IDENTIFICATION OF CRITICAL LOCATIONS FOR INCIDENT MODELLING: A CASE STUDY OF KOLKATA CITY

Kaniska Ghosh and Bhargab Maitra
IIT Kharagpur
kgmd123@gmail.com & bhargab@civil.iitkgp.ernet.in

ABSTRACT

One of the major challenges regarding development of a traffic incident management plan is the response to the incident which depends upon the location of the incident. It is necessary first to fix the locations of an incident in the micro-simulation platform for incident generation. It is quite difficult to simulate incident on each and every point in a road network as theoretically the solution space would be infinite in that case. To address this issue, a set of 'critical' locations is identified within the network for incident modelling. From the perspective of traffic operators, responding to incidents on the critical locations would be a challenging task. For identifying the critical locations, the factors governing the selection of critical locations are identified. Then expert opinion survey is done to assess the relevance of those factors for a pool of pre-selected locations. Then on the basis of the analysis, ranking of the locations conforming to being critical is done. This result from the expert opinion survey is then compared against the result coming from incident simulation analysis using a micro-simulation model of the study network. The final outcome includes ranking of different locations (intersections and mid-block locations) on the basis of the comparative study. From this ranking, top 20 locations (10 intersections and 10 mid-block locations) are selected as critical locations. These critical locations serve as the locations for incident simulation in the micro-simulation model developed for dynamically replicating the field scenario.

1. INTRODUCTION

India is experiencing rapid urbanization and growth of private vehicles in urban areas. As economic efficiency of cities and well-being of urban inhabitants are directly influenced by mobility or the lack of it, the increasing rate of urbanization and city size have already put the urban transport system under great stress (*1*). The urban population in India has increased significantly from 62 million in 1951 to 377 million in 2011 and is estimated to be around 540 million by the year of 2021. In terms of percentage of total population, the urban population has gone up from 17% in 1951 to 31.2% in 2011 and is expected to increase up to around 37% by the year of 2021. The significant growth in urban population and corresponding private vehicles has already resulted in a growing imbalance between demand and supply of transport which makes urban traffic management more complex in Indian cities. This demand-supply imbalance leads to multi-faceted problems such as congestion, road accidents, pollution, etc., affecting the free movement of traffic and sustainability of the overall infrastructure system. This adverse urban scenario is further aggravated by non-recurrent congestion caused by traffic incidents which act as major congestion contributor and pose a significant threat to urban mobility and safety.

Traffic incident may be defined as any non-recurring event that causes a reduction of roadway capacity or an abnormal increase in demand. Such events include traffic crashes, disabled vehicles, spilled cargo, fire, road debris, explosion, highway maintenance and reconstruction projects, and special non-emergency events (*2*). Traffic incident can also be defined as an emergency road user occurrence, a natural disaster, or other unplanned event that affects or impedes the normal flow of traffic (*3*). Incidents lead to congestion when the traffic demand exceeds the reduced roadway capacity at the incident location. The occurrence of an incident can greatly intensify the existing congested traffic conditions at a particular location at a particular instant of time. The immediate effect of the incident propagates to the surrounding road network as shock wave resulting in blockage; which eventually may spread over a larger network if efficient measures are not taken immediately (*4*).

Dealing with traffic incidents is a critically important part of every transportation network management program. It should be considered in all stages of developing and implementing a network management and operations program as a key to reduce congestion. Traffic Incident Management (TIM) is the systematic, planned and coordinated use of human, institutional, mechanical and technical resources to reduce the duration and impact of traffic incidents, and to improve the safety of motorists, crash victims and traffic incident responders (*5*). Effectively using these resources can also increase the operating efficiency, safety and mobility of the roadway system. Most of the available research studies have considered development of micro-simulation models for incident modelling and evaluating the performance of the network under different incident scenarios. One of the major challenges regarding the development of a traffic incident management plan is the response to the incident which depends upon the location of the incident. It is necessary first to fix the locations of an incident in the micro-simulation platform for incident generation. It is quite difficult to simulate incident on each and every point in a road network as theoretically the solution space would be infinite in that case. To address this issue, a set of 'critical' locations is needed to be identified within the network for incident modelling. Critical locations are the locations on the network that are difficult to manage under traffic incident conditions. The choice of critical locations does not simply focus on the locations with the most frequent incident occurrence; rather it considers the complexity regarding traffic management during incidents (*6*). Incidents on these critical locations would cause serious traffic disruptions. From the perspective of traffic operators, responding to incidents on the critical locations would be a challenging task. Unfortunately, adequate investigations have not been carried out in Indian context for developing a framework to identify critical incident locations and formulating rational traffic management strategies on the basis of real-time traffic state. The current practice regarding traffic management during incidents is primarily based on experience and judgment of key personnel (say, local traffic police) involved in the decision-making process. In light of the present scenario, the broad objective of this paper is to develop a methodological framework for identifying critical incident locations required for incident simulation in a road network.

2. LITERATURE REVIEW

In order to investigate the factors governing the choice of critical locations, previous research is reviewed. As mentioned earlier, critical locations are the locations on the network that are difficult to manage under traffic incident conditions. Formulating different rational traffic management measures for implementation around critical location is a challenging task. Incident management consists of several actions. These are time-related steps between the incident occurrence and the time that the traffic flow resumes to normal. These steps are shown in the Figure 1 (next page).

Detection time is the time measured from the occurrence of incident to the time that the related agencies are notified about the incident. Once the incident is detected, depending on the type and the severity of the incident, related agencies are informed and the Emergency Response Unit(s)

(ERU) is/are dispatched. This period is called *dispatch time*. *Response time* is the time required by the ERU to reach the incident site after being informed about the incident. This time is dependent on the dispatching policy of the incident management centre. The duration of ERU response depends on the experience of the police officer in handling the incident and the availability and closeness of the required ERU. *Clearance time* is the time between the arrival of the response team and the time when the incident has been fully cleared (all traffic lanes are open). *Time to normal flow* is the time required for the traffic to reach its normal flow after the completion of the incident clearance (*7*).

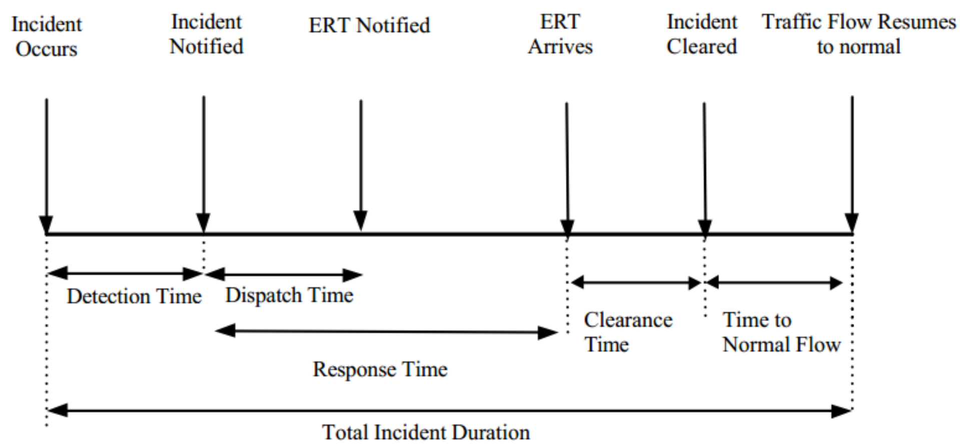

FIGURE 1 Timeline of incident duration

Many past studies have focused on using expert opinion analysis as a tool to identify different key governing factors related to a transportation decision making process. Different techniques have been used to identify the latent factors that explain the manifest variables. The key here is to seek the key influencing factors (motivators or deterrents) and measure their relative importance in terms of their impact on critical location choice. Route and link-related attributes are found to have significant impact on similar decision making processes. Route related attributes such as route topography, presence/ absence of signal, continuity of facility (*8*), average slope, length of route (*9*), roadway condition (*10*) and link-related variables such as presence/ absence of proper parking facility, dedicated mode facility (*8*), provision of traffic calming measures (*11*) are considered in some of the similar transportation studies for expert opinion survey.

Besides the above mentioned measurable factors, some unobserved or latent factors are also considered (*12*). Based on these research findings, several key influencing factors are identified and included in this study. Some studies have preferred user perception over expert judgment for analysis (*13*, *14*). However, from the view point of an informed and balanced policy making, authors feel that along with user perception and preference, experts (engineers and planners) opinion is as important (*15*). Multi Criteria Decision Making techniques such as Analytical Hierarchy Process (*16*, *17*, and *18*), TOPSIS, Fuzzy-AHP and a combination of these (*19*) are extensively used for weighting of such competing opinions. Among others, AHP compares the pair wise responses in terms of numeric values that can be processed and compared in the context of the given problem while maintaining the consistency of the dataset (*20*).

In the context of determining the impact of incidents, traffic incident modelling approaches in the existing literature often rely on queuing models to predict travellers' delay. In a study, incident duration is modelled as a random variable with a deterministic queuing model approach (*21*). The model assumes constant arrival rate, and when there is no incident, a constant departure rate. The authors have inferred that travellers' delay in incident conditions depends on several factors: incident severity/capacity reduction, incident duration, arrival pattern, traffic volume, and the future time of vehicle's arrival at the incident location. Another study has developed a fuzzy queuing model to predict the possible delay or interval of delay that a vehicle experiences at an incident location (*22*). In another related study, an estimation method for delays caused by traffic incidents is proposed (*23*). The authors have used a queuing based approach and compared its results with a simulation model. Another study has used Dynamic Traffic Assignment (DTA) to analyze the impact of incidents on delay (*24*). DTA models produce spatio-temporal trajectories of all vehicles from their origin to their destination under a simulated environment. In another approach, a methodology has been proposed where different types of incidents at critical locations are analyzed through micro-simulation models (*25*). The analysis focuses on incident induced freeway delays, but it also examined other parameters, such as vehicle throughput, travel times and network-wide delays.

3. METHODOLOGY

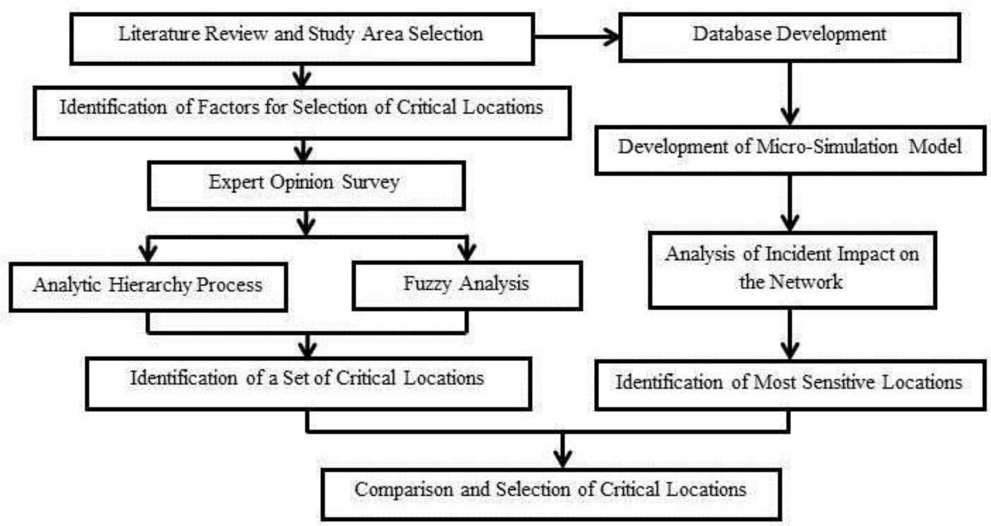

FIGURE 2 Methodological framework of the study

The broad methodological framework of this study is presented in Figure 2. Initially a detailed and thorough study of literature is carried out regarding traffic incidents, impact of incidents, incident modelling and identification of key governing attributes as mentioned in the previous section. The study area is selected in consultation with the local law enforcement agency (Kolkata Traffic Police). A comprehensive database is developed for constructing a micro-simulation model of the study network using VISSIM software. For developing the micro-simulation model, different types of traffic data are required in different points of time. The collected raw data are properly extracted and refined as per the needs. All the network geometry data and traffic signal control data are collected with the help of Kolkata Traffic Police. The existing traffic circulation pattern and the current practice regarding incident management are also noted. Then the impact of incident is quantified and analysed on the basis of repeated simulation runs. Travel time and queue length are used as the Measures of Effectiveness (MOE) to quantify the incident impact on the network. From the analysis results, the sensitive locations (only intersections) are identified and ranked in order. On the other hand, based on the available literature review, various key influencing factors are identified for the selection of critical locations. Then a pool of locations (both intersections and mid-block locations) on the study network is selected and expert opinion survey is conducted. Weights for each factor are decided using Analytic Hierarchy Process (AHP) and for each location, the measures are assessed qualitatively based on fuzzy logic of analysis. Then overall scores are calculated; and based on this scoring, ranking of the locations conforming to being critical, is done. After that, both the results from micro-simulation analysis and expert judgement analysis are compared against each other. Finally the top 20 locations (10 intersections and 10 mid-block locations) are selected as critical locations based on the comparative study.

4. STUDY AREA

The study area considered in this research is the CBD area of Kolkata city. A few sensitive locations were identified and finally the particular study area is selected in consultation with the local law-enforcement agency (Kolkata Traffic Police). The area is marked with some busy and congested streets where some old and vulnerable buildings and factories are located, thereby, making this area highly sensitive to incidents. The boundaries of the area are defined by four major arterial roads namely, Chittaranjan (C.R.) Aveneue on East, Strand Road on West, Mahatma Gandhi (M.G.) Road on North, and S. N. Banerjee Road on South. The study network consists of 141 intersections, 45 of them being signalized ones and the rest 96 intersections are minor and unsignalized. This area is marked with a wide variation in carriageway widths. A few extremely important buildings and infrastructure facilities (Writers Building, Raj Bhawan, Kolkata Police Headquarters, General Post Office, SBI Headquarters, Regional Passport Office, The Lalit Great Eastern Hotel, Central and Chandni Chawk metro railway stations etc.) are located in this area, making this area highly attractive in terms of trip generation. The outline of the area is shown in Figure 3.

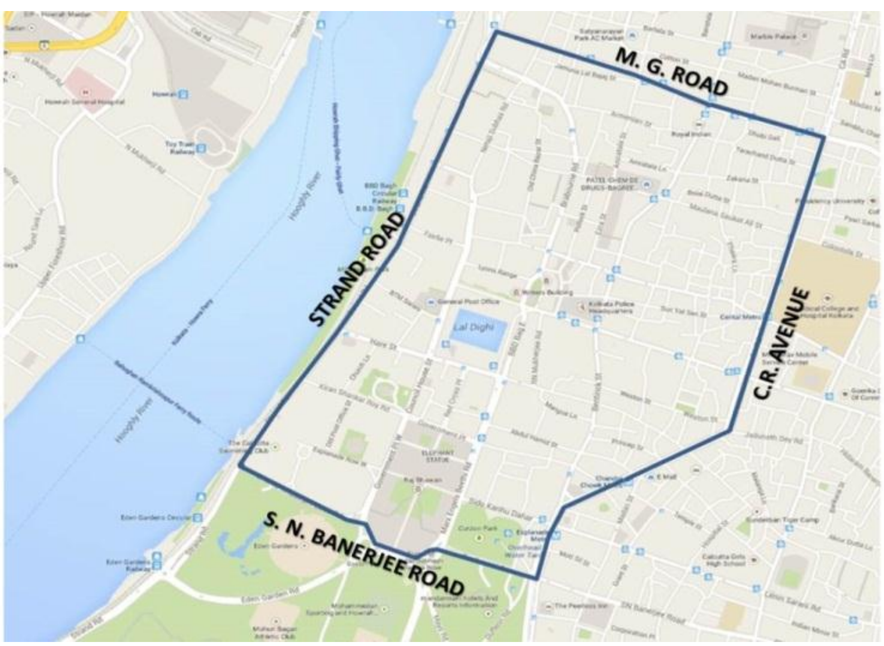

FIGURE 3 Outline of the study area

5. ANALYSIS

5.1 Identification of Factors for Selection of Critical Locations

As stated earlier, the selection of the critical locations should be rational and logical. For satisfying these criteria, several influencing factors are needed to be identified. Based on literature review, the following six factors are identified namely, (i) Traffic Volume, (ii) Scope of Diversion to Alternative Route, (iii) Proximity to Traffic Signal, (iv) Proximity to Major Intersection, (v) Number of Lanes in Each Direction, and (vi) Traffic flow direction.

5.2 Expert Opinion Survey

After identifying the factors, expert opinion survey is done to assess the relevance of those factors for a pool of pre-selected locations. The pool of pre-selected locations includes 45 signalized intersections and 52 important mid-block locations within the network. In this stage, experts are asked to judge the importance of the factors on different scales. For this study, experts are asked to consider only the peak hour characteristics of the locations. This analysis is done in two parts. In the first part, Analytic Hierarchy Process (AHP) is used to find the weightage of each factor. In second part, Fuzzy Logic is applied to find the defuzzified score of each factor for each location. Then Overall Score is calculated; and based on scoring, ranking of the locations conforming to being critical, is done. Overall Score (**Y**) for each location is calculated by using the following equation:

$$\mathbf{Y = a_1x_1 + a_2x_2 + \ldots + a_nx_n}$$

Where $\mathbf{a_i}$ = weightage of factors obtained by AHP, and $\mathbf{x_i}$ = values obtained by defuzzification of the variables collected from the expert survey.

5.2.1 AHP Analysis

Here AHP survey is done by using twenty experts' ratings. To check the consistency of the result, this analysis is done in three ways: (i) considering the judgement of first 10 experts (W_{10}), (ii) considering the judgement of first 15 experts (W_{15}), and (iii) considering the judgement of all 20 experts (W_{20}). The results are found to be generally consistent with some slight variations. Then all the three results are averaged to estimate the final weightages (W_{avg}). The calculated weightage of each factor is summarized below.

TABLE 1 Weightage of Factors Based on AHP

Factors	W_{10}	W_{15}	W_{20}	W_{avg}
Traffic Volume	0.205	0.219	0.216	0.213
Scope of Diversion to Alternative Route	0.233	0.222	0.224	0.226
No. of Lanes in each direction	0.144	0.162	0.174	0.160
Traffic flow direction	0.144	0.126	0.113	0.128
Proximity to Traffic Signal	0.111	0.118	0.118	0.116
Proximity to Major Intersection	0.163	0.154	0.155	0.157

5.2.2 Fuzzy Analysis

As two of the influencing factors (No. of Lanes in Each Direction and Traffic Flow Direction) are cardinal variables, analysis is done on the basis of normalized ranking for those two factors. For the remaining four factors, which are ordinal in nature, data are collected from the experts based on fuzzy variables for each factor for each pre-selected location. The experts have to define the range of fuzzy variables on a scale of 0-100 based on their perceptions. Then they are asked to rate the factors for each location in terms of fuzzy variables. This process is called fuzzification (*26*). Using the weightage and fuzzy values, defuzzification is done using centroid method. Subsequently final score is obtained for each location. Based on final scores, all the locations are ranked respectively. Here Fuzzy analysis is done by collecting opinions of five experts who have adequate knowledge of the network. The top 20 locations (10 intersections and 10 mid-block locations) with their respective overall scores are presented in the table below.

TABLE 2 Ranking of Locations on the Basis of Expert Opinion Analysis

Rank	Mid-Block Location	Overall Score	Intersection	Overall Score
1	On M. G. Road	82.43	M.G. Road-C.R. Avenue	87.70
2	On Ganesh Chandra Avenue	71.13	C. R. Avenue-G.C. Avenue	81.68
3	On Strand Road	65.44	Strand Road-M.G. Road	78.35
4	On Rabindra Sarani	60.67	Bentinck Street-Rabindra Sarani	71.44
5	On Brabourne Road	56.20	Brabourne Road-New CIT Road	68.67
6	On Netaji Subhas Road	52.94	N.S. Road-B.B. Ganguly Street	65.97
7	On C. R. Avenue	48.88	CR Avenue-New CIT Road	60.21
8	On Bentinck Street	47.76	C. R. Avenue- Sido Kanhu Dahar	59.43
9	On B. B. Ganguly Street	46.91	C. R. Avenue-Colootola Street	57.82
10	On Sido Kanhu Dahar	46.83	Kiran Shankar Roy Road-Government Palace West	55.93

5.3 Analysis on the Basis of Micro-Simulation Model

The test network for the study area for incident modelling is developed in VISSIM using network coding. The developed study network is presented in Figure 4.

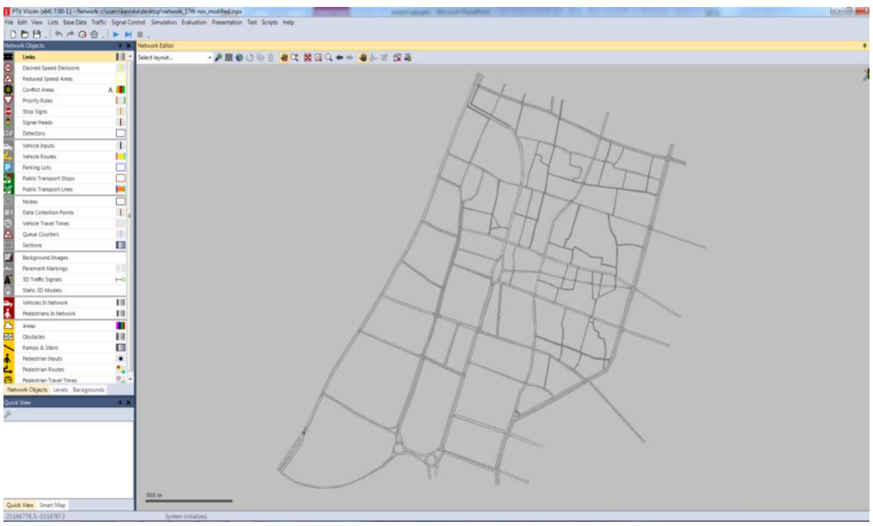

FIGURE 4 Study network in VISSIM

Defining the incident in the VISSIM simulation is done through time-dependent speed reduction areas and signal heads. Incident Location is represented by placing a traffic signal head to model the incident. Lane Closure determines the number of signal heads, with one signal head per each lane closed at the Incident Location. Here full lane closure is considered as the effect of incident in the micro-simulation model. Incident Duration defines the "red" time of the signal used for incident modelling. Speed reduction areas are defined before and after the traffic signal to make sure the vehicles comply with incident conditions and slowdown in the area of lane closure. The database required for the micro-simulation model include link traffic volume, turning movements, average travel time, vehicle composition and routing decisions. All the network geometry data (carriageway width, lane configuration, width of median etc.), traffic signal control data (signal cycle length & its variation over different hours of a day, number of phases, green splitting, change interval, clearance interval etc.) and existing traffic circulation patterns are collected on-site. Capacities of all the roads in the study network are calculated in accordance with IRC: 106-1990 (*27*). In this study, only the intersections are considered as incident locations and the peak hour traffic conditions are considered throughout the network.

There are a total of 131 intersections in the network over which the analysis is conducted. Each of these intersections is considered as the incident location in turns for the simulation study and for each incident location, three different simulation runs are conducted. Then the outputs over those three simulation runs are averaged for analysis purpose. The intersection location varies from signalized big intersections to small densely congested ones. A few insignificant intersections are excluded from the analysis. The intersections considered for incident simulation are shown in Figure 5.

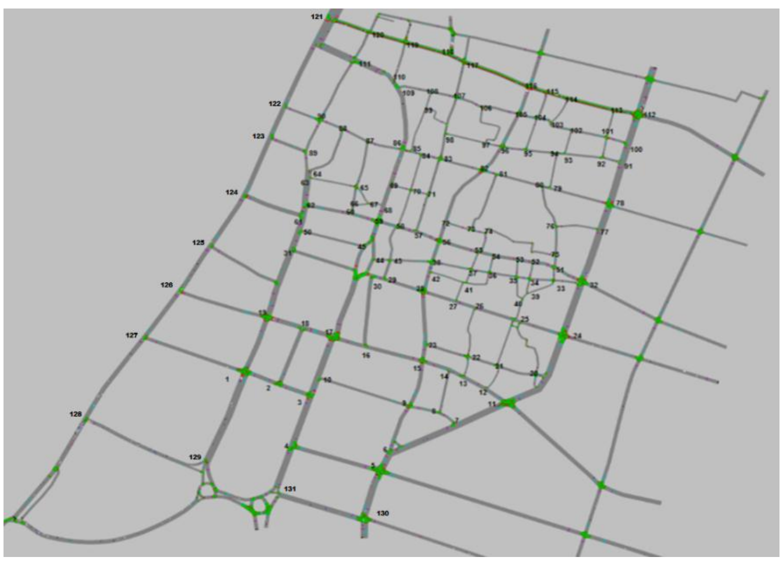

FIGURE 5 Incident locations in the study network

For this analysis, average vehicle travel time and average queue length are considered as the MOEs. For simplification, it is considered that for the first 10 minutes during simulation run, traffic flows in its normal state and then incident duration of 60 minutes is considered. A total of 20 travel time sections of a constant length of 60 meters are kept to cover the spatial impact of incidents throughout the studied network and a total of 64 queue counters are placed at strategic locations to properly cover all of the high density parts of the network. The travel time sections and queue counters in the network are shown in Figures 6 and 7 respectively.

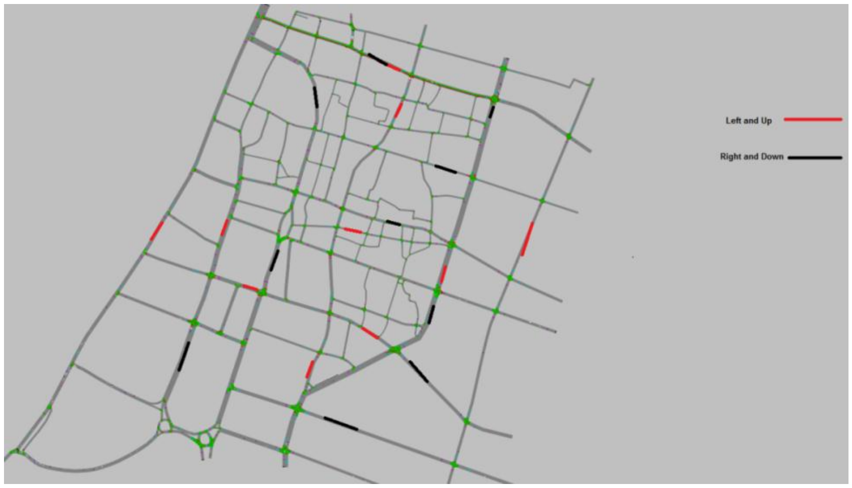

FIGURE 6 Location of vehicle travel time sections

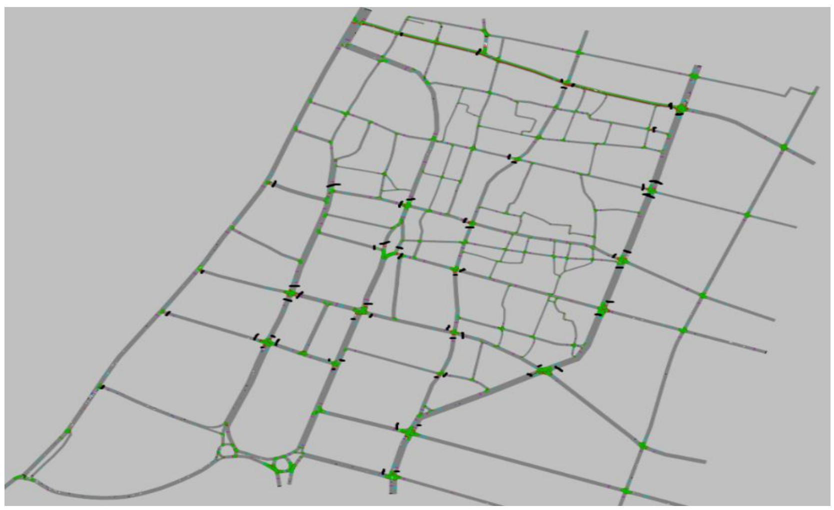

FIGURE 7 Location of queue counters

After fixing the all the model variables, input, and output parameters, the calibrated micro-simulation model is used to quantify the impact of incident over the network. The average vehicle travel time and average queue length comparisons for all the incident locations are presented below.

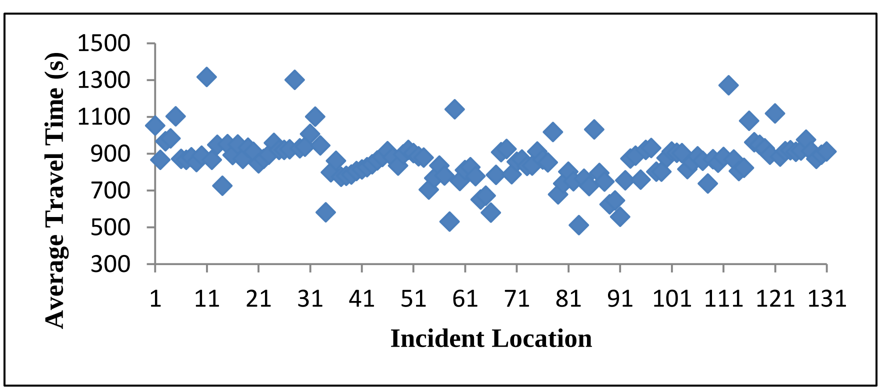

FIGURE 8 Average travel time comparisons for different incident locations

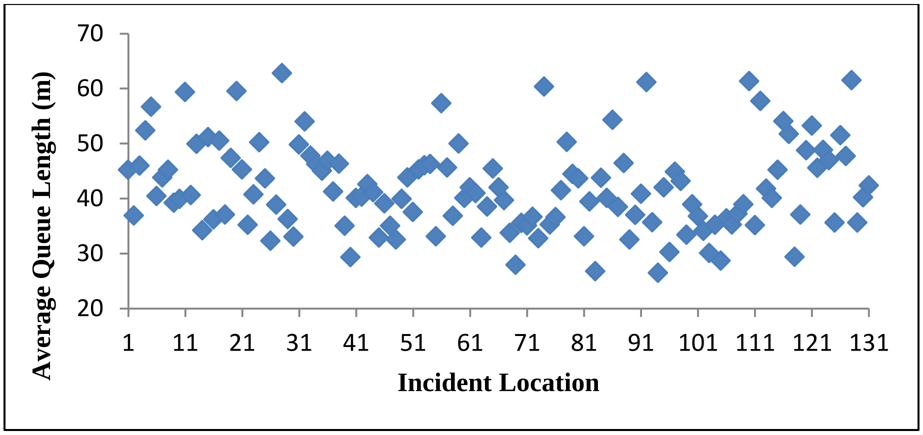

FIGURE 9 Average queue length comparisons for different incident locations

6. COMPARATIVE STUDY AND CONCLUSIONS

The critical locations estimated from expert opinion analysis, are shown in Figure 10 and the 20 most sensitive intersections estimated from the micro-simulation model, are shown in Figure 11. As the simulation study does not include mid-block sections, the final 10 critical mid-block locations are directly taken from the expert opinion analysis. It is found that the results of simulations study and AHP-fuzzy analysis are mostly in agreement, with slight variations among the internal order of the intersections. For example, the intersections between M.G. Road-C.R. Avenue, C. R. Avenue-G.C. Avenue, and Strand Road-M.G. Road are ranked 1st, 2nd and 3rd respectively as per the AHP-Fuzzy analysis, whereas according to the simulation analysis, they are ranked 3rd, 1st and 5th respectively. Nevertheless, almost all of the 10 critical intersections from expert judgement analysis also appear in the list of the same from simulation analysis, thereby validating the effectiveness of the AHP-Fuzzy analysis in predicting the critical locations. These final 20 locations (10 intersections and 10 mid-block locations) can be recommended as the critical incident locations within the study network.

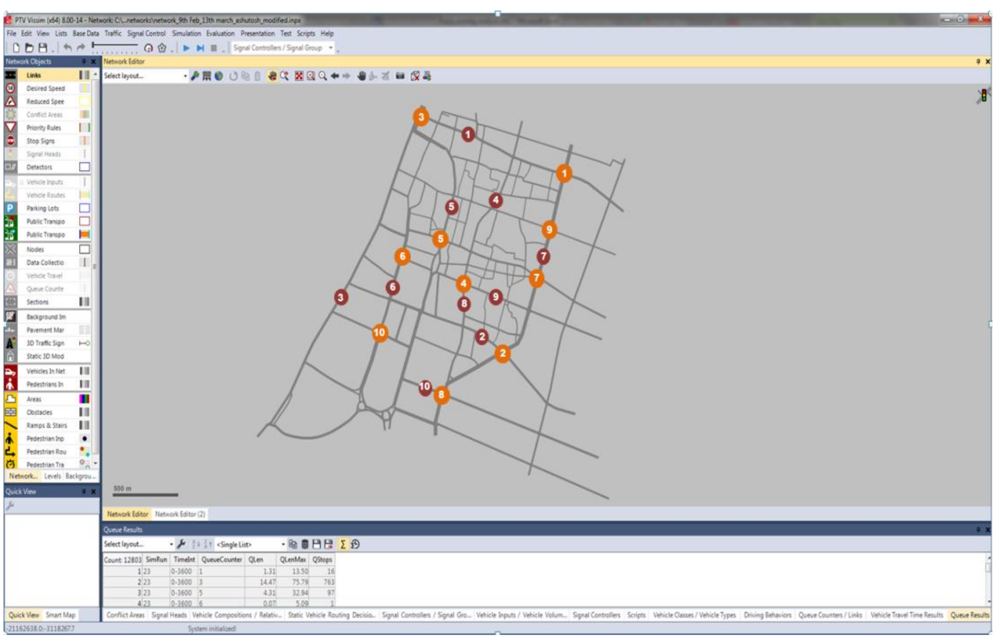

FIGURE 10 Critical locations in the study network using AHP-fuzzy analysis

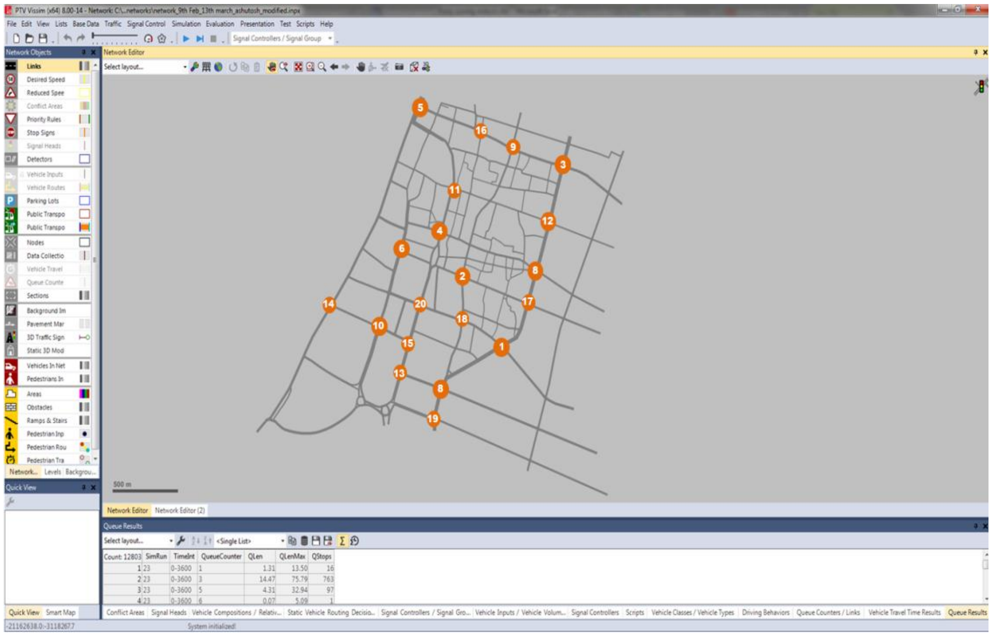

FIGURE 11 Most sensitive intersections in the study network using micro-simulation

The future study may include the same comparative study for the mid-block locations also. The variations between peak hour and off-peak hour may also be considered for further study. For analysis using micro-simulation model, effects of considering more MOEs can be explored. Considerations of different incident scenarios and implementation of traffic incident management measures may also be included for future research.

REFERENCES

(1) Padam, S., and S. K. Singh. Urbanization and Urban Transport in India: The Sketch for a Policy. Presented at Transport Asia Project Workshop, Pune, India, 2001.

(2) Farradyne, P. B. *Traffic Incident Management Handbook*. Federal Highway Administration, U.S. Department of Transportation, 2010.

(3) *Manual on Uniform Traffic Control Devices*. Federal Highway Administration, U.S. Department of Transportation, 2009.

(4) Ghosh, K., and B. Maitra. Evaluation of Post-Incident Traffic Management Strategies: A Case Study of Kolkata City. Presented at 12th Transportation Planning and Implementation Methodologies for Developing Countries, Mumbai, 2016.

(5) Ozbay, K., W. Xiao, G. Jaiswal, and B. Bartin. *Evaluation of Incident Management Strategies*. No. FHWA-NJ-2005-020. New Jersey Department of Transportation Bureau of Research and U.S. Department of Transportation Federal Highway Administration, 2005.

(6) Tasic, I. *Using Microsimulation to Evaluate Traffic Incident Responses for Traffic Operations Center Decision Making*. Diss. The University of Utah, 2012. pp. 17-35.

(7) Ozbay, K., & B. Bartin. Incident management simulation. *Simulation*, 79(2), 2003. pp. 69-82.

(8) Stinson, M., and C. Bhat. A Comparison of the Route Preferences of Experienced and Inexperienced Bicycle Commuters. *Transportation Research Record: Journal of the Transportation Research Board*, No. 05-1434, 2004.

(9) Jason, G. S., M. Winters, M. Nunes, and B. Micheal. Designing a route planner to facilitate and promote cycling in Metro Vancouver, Canada. *Transportation Research Part A*, 44 (2010), 2010. pp. 495–505.

(10) Litman, T. *Evaluating Non-Motorized Transportation Benefits and Costs*. Victoria Transport Policy Institute, 2013.

(11) Pucher, J., and R. Buheler. Making Cycling Irresistible: Lessons fromThe Netherlands, Denmark and Germany. *Transport Reviews*, Vol. 28, No. 4, 2008. pp. 495–528.

(12) Li, Z., W. Wang, C. Yang, & D. R. Ragland. Bicycle Commuting Market Analysis Using Attitudinal Market Segmentation Approach. *Transportation Research Part A*, 47, 2013. pp. 56–68.

(13) Winters, M., G. Davidson, D. Kao, and T. Teschke. Motivators and Deterrents of Bicycling: Comparing Influences on Decisions to Ride. *Transportation*, 38, 2011. pp. 153-168.

(14) Hair. J., R. Anderson, R.L. Tatham, and W. C. Black. *Multivariate data analysis*. Prentice-Hall, New Jersey, 2012.

(15) Majumdar, B. B., and S. Mitra. Analysis of Factors Influencing Bicycling in Small Sized Cities: a Case study of Kharagpur, India. *Case Studies on Transport Policy*, 3.3, 2015. pp. 331-346.

(16) Wong, J. K., and H. Li. Application of the Analytic Hierarchy Process (AHP) in Multi-Criteria Analysis of the Selection of Intelligent Building Systems. *Building and Environment*, 2007.

(17) Cheng, E. W. L., and L. Heng. Construction Partnering Process and Associated Critical Success Factors: Quantitative Investigation. *Journal of Management in Engineering*, 2002. pp. 194-202.

(18) Shelton J., and M. Medina. Prioritizing Transportation Projects using an Integrated Multiple Criteria Decision-Making Method. *TRB 89th Annual Meeting: Compendum of Papers DVD*, 2010.

(19) Ho, G. T. S., K. L. Choy, C. H. Y. Lam, and D. W. Wong. Factors Influencing Implementation of Reverse Logistics: A Survey among Hong Kong Businesses. *Measuring Business Excellence*, *16*(3), 2012. pp. 29-46.

(20) Kong, D. *Using a Quality Based Analytic Hierarchy Process to do Decision-making Analysis in Transportation*. M. S. Thesis, Industrial and Management Systems Engineering, The Graduate College at University of Nebraska, 2010. pp. 5-19.

(21) Fu, L., and L. R. Rilett. Real-Time Estimation of Incident Delay in Dynamic and Stochastic Networks. *Transportation Research Record 1603*, Transportation Research Board of the National Academies, 1997. pp. 99-105.

(22) Fu, L., and B. Hellinga. *Real-time, Adaptive Prediction of Incident Delay for Advanced Traffic Management and Information Systems*. Proceedings of the Annual Conference of the Canadian Institute of Transportation Engineers, Canada, Ottawa, 2002.

(23) Gursoy, M. B., W. Xiao, and K. Ozbay. Modeling Traffic Flow Interrupted by Incidents. *European Journal of Operational Research*, 195, 2009. pp. 127-138.

(24) Ngassa, C. K. *Estimation of Network Based Incident Delay in a Transportation Network Using Dynamic Traffic Assignment*. PhD Dissertation, The City University of New York, 2006.

(25) Martin, P. T., P. Chaudhuri, I. Tasic, and M. Zlatkovic. *Freeway Incidents: Simulation and Analysis*. No. MPC Report No. 10-229D. Mountain-Plains Consortium, 2011. pp. 11-34.

(26) Chu, T. C., & C. T. Tsao. *Ranking Fuzzy Numbers with an Area between the Centroid Point and Original Point*. Computers & Mathematics with Applications, 43(1), 2002. pp. 111-117.

(27) Indian Roads Congress. *Guidelines for capacity of urban roads in plain areas*. IRC-106, 1990.