three location results shows that the speed are increased at all the location up to 41% only the location under Srinivasapuri section is decreased to 4%. The speed is increased to 12.36% at network level. The network level average, stopped and total delays of this option is decreased up to 11.55%. The section level delay times for the elevated sections decreased up to 30% but even after elevated road option also the delay on DND section is increased 1.2%.The travel times on all most all section decreased up to 30%. The travel time on elevated section from Ashram to DND flyover entry is increased to 1.2%, travel times on under elevated sections is increased to 45%. In this option the travel time and delay are increased on one of the section (under elevated road) 50% of the sections the delay times are increased. This option performance is better over dedicated bus lane.

This scenario elevated road, we are adding the additional capacity by spending some money, the performance of this scenario is very well, but at some section (at grade section) where the at grade traffic more, the travel time is increased marginally.

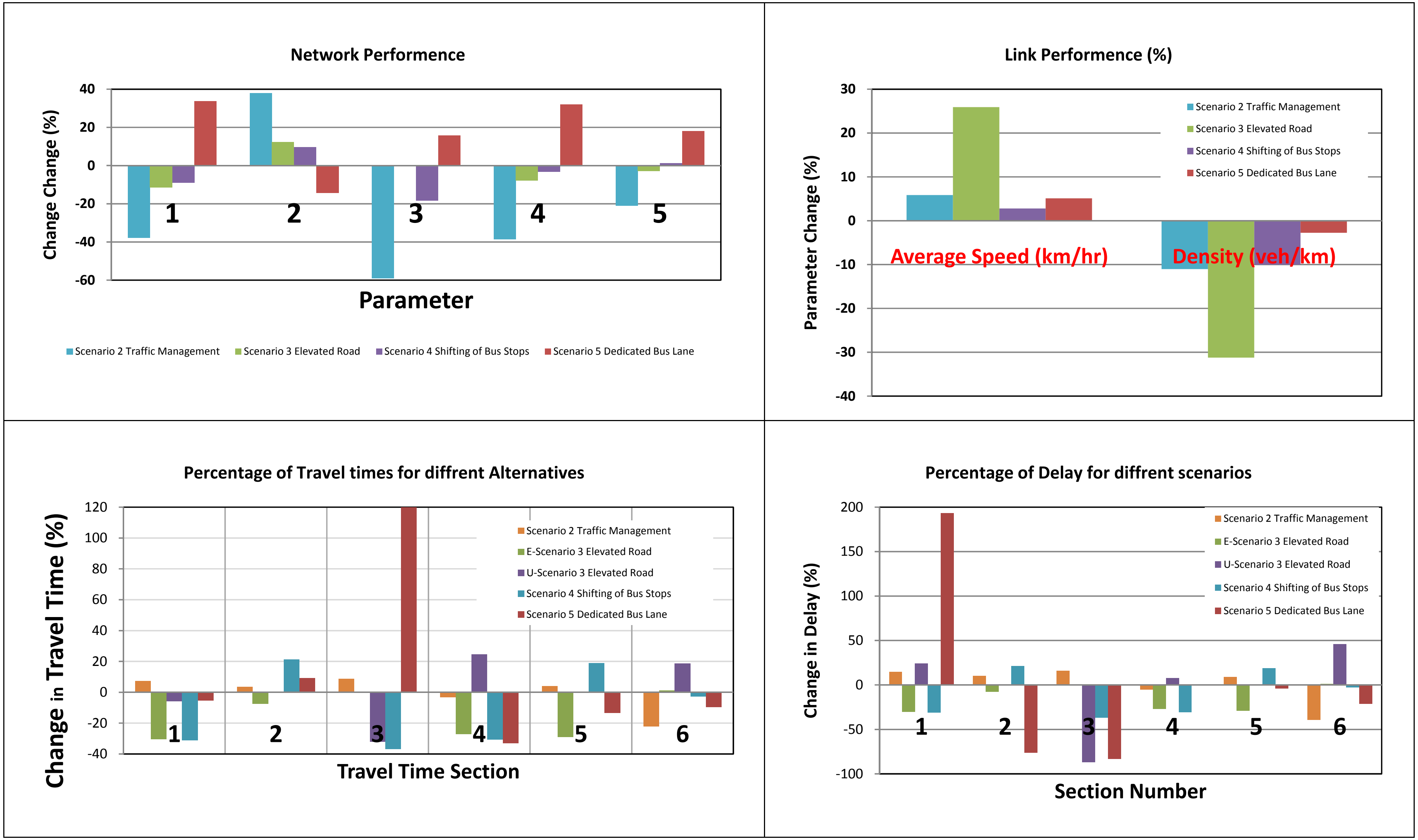


Figure 5 Congestion mitigation scenarios performance

6.6 Scenario 4 (Shifting of Bus Stops)

The spot speed at three location results shows that the speed are increased at two location Gupta Market 13.5% and Maharanibagh 54.1% and the speed at Srinivasapuri is reduced to 8.1%. The speed is increased to 9.75% at network level. The average, stopped and total delays of this option is decreased up to 18.29%.The density (veh/km) at individual link level is decreased to 10.02%. The travel times on almost all the sections are decreased up to 36%, nominal 2.7% decrease on Ashram flyover to DND flyover entry. The travel time increased up to 21% both flyovers. This option performance is very well other than two flyovers. The overall performance of this option is well and the Srinivasapuri section performance is not good by this option there may be some other reason for congestion other than the bus stop location.

The output shows by relocation bus stops have impact on network performance such as delays and travel time deceased. The performance at certain location is not increased at that location the relocation of us stop does not have significant impact, it shows that the relocation of bus stops may reduce traffic congestion up to certain level only, it may not reduce the traffic congestion fully.

6.7 Scenario 5 (Dedicated Bus Lane)

This scenario out puts shows that, the spot speeds of all the vehicles are reduced at two locations (up to 3%) and of one location it is increased marginally. The average speed at network level is decreased by 14.3%. The bus speeds in dedicated bus lane are increased (50-80%) drastically, but other mode speeds in remaining two lanes are reduced (up to 9%). The average, stopped and total delays of this option is increased up to 33% and the delay on one section is increased to 193%.The density (veh./km) at individual link level is decreased to 2.74%. The travel times on the one flyover and under the flyover sections are increased up to 121%. Travel time on one flyover, some sections where there is bus stop located are increased (up to 50%). Network level performances are not attractive in this scenario.

This scenario shows the reduction of network level parameters, because the existing carriageway is reduced for all the modes, hence the speeds of these modes are reduced. The performance of the bus speeds are increased drastically. This scenario works very well if we construct the additional lane for buses, and also work very well when the capacity of the roads are underutilized. It is observed in this study, the performance of these scenarios is not good.

6.8 Change in Congestion Index

Congestion mitigation alternatives and their impacts on various parameters such as speed, travel time, delay etc. are evaluated. In additions to these parameters the impact of congestion index for various alternatives are calculated using VISSIM out puts. Congestion index is recalculated at three critical locations namely Lajpath Nagar, Srinivasapuri and Maharanibagh. The Figure 6shows the impact of arterial congestion index by various scenarios. From the graphs the option traffic management is reducing the overall congestion at all locations with respect to other scenarios.

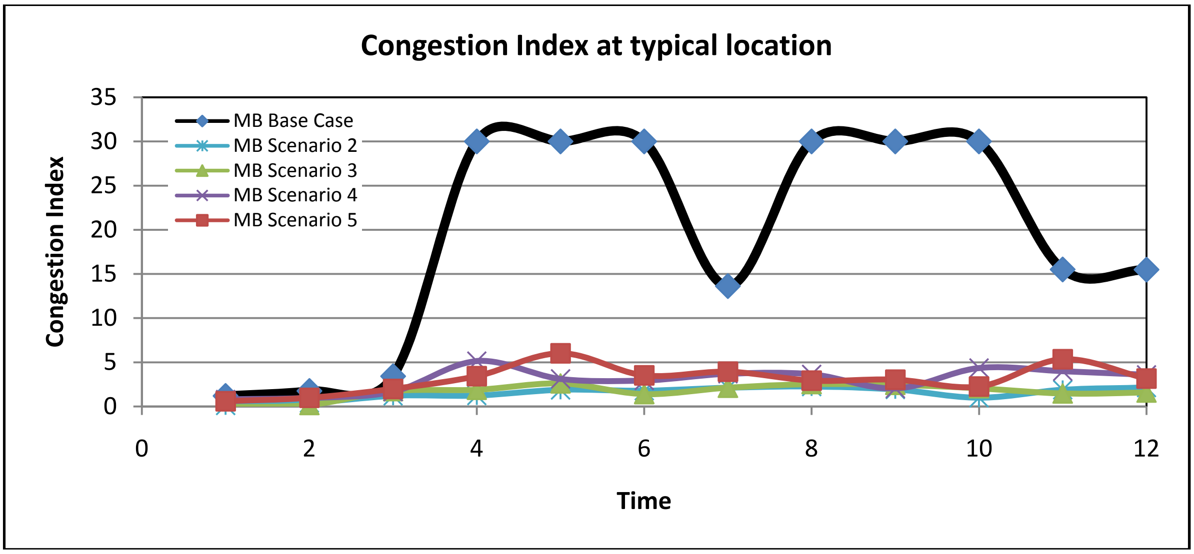


Figure6Congestion Index at a typical location (Inner Ring Road Delhi)

7. Summary and Conclusions

The spot speeds results show that the scenario elevated road, shifting bus stop have some improvement of the speed, whereas the performance of traffic management shows that the speeds are increased drastically. The Figure 7 summarizes the speeds for various scenarios. The rest parameters performances with respect to the scenarios are presented in Figure 6 (note in the Figure: The numbers shown in network performance are denoted such as 1-Average Delay Time per vehicle (sec), 2-Average Speed (km/hr), 3- Stopped Delay(average) per vehicle (sec), 4-Total Delay Time (h), 5-Total Travel Time (h) and the number given on x-axis for travel times and delays are represented in the section names such as 1-Mool Chand to L Flyover entry, 2-Lajpath Nagar Flyover, 3-Under Lajpath Nagar Flyover, 4-Srinivasapuri Link Between Two Flyovers, 5-Ashram Flyover, 6-Ashram Flyover to DND Flyover) (Mohan Rao 2013).

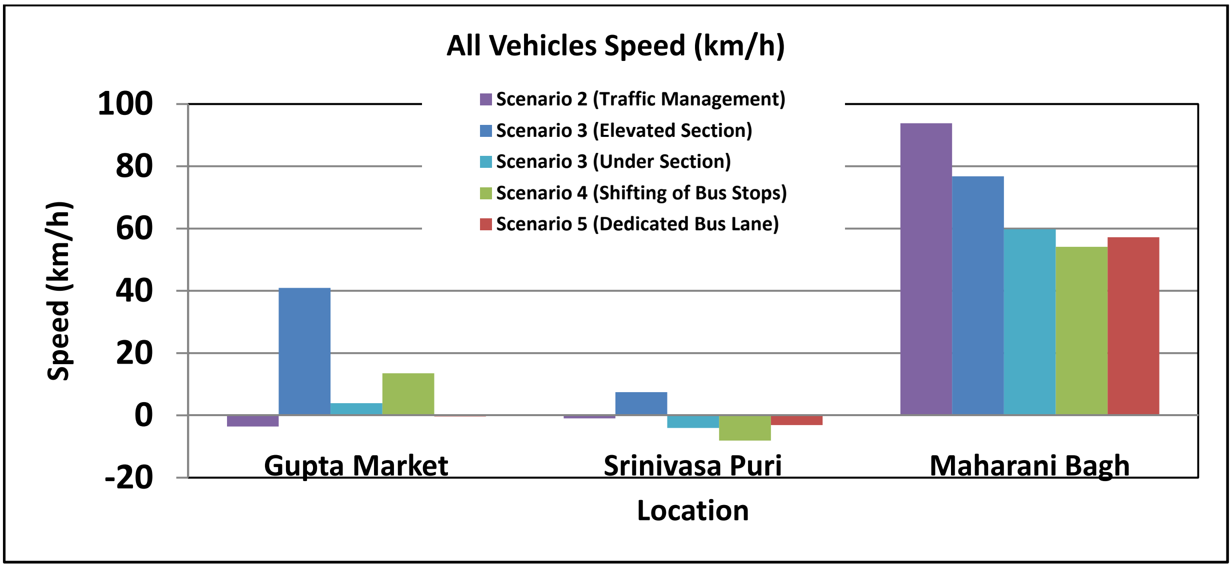


Figure7Spot speed comparison for all scenarios, (Inner Ring Road Delhi)

7.1 Conclusions

The conclusions based on this study are presented below.

- Traffic simulation models developed in VISSIM environment show a lot of promise in the form of incorporating different vehicle types and test the various scenarios.
- The based speeds and travel times for elevated road option seems to perform better.
- The scenario of shifting of bus stops has led to the increase of spot speeds. However, the congestion near Srinivaspuri has not come down in spite of shifting the bus stop upstream, as downstream shifting was not possible due to its location on the bridge (rail over bridge). On the other hand congestion has reduced at the remaining bus stops upstream, Lajpath Nagar and Gupta market and downstream (Maharanibagh bus stop).
- The Traffic management option, that involves restricting the right turn movement at Ashram intersection has performed well in terms of increased speed, the improved the network performance measures like average delay, travel time, density. In this way one can identify some critical locations on entire corridor and improve the adjoining junctions that merge with the corridor.
- The performance of the dedicated bus lane option results in marginal speed reduction, while the network densities and travel times increased on all the sections. However, its performance in terms of person/commuter movement is the best among all other scenarios, by moving the same number of commuters in half the space, i.e., on the bus lanes.

Acknowledgements
One of the authors (AMR) wishes to thank, Dr. S. Gangopadhyay, Director, Central Road Research Institute, New Delhi, India for giving permission to publish this paper.

References

Balakrishna, R., Antoniou, C., Ben-Akiva, M., Koutsopoulos, H. and Wen, Y. (2007). "Calibration of Microscopic Traffic Simulation Models: Methods and Application." *Transportation Research Record*, *1999*(1), 198-207.

Crowe, J. M. (2009). *The Calibration, Validation, and Comparison of VISSIM Simulations Using The Two-Fluid Model. Scenario*.M.S. Thesis, Department of Civil Engineering, University of Central Florida.

Daganzo, C.F. Laval, J. and Munoz, J.C. (2002). "*Ten Strategies for Freeway congestion Mitigation with Advanced Technologies*". Research Report http://escholarship.org/uc/item/4kd6v6qf

Dia, S. P. and Rakha H. (2005). "Comparative Evaluation of Microscopic Car-Following Behaviour." *IEEE Transactions on Intelligent Transportation Systems*, *6*(3), 314-325.

Duong, D., Hellinga, B. and Saccomanno, F. (2010). "A mechanistic approach for evaluating the safety impacts of left-turn lane offsets." *Proceedings the 2010*

Transportation Association of Canada Annual Conference, Halifax, Nova Scotia, 2010, 1-18

Fellendorf, M. and Vortisch, P. (2010). “Microscopic Traffic Flow Simulator VISSIM. Traffic”. doi:10.1007/978-1-4419-6142-6, 63-94

Gao, Y. and Rakha, H. (2008). “*Calibration and Comparison of the VISSIM and INTEGRATION Microscopic Traffic Simulation Models*”, M.S in Civil and Environmental Engineering, Virginia Polytechnic Institute and State University

Halkias, B. Kopelias, P., Papandreou, K., Politou, A., Prevedouros, P. and Skabardonis, A. (2007) “Freeway Bottleneck Simulation, Implementation and Evaluation” *Transportation Research Record*No. 2012, 84-93.

Hourdakis, J., Michalopoulos, P. G. and Kottommannil, J. (2003). “A Practical Procedure for Calibrating Microscopic Traffic Simulation Models.”*Presented at the 82nd Annual Meeting of the Transportation Research Board, Washington, DC.,*1-36.

Kim, S.-J., Kim, W. and Rilett, L. (2005).“Calibration of Micro-simulation Models Using Nonparametric Statistical Techniques.”*Transportation Research Record*, *1935*(1), 111-119.

Lownes, N. E. and Machemehl, R. B. (2006).“VISSIM: A Multi-Parameter Sensitivity Analysis”*Proceedings of the 2006 Winter Simulation Conference,* 1406-1413.

Ma, J., Dong, H. and Zhang, H. (2007).“Calibration of Micro-simulation with Heuristic Optimization Methods.”, *Transportation Research Record*, *1999*(1), 208-217

Ma, T. and Abdulhai, B. (2002).“Genetic Algorithm-Based Optimization Approach and Generic Tool for Calibrating.”*Transportation Research Record*, *1800*(02), 6-15.

Moen, B, Fitts, J, Carter, Dwight and Ouyang, Y (2000).“A Comparison of the VISSIM Model to Other Widely Used Traffic Simulation and Analysis Programs”, Conference on Institute of Transportation Engineers (ITE) Annual Meeting and Exhibit. 22.

Mohan Rao A (2013) “*Traffic congestion measurement and mitigation on urban arterials*”. PhD thesis, Department of Civil Engineering, Indian Institute of Technology Delhi.

Mulley, C. (2011). “No car lanes or bus lanes : which gives public transport the better priority ? An evaluation of priority lanes in Tyne and Wear.” <http://sydney.edu.au/business/__data/assets/pdf_file/0018/91242/WP-11-03.pdf> (5 December 2012)

Organization for Economic Co-operation and Development (OECD). (2004). “Managing Urban Traffic Congestion. Managing”, 1-31.

Papageorgiou, G., Ioannou, P., Pitsillides, A., Aphamis, T., &Maimaris, A. (2009). “Development and Evaluation of Bus Priority Scenarios via Microscopic Simulation Models”, Proceedings 12th IFAC Symposium on Control in Transportation Systems, Los Angeles, California.1-8.

Park, B. B. and Qi, H. M. (2005). “Development and Evaluation of a Procedure for the Calibration of Simulation Models.”*Journal of the Transportation Research Board*, *1934*, 208-217.

PTV A.G VISSIM (2011).*VISSIM 5.40-01 - User Manual* (pp. 1-730),. Germany.

Toledo, T., Ben-akiva, M. E., Darda, D., Jha, M. and Koutsopoulos, H. N. (2004)“Calibration of Microscopic Traffic Simulation Models with Aggregate Data.”, *Transportation Research Record*, *1876*(13), 10-19.

Vedagiri, P. and Jain, S. (2012). “Simulating Median Side Bus Lanes in Indian Traffic Conditions.”*ProceedingsThe International Simulation Conference of India (ISCI)*, ISCI 2012, IIT Mumbai, 2-4 Feb 2012, (pp. 1-9)

Venglar, S., Fenno, D., Goel, S., & Schrader, P. (2001). “*Managed Lanes - Traffic Modelling*”. <http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/4160-4.pdf> (5th December 2012)

Weinan, H. and Jain, S. (2009). “A NGSA-II based Parameter Calibration Algorithm for Traffic Micro-simulation Model.” *Proceedings of the IEEE Computer Society: 2009 International Conference on Measuring Technology and Mechatronics Automation, 2009.* (pp. 1-4).

Wheeler, N. and Figliozzi, M (2011) “Multicriteria Freeway Performance Measures for Trucking in Congested Corridors” Transportation Research Record: Journal of the Transportation Research Board, Volume 2224

Wiedemann, R. (1974). “*Simulation des Straßenverkehrsflusses*” vol. Heft 8, Karlsruhe, Germany: InstitutsfürVerkehrswesen der Universität Karlsruhe

Zhang, G., Yan, S. and Wang, Y. (2009) “Simulation-Based Investigation on High-Occupancy Toll Lane Operations for Washington State Route 167”, *Journal of Transportation Engineering,* Vol. 135, No. 10, 667-686.