# A Framework for Assessing Incident Management Strategies using Micro-simulation Techniques

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## ABSTRACT

Incidents, pre-programmed or random, are major sources of congestion on urban freeways. With many of urban freeways in the US operating close to capacity, the need to reduce the impact of incident-related congestion has become critical. Incident Management Strategies (IMS), when properly developed and deployed, have the potential to reduce such congestion on urban freeways.

The purpose of this paper is to develop an analytic framework for the calibration and application of a micro-simulation model (AIMSUN) for testing the impact of alternate IMS's on an urban transportation network. The authors initially present a framework in a conceptual form, and demonstrate the calibration and application of the model on a real life network in the Detroit metropolitan region. While the initial results are positive, full-scale validation and testing with larger networks are recommended to justify the use of micro-simulation techniques for assessing the impact of different IMS's.


## INTRODUCTION

Incidents continue to be major sources of congestion on urban freeways and arterials. Law enforcement and transportation agencies, along with emergency service providers in the United States are working together to develop viable incident management strategies (IMS) to alleviate freeway congestion problems. A traffic incident is defined as "any occurrence on a roadway that impedes normal traffic flow" (*1*). Typically, these are non-recurring events that cause temporary reduction in roadway capacity. Similar definitions are also provided in other sources (*2-3*). Incidents can be pre-programmed, such as pre-announced work zone activities, or random, such as traffic crashes disabled vehicles, spilled cargo, etc. Figure 1 shows that events as defined above, contribute significantly to traffic congestion on US highways.

With many of the US roadways operating close to capacity under the best of conditions, the need to reduce the impact of incident-related congestion has become critical. One way to achieve this is to improve the management of traffic after an incident has occurred, including the use of traffic diversion strategies. Thus, key components of successful IMS are early detection, efficient recovery, and effective diversion of traffic to the surrounding links in the network, using variable message signs (VMS), and emerging technologies such as vehicle-vehicle communication, vehicle infrastructure integration (VII), etc. A crucial component of any IMS is the recovery stage, particularly the utilization of traffic diversion strategies. Prolonged recovery stages are associated with increased delay and longer queues.

**Problem Statement**

With the current emphasis on IMS, standardized techniques are not available to assess the impact of these strategies. The problem addressed in this paper deals with the question of dynamically finding alternate paths in a given network for travel between zone pairs, when a section of the network is temporarily incapacitated because of incidents, either pre-programmed or random. Instant knowledge of such alternate paths with surplus capacities may enable Traffic Management Centers (TMC) to efficiently divert traffic from the affected portion of the network, thereby helping alleviate congestion. In this paper, the authors present an analytic framework that can be used for:

- The calibration of a micro-simulation model on a portion of a transportation network of a major metropolitan region.
- The application of the (calibrated) model on the network to assess the impact of incidents on a section of a given freeway, and the effect of the deployment of different IMS's on the same network.

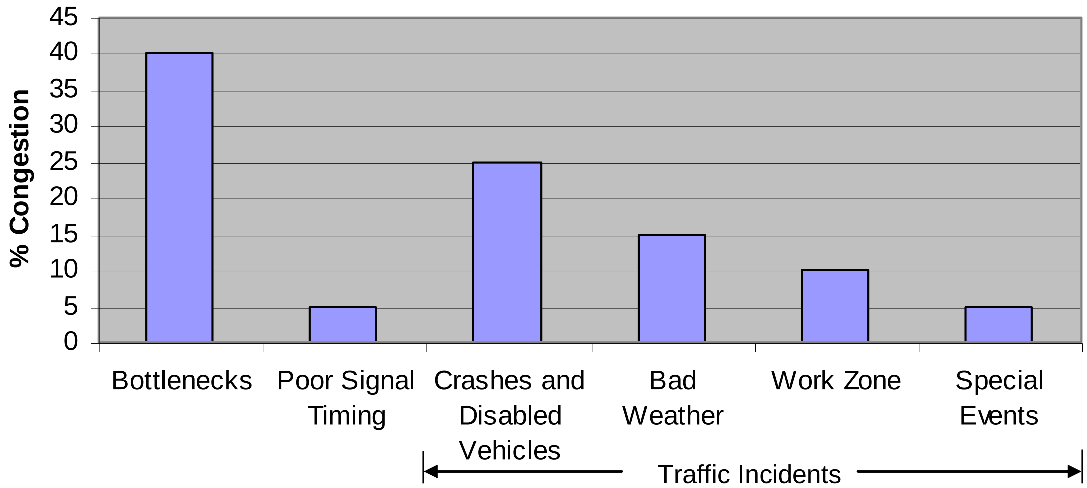


**FIGURE 1 The sources of congestion: National Summary** (*4*)

**Simulation as a Tool**

Simulation techniques have been used over the last fifty years to describe traffic flow over a transportation network. It is a process used to replicate a real-life phenomenon, such as traffic flow, through a set of models or mathematical formulations that are inter-linked to describe the behavior of all the entities involved (the driver, the vehicle, the roadway, and the traffic control devices in the case of traffic flow) along with their interactions. The primary advantage of simulation is that it enables the analyst to assess the impact of various operational strategies on the performance of the system without physical experiments that typically require significant resources, and cause severe traffic disruptions.

Micro-simulation models have received significant research attention lately, that focus on the movement of each individual vehicle by applying appropriate car-following, lane changing, and gap acceptance rules, and thus provide a more accurate representation of driver behavior and network performance. Micro-simulation models are being used increasingly to study new systems, and to determine system requirements to optimize network performance. Macro-simulation models, by contrast, are used to study “group behavior” i.e. traffic flow for a group of vehicles that are essentially expected to obey the same set of rules. Macro-models have also received extensive application in traffic studies. A third category, mesoscopic models are also receiving increased attention for studying dynamic traffic behavior. Meso-models attempt to combine the best features of micro and macro models, by retaining some of the individual vehicular characteristics and yet using some of the aggregate flow-density-speed relationships.

Many simulation software packages have been used over the years for dynamic traffic assignment, a complete discussion of which is beyond the scope of this paper. Examples include: CONTRAM (*5*), INTEGRATION (*6*) and DYNASMART (*7*), DYNAMIT/MITSIM (*8-9*), AIMSUN (*10*), CORSIM (*11*), PARAMICS (*12*), VISSIM (*13*). Each model has its own special characteristics, and was developed with a specific focus.

CONTRAM, INTEGRATION and DYNASMART are ‘macro-particle’ traffic simulation models where individual vehicles are tracked as they move through the network, but their velocities are determined by macroscopic speed/flow/density relationships. By contrast, DYNAMIT/MITSIM, CORSIM, PARAMICS, and VISSIM are microsimulation models, where each vehicle is modeled as an individual entity through the entire simulation process. AIMSUN is unique in it that all the three features, (i.e. macro, micro and meso) are embedded in the model. Some models also allow representation of alternative route choice behaviors, including allowances for dynamic response to real-time information. Examples of simulation-based research under congested conditions include Breheret et al. (*14*), Ha et al. (*15*), Hounsell et al. (*16*), Smith and Ghali (*17*) and Smith and Russam (*18*)

## LITERATURE REVIEW

As a part of the project that served the basis of the paper, a thorough review of the pertinent literature was conducted in four specific areas: (1) IMS’s and alternate route diversion on freeways and arterials, (2) various types of path and route choice models applied in IMS, (3) measures of effectiveness (MOE’s) used to evaluate IMS, and (4) the application of micro-simulation models to analyze IMS’s. A detailed discussion of this literature in this paper is not feasible because of space restrictions. Only a brief review of the first topic (IMS’s and alternate route diversion) over the last fifteen year period is presented below.

Koutsopoulos et al. proposed a stochastic traffic assignment approach for assessing the effectiveness of motorist information systems in reducing recurrent traffic congestion (*19*). The model were used for examining interactions among important parameters of the problem such as level and amount of information provided, users' access to information, and congestion levels. Abdel-Aty et al. reviewed a number of studies to understand driver behavior, and in particular, behavior when influenced by an Advanced Traveler Information System (ATIS) (*20*). He concluded that there is a need to understand how drivers choose or change routes in the absence of information in order to gain an understanding of route choice behavior in the presence of information. The study concluded that ATIS is helpful in driver decision making.

Khattak et al. developed a methodology for incident duration prediction, by using a series of truncated regression models (*21*). The model accounts for the fact that incident information at a Traffic Operations Center is acquired over the life of the incident. Cragg and Demetsky examined the merits and demerits of using simulation model as a decision aid for deploying traffic diversion strategies (*22*). A methodology for using such a model was demonstrated to determine the effects of various incident types on freeway traffic flow and the diversion of freeway traffic on the arterial network. The study concluded that simulation is an effective tool for IMS.

Madanat and Feroze predicted incident clearance time for Borman Expressway, Indiana (*23*). A parametric least-generalized cost path algorithm is presented to determine a complete set of extreme efficient time-dependent paths that simultaneously consider travel time and cost criteria. FHWA developed a framework for evaluating a multiagency traffic incident management program involving many agencies (*24*).

Balke et al. conducted a survey of traffic, law enforcement, and emergency service personnel to identify incident management performance measures in Texas (*25*). The basic objective of the survey was to collect driver behavior information and preferred route selection during incidents on road networks. Hidas investigated the effectiveness of variable message signs (VMSs) for incident management (*26*). A survey was conducted in the Sydney Metropolitan Region to collect information on driver response to a range of VMS messages. He proposed a route-choice model to predict diversion rates resulting from various VMS's.

FHWA developed an alternate route information guide during various types of incidents (*27*). Five aspects are broadly discussed in the study (a) alternate route planning (b) alternate route selection (c) alternate route plan development (d) traffic management planning, and (e) implementation. FHWA also developed an Incident Command System (ICS), a tool for systematic command, control, and coordination for emergency response (*28*). ICS allows agencies to work together using a common terminology and a standardized operating procedure for controlling personnel, facilities, equipment, and communications at an incident scene

Wirtz et al. tested a dynamic traffic assignment model for managing major freeway incidents (*29*). Incidents of various scales and durations were modeled for a highway network in the northern Chicago area, and the impact of incidents and response actions were measured. It was found that the best response action to a given incident scenario was not necessarily intuitive and that implementing the wrong response could often worsen congestion.

The detailed literature review conducted as part of the project (only a part of which is reported above) clearly indicated that:

- Traffic incidents are major causes of delays on US highways. IMS's, if properly deployed, may have a significant impact on reducing traffic delay.
- Micro-simulation models are being increasingly used to analyze procedures to alleviate congestion problems
- Various MOE's have been used to evaluate different operational strategies, including: travel time, delay, queue length, and volume to capacity ratio.
- Information, when properly communicated to motorists relative to time, space and sequence can be utilized effectively by motorists to find alternate paths in the network.

## METHODOLOGY

The purpose of this paper is to present a framework for using micro-simulation techniques in assessing the effect of IMS's. The calibration and application of the framework is also presented on an actual transportation network, comprising freeways and arterials in the northern part of the Detroit metropolitan area, USA. The Michigan Department of Transportation (MDOT), in collaboration with US Department of Transportation (USDOT) has established a Traffic Management Center (TMC) in Detroit, designed to monitor the performance of the regional freeway network, instrumented with state-of-the-art ITS equipment including sensors, detectors, cameras, and close-circuit televisions. Much of the data used in the calibration and application of the model was extracted from archived records of the MDOT/TMC commonly referred to as the Michigan Intelligent Transportation Systems Center (MITSC).

### Framework

The proposed framework is presented in Figure 2. The five step methodology encompassing policy and operational strategies associated with IMS can be summarized as follows;

Step 1: Network creation and assembling different databases.

Step 2: Identification of policies and development of algorithm that comprise the IMS

Step 3: Calibration of micro-simulation model

Step 4: Conducting micro-simulation based experiments, by creating incidents on the network, and by using the databases, algorithm and policies identified in the earlier steps.

Step 5: Analysis of results.

**Experimental Design**

The experimental design used in testing the framework encompasses of two major components: (1) Model Calibration, (2) Model Application

***Model Calibration***

The purpose of model calibration is to ensure that the model output is a reasonable replication of traffic flow characteristics observed in the field. The parameters that explain the field data are then used in testing the effectiveness of different strategies. In this case, the experimental design consists of:

1. Selecting an appropriate real life network.
2. Developing network characteristics for computer simulation.
3. Collecting information on current traffic including traffic volume, turning counts, signal operation, etc.
4. Using the traffic volume data as an input to the micro-simulation model to generate a synthetic trip table (OD matrix), appropriate for the network developed in step 2.
5. Assigning the trip table to the network.
6. Comparing the assigned volume with an independently collected volume data for goodness-of-fit statistics.
7. Reiterating steps 4, 5, and 6 by changing model parameters until a desired goodness-of-fit is achieved.
8. Designating a set of parameters that provides the desired goodness-of-fit as a part of the calibrated model.

While the procedure described above has been used in number of studies in the past, a special characteristic of this study is the utilization of archived data collected from sensors in the freeway network available through MDOT/MITSC and a private operator Traffic.com. These are described in detail later.

***Model Application***

The model thus calibrated along with the appropriate parameters was used to test the effectiveness of alternate IMS's on the same network. The various IMS's tested are: Lane closure, Incidents, Forced turning. These are defined later in the document.

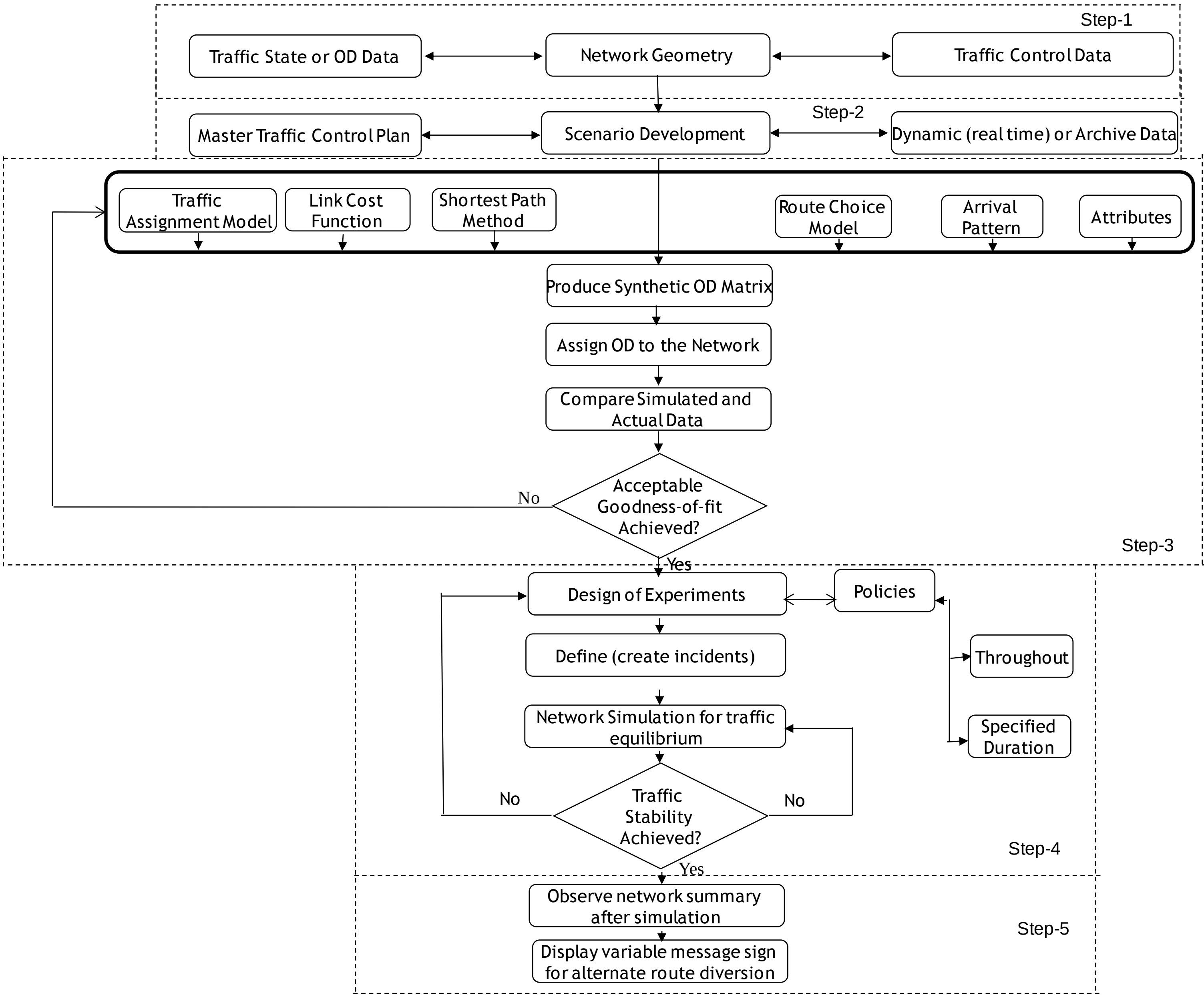


**FIGURE 2 Framework for Testing Incident Management Strategies**

## TESTING OF THE FRAMEWORK

The microsimulator available in the Advanced Interactive Microscopic Model for Urban and Non-urban Networks (AIMSUN) software is used to test the methodology. AIMSUN is developed by Transportation Simulation Systems (TSS), Barcelona, Spain and is capable of incorporating various types of incidents in a network consisting of detectors, traffic signals, variable message signs and other attributes. The input data requirement for AIMSUN is a set of scenarios (network description, traffic control plan and traffic demand data) and parameters (simulation time, statistical intervals, reaction time, etc) which define the experiment (*10*). Measures of Effectiveness (MOE) used in assessing the performance of the model are: travel time, delay and queue length.

## Network Description

The methodology is applied to test a heavily traveled portion of urban network in the Detroit metropolitan area. The network consists of two freeways, and 11 arterials (Figure 3). The freeways, Interstate 75 (I-75) and Interstate 696 (I-696) provide major mobility needs in the region in the North-South and East-West directions respectively. The arterials serve a combination of mobility and access function in the region. A summary of the network features is presented in Table 1.

The object of analysis is to assess the possible impact of incidents on I-75 in the northern part of the region. MDOT is planning to embark upon a major reconstruction program of I-75. Hence the proposed framework is tested on I-75 by the authors as a part of the project that serves as the basis of this paper. All the E-W routes with an interchange on I-75, all N-S facilities connecting to the major E-W arterials are included in the network, so that any traffic diverted from I-75 because of incidents could find alternate routes through E-W and N-S arterials.

The network analyzed consists of 47 nodes and 108 links is shown in Figure 3. There are 3152 sections in the network, where a section is defined as a group of contiguous lanes where vehicles move in the same direction. The partition of the traffic network into sections is usually governed by the physical boundaries of the area and the existence of turning movements. There are 26 centroids representing 26 zones that comprise 676 origin destination (O-D) pairs. VMS's can be placed before freeway exits to inform drivers of regulations that are applicable only during certain periods of the day or under certain traffic conditions (*30*). Freeway ramps, merging points and exit points are coded according to their lengths and curvatures. Traffic volume and signal timing data were collected from the Southeast Michigan Council of Governments (SEMCOG), Macomb County Road Commission (MCRC), and Traffic.com, a private agency that works closely with MDOT.

**TABLE 1 Network Summary**

| Highway Name | Highway Class | # of Lanes per direction | Posted Speed Limit (miles per hour) | Approximate Length (miles) |
|---|---|---|---|---|
| I-75 | Freeway | 3* | 70 | 18.97 |
| I-696 | Freeway | 3* | 70 | 14.48 |
| Telegraph | Major Arterial | 3 | 40 | 15.16 |
| Woodward | Major Arterial | 4 | 40 | 16.05 |
| Ryan | Major Arterial | 2 | 30 | 12.38 |
| Van Dyke | Major Arterial | 3 | 40 | 12.58 |
| M59 | Arterial | 3 | 40 | 15.88 |
| 8 Mile | Arterial | 4 | 45 | 13.57 |
| 12 Mile | Arterial | 2 | 40 | 13.32 |
| 14 Mile | Arterial | 2 | 40 | 13.27 |
| Big Beaver | Arterial | 3 | 40 | 7.90 |

Note*: Some sections of freeway (I-75 and I-696) consists of 4 lanes per direction

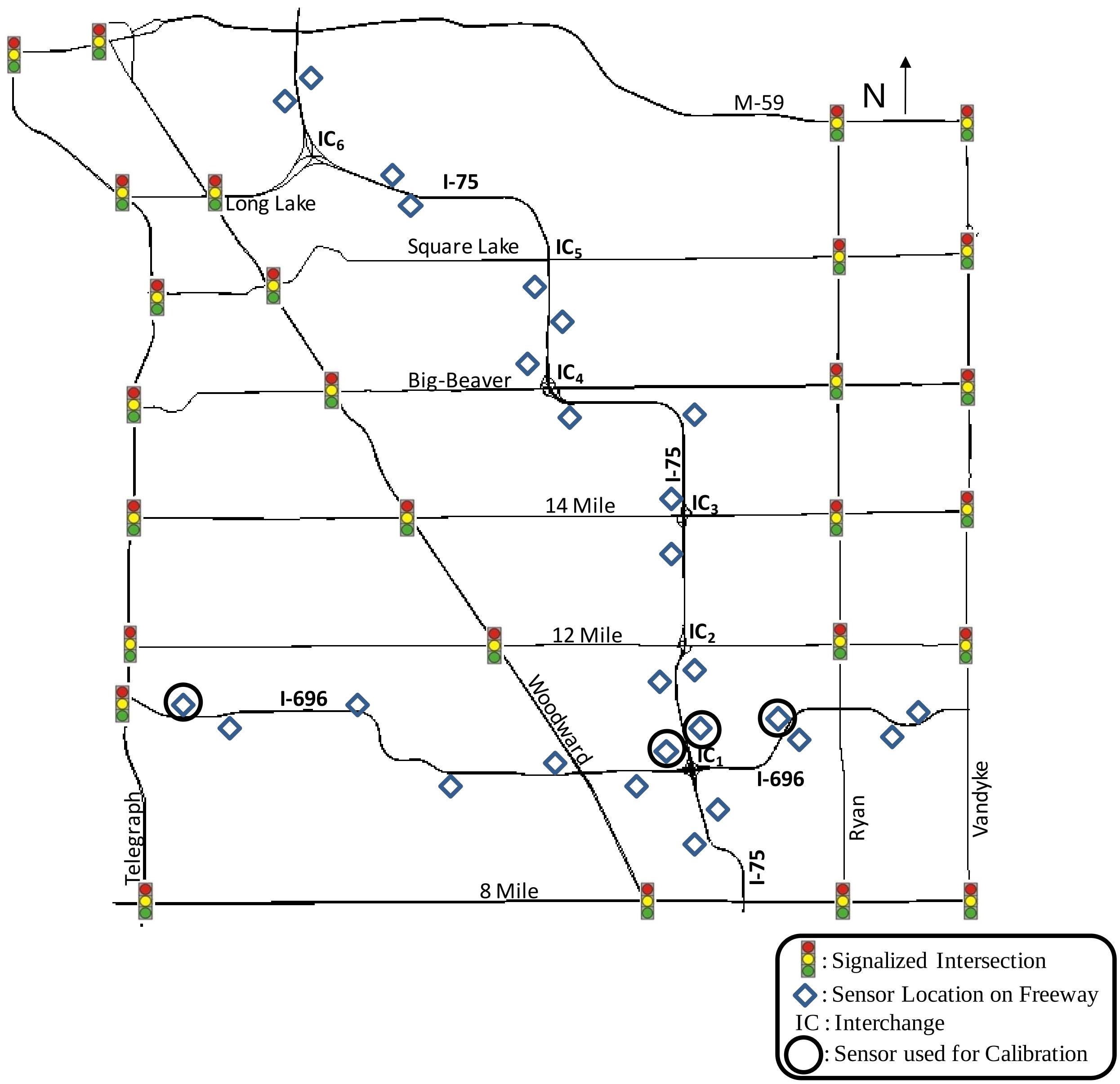


**FIGURE 3 Study Area Network**

## Model Calibration

The model calibration process was accomplished following the steps described earlier. Key features of calibration are as follows:

- First, a set of volume data was collected from sensors on I-75 and I-696 on Tuesday, 10th June 2008 for three hours between 7AM and 10AM. Turning movements and traffic signal data collected for the same period are also given as input to the network.

- These volume data when input to AIMSUN, was instrumental in creating a 26 x 26 O-D matrix for the exact time period between 7AM and 10AM.
- This trip table, when assigned to the network, produced a set of volume data on the freeway and arterials in five minute intervals for a total of 36 intervals for the three hour period.
- For assessing the goodness-of-fit of the assigned volume data, a second set of traffic volume data on the freeways was collected on Tuesday, 17th June 2008 between 7AM to 10AM from archived records.
- A set of preliminary visual tests were conducted between the assigned volume (model output) and second set of volume data (observed data) in an iterative manner, and the parameters were adjusted at every iteration until there was a reasonable match between the two sets of data.
- In Figure 4(a)-4(d) the authors present the best match for two sensor locations on each freeway. Each of the data pairs represent a five minute volume, the model output and the observed data. There being 36 five minute intervals over the simulation period of three hours, as many data pairs are shown in the figures 4(a) through 4(d). (Note: The four locations can be identified as the circle marked sensors in Figure 3)
- It should be noted that the sections presented in Figures 4(a) through 4(d) have four lanes.
- These figures indicate that even though there is not a perfect match, a reasonable correspondence was attained between the two sets of data. Similar comparisons was conducted for a number of sensor locations, but not reported for brevity.
- Table 2 lists a set of tests that were conducted to further validate the model. These goodness-of-fit statistics are used in literature for micro-simulation model calibration (*31-36*).
- Results of this test are presented in Table 3, that shows that for all the tests conducted, the goodness-of-fit measures are acceptable, either by error or by degree of correlation.
- A composite Root Mean Square Error (RMSE) test was also conducted for the goodness-of-fit between the two sets of volume data in the network for I-75. The simulated volume and actual volume are plotted in Figure 5 showing 612 data points being the result of multiplying 17 locations with 36 five minute counts at each location. The RMSE value computed as 0.001. Other goodness-of-fit statistics for I-75 corridor are presented in the last row of Table 3. Further, the two sets of values, when plotted on a graph, formed a linear representation at $45^0$ (Figure 5).

**TABLE 2 Goodness-of-fit measures for Calibration** (*31-36*)

| Goodness-of-fit Measures | Formulae | Desirable |
|---|---|---|
| RMSE<br>(Measures Overall % Error) | $\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{x_i - y_i}{y_i}\right)^2}$ | Close to 0 |
| Correlation Coefficient: *r*<br>(Measures Linear Association) | $\frac{1}{n-1}\sum_{i=1}^{n}\frac{\left(x_i-\bar{x}\right)\left(y_i-\bar{y}\right)}{\sigma_x\sigma_y}$ | Close to 1 |
| Theil's Inequality Coefficient: *Ui*<br>(Disproportionate Weight of Large Errors) | $\frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_i-y_i\right)^2}}{\sqrt{\frac{1}{n}\sum_{i=1}^{n}y_i^2}+\sqrt{\frac{1}{n}\sum_{i=1}^{n}x_i^2}}$ | Close to 0 |
| Theil's Component: *Us*<br>(Measure of Variance Proportion ) | $\frac{n\left(\sigma_y-\sigma_x\right)^2}{\sum_{i=1}^{n}\left(y_i-x_i\right)^2}$ | Close to 0 |
| Theil's Component:*Uc*<br>Measure of Covariance Proportion | $\frac{2\left(1-r\right)n\sigma_y\sigma_x}{\sum_{i=1}^{n}\left(y_i-x_i\right)^2}$ | Close to 1 |
| Theil's Component:*Um*<br>(Measure of Bias Proportion) | $\frac{n\left(\bar{y}-\bar{x}\right)^2}{\sum_{i=1}^{n}\left(y_i-x_i\right)^2}$ | Close to 0 |

Notations used in the goodness-of-fit measures are:

$x_i$ : Simulated traffic measurement value at time *i*
$y_i$ : Actual traffic measurement value at time *i*
$\bar{x}$ : Mean of simulated traffic measurement values
$\bar{y}$ : Mean of actual traffic measurement values
$\sigma_x$ : Standard deviation of simulated traffic measurement values
$\sigma_y$ : Standard deviation of actual traffic measurement values

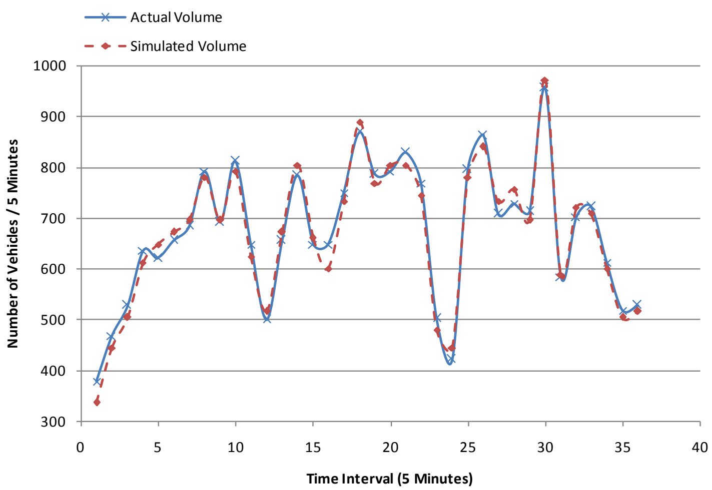


**FIGURE 4(a) Actual and Simulated Volume on I-75 South and I-696**

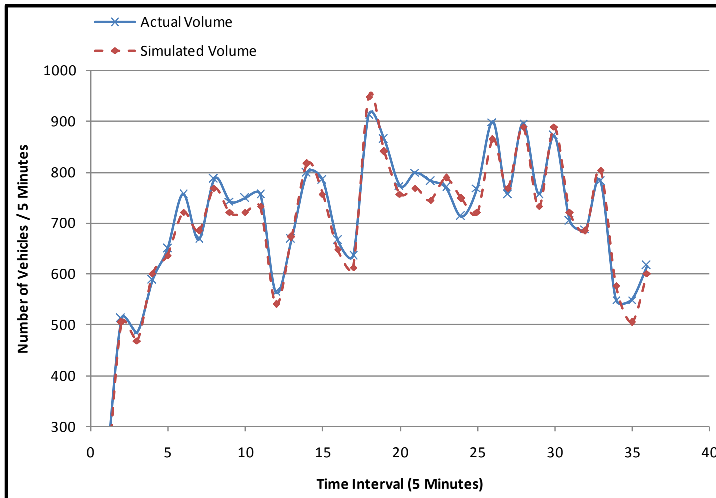


**FIGURE 4(b) Actual and Simulated Volume on I-75 North and I-696**

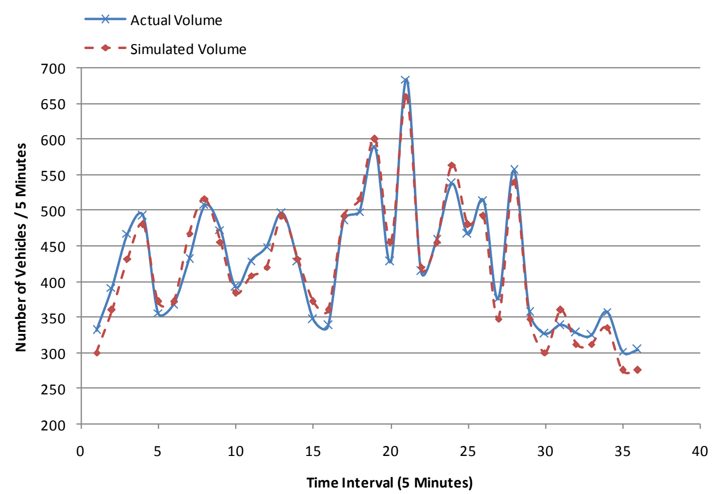


**FIGURE 4(c) Actual and Simulated Volume I-696 at East and North I-75**

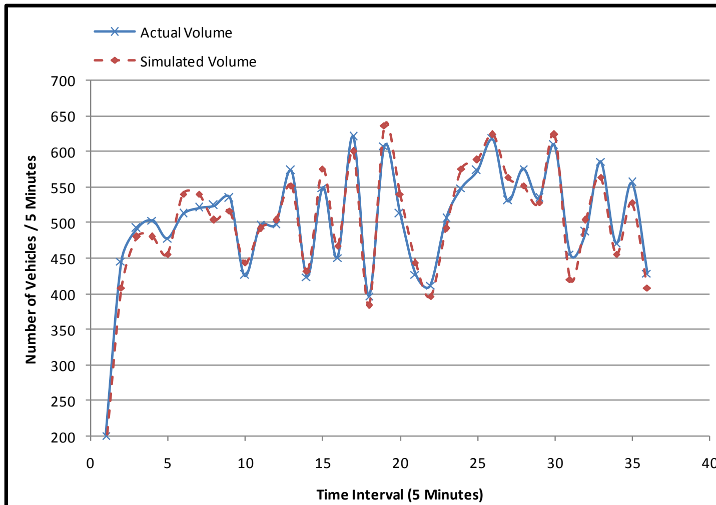


**FIGURE 4(d) Actual and Simulated Volume on I-696 near Telegraph**

**FIGURE 4 Actual and Simulated Volume**

**TABLE 3 Summary of Goodness-of-fit measures**

| Location | Root Mean Square Error (RMSE) % Error | Correlation Coefficient (*r*) | Theil's Weight of Large Errors (*Ui*) | Theil's Variance Proportion (*Us*) | Theil's Covariance Proportion (*Uc*) | Theil's Bias Proportion (*Um*) |
|---|---|---|---|---|---|---|
| I-75 at I-696 | 0.036 | 0.988 | 0.015 | 0.053 | 0.928 | 0.045 |
| I-75 at 14 Mile | 0.054 | 0.988 | 0.018 | 0.002 | 0.873 | 0.014 |
| I-696 at Telegraph | 0.053 | 0.975 | 0.024 | 0.046 | 0.922 | 0.058 |
| I-696 at Telegraph | 0.044 | 0.97 | 0.020 | 0.089 | 0.915 | 0.013 |
| I-75 Corridor | 0.001 | 0.995 | 0.013 | 0.000 | 0.987 | 0.014 |

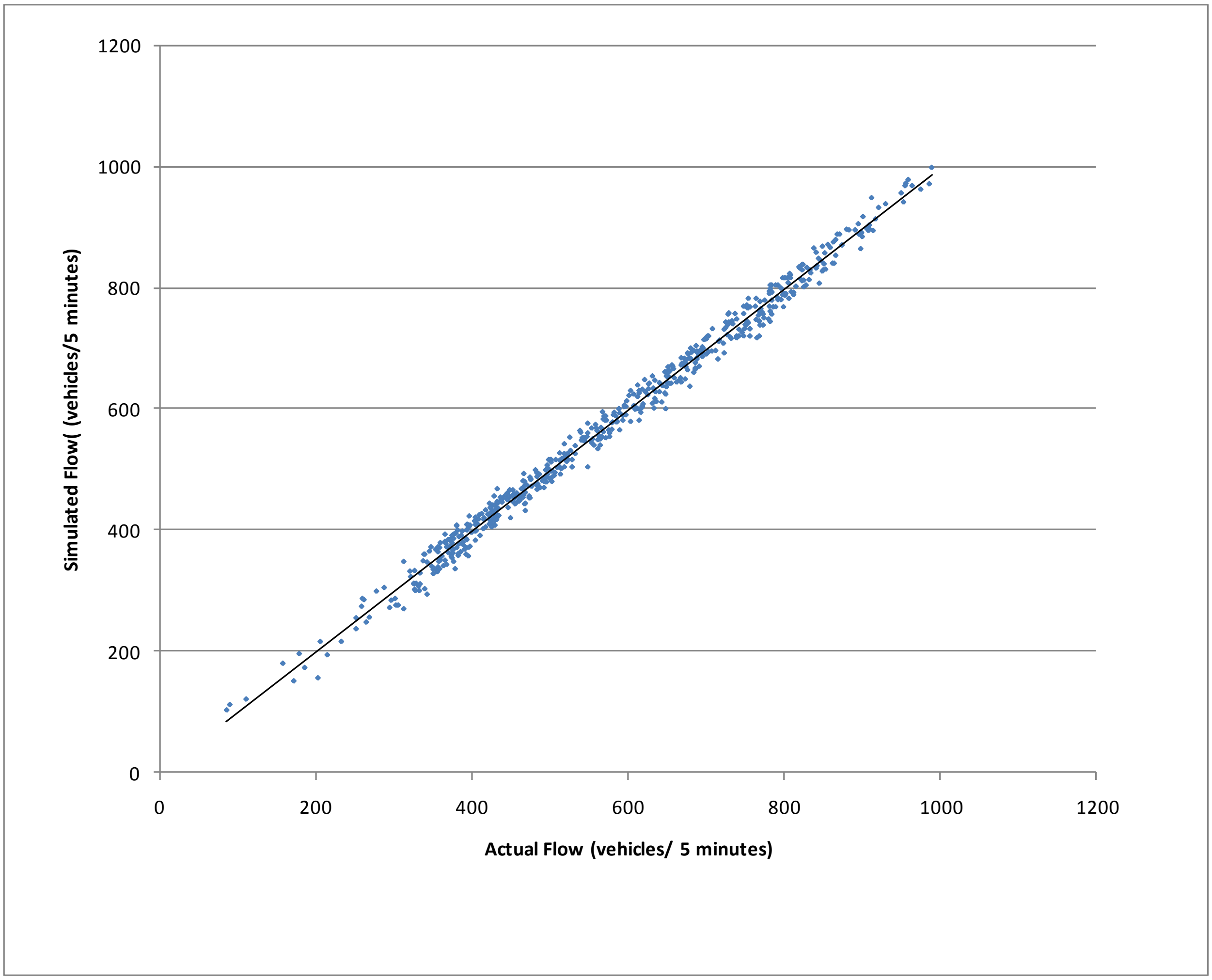


**FIGURE 5 Actual and Simulated flow on I-75 (7AM -10AM)**

**Model Application**

The calibrated model was used to test the implication of four incident management strategies adapted from AIMSUN;

- **Lane closure**: where a single or multiple lanes are closed for a given section.
- **Section incident**: where a section of lane(s) is blocked due to a traffic crash, disabled vehicles or any other specific reasons.
- **Forced turning**: where vehicles are forced to turn from its original path because of a complete road closure.
- **Congestion**: where the volume to capacity ratio is more than 0.9 in at least one link of the network

For the purpose of this paper, strategies are defined as pre-planned courses of actions taken to minimize the advance impact of incidents. IMS's are typically governed by different policies. Table 4 shows two types of policies considered in this paper to constitute a strategy-policy combination:

- **Throughout**: where a policy is kept activated during the entire period of simulation.
- **Specific duration**: where a policy is kept activated only during part of the simulation period.

**TABLE 4 Incident Type and Policy Explanation**

| Serial Number | IMS | Policy | Simulation Duration for Case Study (min) |
|---|---|---|---|
| 1 | Lane Closure | Throughout | *s* |
| 2 | Section Incident | Specified Duration | 0.5*s*, and 0.75*s* |
| 3 | Forced Turning | Specified Duration | 0.5*s*, 0.75*s* and *s* |
| 4 | Congestion | Throughout | *s* |

Note: *s*:  Simulation Period in minutes

Results of the incident management strategies tested in this paper are presented in three scenarios as explained below:

- **No Incident**: Represents the base condition depicting normal traffic flow. Traffic conditions in this case are not affected by the incidents or any IMS, as there are no incidents in the first place.
- **Unguided**: Represents situations where incidents have occurred but no IMS has been deployed. Thus situation represents conditions where drivers essentially use their knowledge of the network, or use their intuition in selecting the shortest path. AIMSUN in this case appears to use a "static" assignment process, and route selection is based upon the shortest path, given an incident (e.g. lane closure, speed change, etc.) has occurred. Ideally, MOE data for such "unguided" conditions should be derived from archived data, if available from the Traffic Management Center (TMC). For the purpose of testing the framework, simulation data generated by the model, based on static assignment as discussed above is used, as no archived data on delay, travel time, and queue length was readily available.

- **Guided**: Represents a situation where an appropriate IMS has been deployed during/after the incident, and vehicles are "guided" through the network following a dynamic assignment procedure. Under these conditions, vehicles are "guided" through VMS to the shortest path that is dynamically updated at a pre-specified route choice cycle. Note, only a fraction of the trips, that are 'captured' during the route choice cycle are assigned to the then shortest route, that may change from cycle to cycle. Remainder fractions are dynamically assigned to the respective shortest routes during successive route choice cycles, until all trips are exhausted for the specified time duration.

Results for each strategy tested are presented below. The procedure used in testing these strategies consisted of

1. Searching the archived database in identifying the incidents stated above.
2. Obtaining the freeway volume data during the incidents from archived (sensor) data
3. Using the volume data to generate a trip table and to produce network performance data under "no-incident" condition.
4. Regenerating the network performance data from the specific incident that resulted in two pieces of information, "unguided" and "guided" condition explained above.

IMS's tested for a multiple number of days and on different locations is presented in Table 5. Four types of IMS's are presented in the first column of Table 5 (i.e. Lane Closure, Section Incident, Forced Turning and Congestion). Days and time of these IMS's tested are presented in the second and third column of Table 5. The last two columns of the table show the notation used in designating an IMS, and the location of incidents.

Results of the network performance summaries for different IMS's tested are presented in Table 6 through Table 9. One hour of simulation period is considered in all the strategies analyzed. As mentioned earlier, in the absence of archived data, a comparison of MOE's can only be made between "guided" and "unguided" conditions, assuming that "unguided" conditions represent actual actions of drivers. For each IMS tested, two types of performance data are presented; unit travel time and unit delay, both measured in seconds/mile/vehicle.

***<u>Lane Closure</u>***

Table 6 shows unit travel time and unit delay under three lane closure conditions, namely: (1) 1 Lane Closed, (2) 2 Lanes Closed, (3) All Lanes Closed. A hypothetical "no-incident" scenario is also presented. In all cases analyzed, there were reductions (improvements) in unit travel time. The percentage reduction ranged from a low of 20 to a high of 43. In all "unguided" conditions the unit travel time is higher than the "no-incident" condition, as expected. The "guided" conditions produced reduced unit travel time compared to "no-incident" and "unguided" conditions. The "1 Lane Closed" strategy produced better results than its "2 Lanes Closed" counterpart, since the reduction in capacity is much more for a two lane closure condition. The "All Lanes Closed" strategy produced the least unit travel time. This is reasonable, since all the vehicles completely avoid the "All Lane Close" section, being "guided" to alternate routes. Similarly, for the delay data shown in Table 6, there were improvements in all the cases analyzed. The percentage improvement ranges from a low of 24 to a high of 50. The highest percentage increase generally occurred under the “All Lanes Closed” condition.

### ***Section Incidents***

Table 7 shows impact of section incidents prevailing over 30 and 45 minutes of incident durations. In all the 15 cases analyzed, the “guided” condition resulted in better performance that reflects in lower unit travel time compared to “unguided” condition. The percent improvement ranged from 17 to 25, the higher improvements generally being attained under “One Lane Closed” condition. The performance measure does not appear to vary significantly between 30 minute and 45 minute duration. The unit delay data shown in Table 7 essentially shows similar trends. In all the cases analyzed, the “guided” condition results in smaller delays with the higher improvement occurring for “Two-Lanes Closed” condition. Further, the incident duration of 30 minute generally produces higher improvement compared to 45 minute duration.

**TABLE 5 Location and Timing of Lane Closure, Section Incident, Forced Turning, and Congestion in the Network**

| Type | Date | Time | Notation | Location in the Network |
|---|---|---|---|---|
| Lane Closure | 2/20/2006 | 9:00 AM – 10 AM | L1 | On I75North at 14 Mile Rd |
| | 3/24/2006 | 7:00 AM-8:00 AM | L2 | On I75North at 14 Mile Rd |
| | 6/02/2006 | 7:00 AM-8:00 AM | L3 | On I75North at 12 Mile Rd |
| | 6/09/2006 | 9:00 AM-10:00 AM | L4 | On I75North between 12 Mile Rd and I696 |
| | 6/04/2007 | 1:00PM-2:00PM | L5 | On I75North between 14 Mile and 12 Mile |
| Section Incident and Forced Turning | 6/21/2006 | 10: 00 AM-11:00 AM | S1 | On I75North at Big Beaver Rd |
| | 8/27/2006 | 12: 00 PM-1:00 PM | S2 | On I75North between 14 Mile and 12 Mile |
| | 5/2/2007 | 7: 00 AM-8:00 AM | S3 | On I75North at 14 mile Rd |
| | 6/22/2007 | 10: 00 AM-11:00 AM | S4 | On I75North between 14 Mile and 12 Mile |
| | 10/11/2007 | 7: 00 AM-8:00 AM | S5 | On I75North approaching 12 Mile Rd |
| Congestion | 6/2/2006 | 4:00 PM - 5.00 PM | C1 | On I75South to the west of 12 Mile Rd |
| | 6/21/2006 | 5.00 PM - 6.00 PM | C2 | On I75North to the west of I696 |
| | 5/2/2007 | 4:00 PM - 5.00 PM | C3 | On I75South to the west of I696 |
| | 6/22/2007 | 2.00 PM - 3.00 PM | C4 | On I75South to the west of 14 Mile Rd |
| | 6/10/2008 | 5.00 PM - 6.00 PM | C5 | On I75North to the west of I696 |

### ***Forced Turning***

When all the lanes are closed in a section incident, motorists are forced to turn from the original path resulting in a strategy termed as “Forced Turning”. Thus, the “Forced Turning” strategy is a special case of the “Section Incident” strategy. The effects of “Forced Turning” are reflected in Table 8 for three cases; 30 minutes, 45 minutes and 60 minutes. Table 8 shows that the improvement in unit travel time is significant in all 15 cases analyzed, the percent improvement ranging from 26 to 46. Generally, the largest percentage improvement occurred at the highest level of “Forced Turning”, i.e. 60 minute. No major difference is observed between 30 minute and 45 minute duration. Table 8 shows reductions in unit delay were attained in all the 15 cases analyzed for the “guided” condition compared to the “unguided” counterpart, the percent improvement ranging from 38 to 58. Generally the highest level of improvement was obtained for 60 min duration.

***Congestion***

The “congestion” case is designated to reflect a higher volume to capacity ratio on one or more links in the network (Table 9). Five days of data is considered, and two cases, i.e. “unguided” and “guided” are presented for unit travel time and unit delay. Lower unit travel time and lower unit delay are observed for “guided” condition for all the five cases.

***Queue Length***

A series of queue length comparisons for “unguided” and “guided” conditions on various sections is presented in Figure 6(a) through 6(d). These are average queue lengths for one hour simulation for “All Lane Closure”, on 2$^{nd}$ June 2006, 7:00 AM to 8:00 AM (notation “L3” in Table 5) for four locations in the network. There are 24 data points in each figure, 12 representing for “guided” and 12 for “unguided” conditions. Each guided and unguided case consists of 12 data points for a five minute interval in one hour of simulation period. The four locations used to test the goodness-of-fit in calibration are also used for queue length demonstration. In all the cases, “guided” condition provided shorter queue length than the “unguided” counterpart. The queue lengths presented in Figure 6 are for Lane Closure strategy. Similar results can be produced for all other strategies.

**TABLE 6 Travel Time and Delay Data for Lane Closure (sec/mi/vehicle)**

| Measure | Notation | No Incident | 1 Lane Closed | | | 2 Lanes Closed | | | All Lanes Closed | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Unguided | Guided | % Improvement | Unguided | Guided | % Improvement | Unguided | Guided | % Improvement |
| Travel Time | L1 | 70.65 | 77.26 | 58.23 | 24.64 | 80.92 | 63.46 | 21.57 | 85.66 | 50.02 | 41.60 |
| | L2 | 72.84 | 76.64 | 59.34 | 22.57 | 80.48 | 64.65 | 19.67 | 87.08 | 49.61 | 43.03 |
| | L3 | 77.33 | 81.05 | 61.19 | 24.50 | 86.68 | 68.17 | 21.35 | 92.24 | 54.34 | 41.10 |
| | L4 | 77.44 | 82.83 | 62.93 | 24.03 | 88.35 | 69.07 | 21.82 | 93.76 | 56.20 | 40.05 |
| | L5 | 78.05 | 80.63 | 62.30 | 22.73 | 86.85 | 69.14 | 20.40 | 92.31 | 53.34 | 42.22 |
| Delay | L1 | 14.83 | 17.97 | 13.16 | 26.77 | 20.61 | 15.70 | 23.81 | 23.73 | 11.84 | 50.10 |
| | L2 | 15.98 | 19.89 | 14.42 | 27.51 | 22.43 | 16.99 | 24.25 | 25.74 | 13.05 | 49.31 |
| | L3 | 16.23 | 21.80 | 14.93 | 31.51 | 24.65 | 17.49 | 29.05 | 27.58 | 14.24 | 48.37 |
| | L4 | 16.43 | 21.37 | 15.27 | 28.54 | 24.26 | 17.75 | 26.86 | 27.92 | 13.95 | 50.03 |
| | L5 | 17.28 | 23.78 | 16.41 | 30.99 | 25.87 | 18.78 | 27.43 | 29.78 | 15.41 | 48.24 |

**TABLE 7 Travel Time and Delay Data for Section Incident (sec/mi/vehicle)**

| Measure | Notation | No Incident | 30 minutes | | | | | | 45 minutes | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 Lane Closed | | | 2 Lanes Closed | | | 1 Lane Closed | | | 2 Lanes Closed | | |
| | | | Un-guided | Guided | % Improvement | Un-guided | Guided | % Improvement | Un-guided | Guided | % Improvement | Un-guided | Guided | % Improvement |
| Travel Time | S1 | 75.75 | 79.42 | 62.80 | 20.93 | 81.43 | 65.62 | 19.42 | 80.48 | 64.57 | 19.77 | 82.56 | 67.40 | 18.36 |
| | S2 | 75.48 | 80.40 | 60.03 | 25.34 | 81.98 | 62.30 | 24.00 | 80.71 | 61.01 | 24.40 | 83.30 | 64.70 | 22.33 |
| | S3 | 77.26 | 80.50 | 60.37 | 25.00 | 82.49 | 63.02 | 23.60 | 81.62 | 61.72 | 24.38 | 83.52 | 64.94 | 22.25 |
| | S4 | 69.96 | 74.03 | 59.66 | 19.41 | 76.14 | 62.40 | 18.05 | 75.48 | 61.54 | 18.46 | 77.22 | 64.31 | 16.71 |
| | S5 | 77.62 | 83.56 | 63.91 | 23.51 | 85.53 | 66.53 | 22.22 | 84.46 | 65.16 | 22.84 | 86.92 | 68.48 | 21.21 |
| Delay | S1 | 17.20 | 19.28 | 15.16 | 21.37 | 21.16 | 16.85 | 20.38 | 20.51 | 15.96 | 22.20 | 22.22 | 17.78 | 19.99 |
| | S2 | 16.67 | 19.00 | 15.30 | 19.48 | 20.85 | 16.93 | 18.83 | 20.16 | 16.14 | 19.95 | 21.85 | 18.09 | 17.23 |
| | S3 | 18.84 | 20.71 | 16.62 | 19.74 | 22.38 | 18.28 | 18.33 | 21.77 | 17.68 | 18.77 | 23.43 | 19.60 | 16.35 |
| | S4 | 14.11 | 16.78 | 13.31 | 20.71 | 18.41 | 14.95 | 18.79 | 17.73 | 14.34 | 19.15 | 19.36 | 16.04 | 17.12 |
| | S5 | 20.88 | 22.64 | 18.09 | 20.11 | 24.33 | 19.84 | 18.45 | 23.67 | 19.23 | 18.76 | 25.34 | 20.93 | 17.40 |

**TABLE 8 Travel Time and Delay Data for Forced Turning (sec/mi/vehicle)**

| Measure | Notation | No Incident | 30 minutes All Lanes Closed Unguided | 30 minutes All Lanes Closed Guided | 30 minutes All Lanes Closed % Improvement | 45 minutes All Lanes Closed Unguided | 45 minutes All Lanes Closed Guided | 45 minutes All Lanes Closed % Improvement | 60 minutes All Lanes Closed Unguided | 60 minutes All Lanes Closed Guided | 60 minutes All Lanes Closed % Improvement |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Travel Time | S1 | 76.78 | 83.17 | 61.17 | 26.45 | 86.39 | 59.39 | 31.25 | 89.67 | 52.39 | 41.58 |
| | S2 | 76.96 | 83.62 | 57.78 | 30.90 | 86.85 | 55.86 | 35.68 | 90.09 | 49.81 | 44.70 |
| | S3 | 78.74 | 84.38 | 58.13 | 31.10 | 87.98 | 55.53 | 36.89 | 91.25 | 49.06 | 46.24 |
| | S4 | 71.86 | 78.44 | 56.93 | 27.43 | 81.99 | 55.29 | 32.57 | 85.23 | 48.62 | 42.95 |
| | S5 | 79.31 | 87.19 | 62.22 | 28.64 | 90.72 | 60.35 | 33.47 | 94.06 | 53.39 | 43.24 |
| Delay | S1 | 18.13 | 23.56 | 13.52 | 42.62 | 26.79 | 14.77 | 44.86 | 29.75 | 13.23 | 55.54 |
| | S2 | 18.91 | 25.25 | 13.63 | 46.02 | 28.59 | 15.12 | 47.10 | 31.79 | 13.37 | 57.95 |
| | S3 | 20.76 | 24.59 | 14.98 | 39.07 | 27.82 | 16.35 | 41.24 | 30.68 | 14.71 | 52.07 |
| | S4 | 15.46 | 20.10 | 11.68 | 41.87 | 21.75 | 13.10 | 39.79 | 24.76 | 11.44 | 53.80 |
| | S5 | 21.61 | 26.53 | 16.43 | 38.08 | 29.59 | 17.84 | 39.70 | 32.55 | 15.96 | 50.96 |

**TABLE 9 Travel Time and Delay Data for Congestion (sec/mi/vehicle)**

| Measure | Notation | Unguided | Guided | % Improvement |
|---|---|---|---|---|
| TT | C1 | 98.81 | 65.62 | 33.59 |
| | C2 | 96.11 | 63.04 | 34.40 |
| | C3 | 96.44 | 63.62 | 34.03 |
| | C4 | 92.69 | 60.55 | 34.68 |
| | C5 | 85.92 | 57.12 | 33.52 |
| Delay | C1 | 35.61 | 17.96 | 49.57 |
| | C2 | 36.86 | 19.84 | 46.18 |
| | C3 | 36.57 | 19.42 | 46.90 |
| | C4 | 29.17 | 15.04 | 48.43 |
| | C5 | 21.22 | 11.31 | 46.70 |

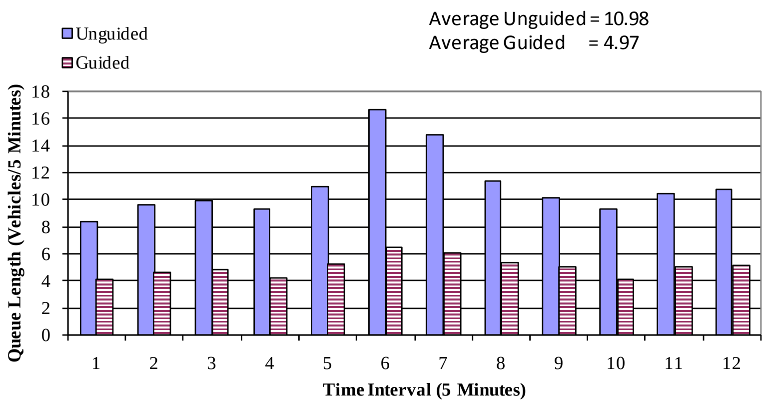


**FIGURE 6(a) Queue Length for "Unguided" and "Guided" Scenarios on I-75 South and I-696**

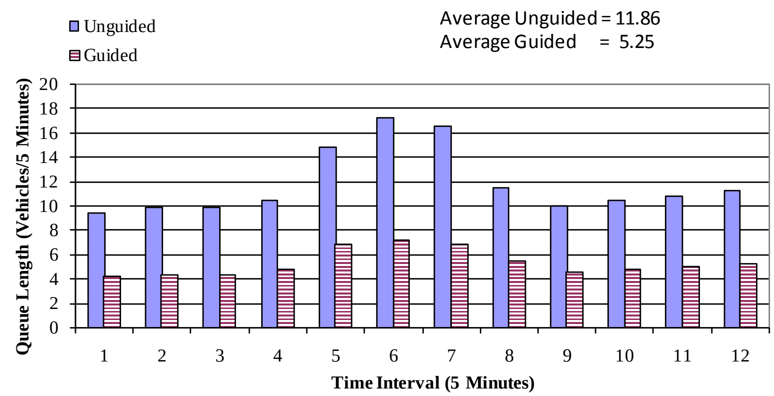


**FIGURE 6(b) Queue Length for "Unguided" and "Guided" Scenarios on I-75 North and I-696**

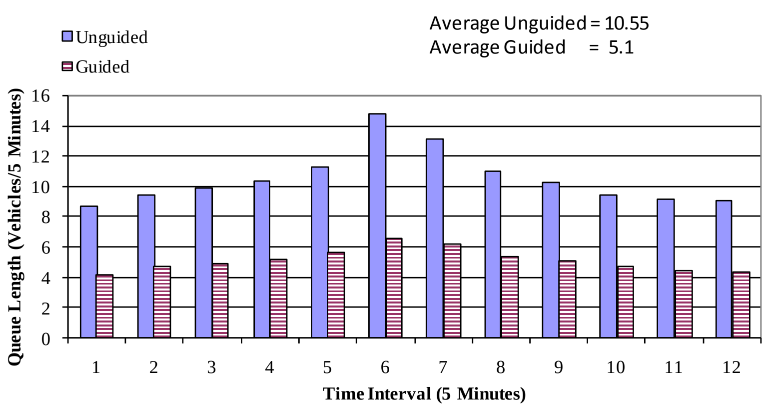


**FIGURE 6(c) Queue Length for "Unguided" and "Guided" Scenarios on I-696 at East and North I-75**

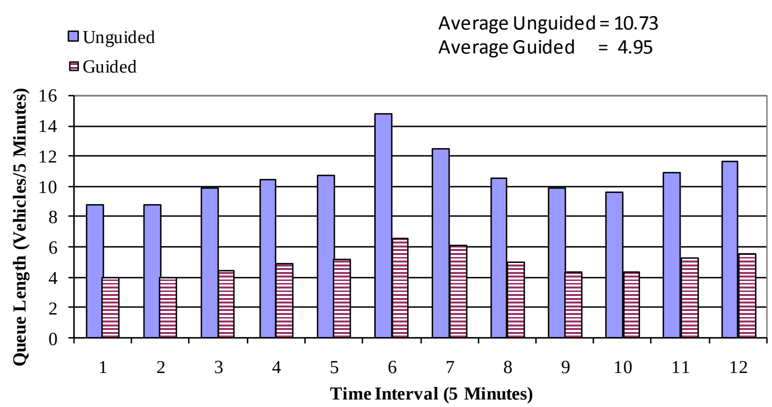


**FIGURE 6(d) Queue Length for "Unguided" and "Guided" Scenarios on I-696 near Telegraph**

**FIGURE 6 Queue Length for Unguided and Guided Scenarios for Lane Closure Strategy (L3)**

## CONCLUSIONS

The purpose of the paper is to present a framework for testing the impact of alternate incident management strategies on an urban transportation network through the use of the micro-simulation model (AIMSUN). Results of testing the framework through calibration and application of the model are also presented. An analytic framework is initially presented in conceptual form that incorporates various policy and operational considerations associated with the deployment of different IMS's.. For testing of the framework, the authors use an actual network in the Detroit metropolitan area, where reconstruction program of a freeway is soon to be undertaken. Four types of strategies are simulated: Lane Closure, Section Incident, Forced Turning and Congestion. Conclusions of the study are;

- The framework presented is conceptually sound and robust, and it incorporates five critical steps that lend themselves testing of various policy options, as well as operational changes reflecting different IMS's.
- Model Calibration demonstrated with two sets of independent data sources collected from sensors in the freeway system appears to reflect a reasonable correspondence between the model output and observed data.
- Model application to test three IMS's, shows that the model output is sensitive to the operational changes associated with the strategies tested and that the trends observed in the model output appear to be logical and reasonable
- In virtually all the cases analyzed, the unit travel time for "no-incident" condition is lower than that for "unguided" condition, and the same for "guided" condition is lower than the "no-incident" condition. Similar results were obtained for the unit delay MOE.
- Even though the testing of the framework shows positive results relative to calibration and application, the authors recommend additional testing with a larger network, and with additional IMS's if possible, before the micro-simulation model can be used as a tool for assessing the impact of IMS's.

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**REFERENCES**


1. *Highway Capacity Manual*. Transportation Research Board, National Research Council, Washington, D.C., 2000.
2. *Traffic Incident Management Handbook*, Federal Highway Administration, FHWA, pp. 1-46, 2000.
3. *Traffic Management Data Dictionary*, Institute of Transportation Engineers, Washington DC, USA, 2007.
4. *Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation*. Prepared for Federal Highway Administration, FHWA, by Cambridge Systems Inc., and Texas Transportation Institute, USA, pp 1-20, 2004.
5. Taylor, N. B. CONTRAM 5: an enhanced traffic assignment model. *TRRL Research Report 249*, 1990.
6. Van Aerde, M. and Yagar, S. Dynamic integrated freeway/traffic signal networks: a routing-based modeling approach. *Transportation Research A*, 22 (A), 6, 1988, pp. 435-443.
7. Mahmassani, H. S., Hu, T. Y. and Jayakrishnan R. Dynamic traffic assignment and simulation for advanced network informatics (DYNASMART). *Proceedings of the 2nd International Capri Seminar on Urban Trajic Neworks*, Capri, Italy, 1992.
8. Ben-Akiva, M., Cortes, M., Davol, A., and Toledo, T. MITSIMLab: Enhancements and Applications for Urban Networks. Document Prepared for Presentation at Stockhalm, 2000,
9. Yang Q., Koutsopoulos H.N. and Ben-Akiva M. A simulation laboratory for evaluating dynamic traffic management systems. *Transportation Research Board, 79th Annual Meeting*, 2000.
10. *AIMSUN*: Advanced Interactive Microscopic Model for Urban and Non-urban Networks. Transportation Simulation Systems. Barcelona, Spain, 2007.
11. CORSIM. Product Information. Available from McTrans Website, http://mctrans.ce.ufl.edu/store/description.asp?itemID=450, Date Accessed 20th July 2008.
12. PARAMICS. Product Information Available from Paramics Website http://www.paramics-online.com/, Date Accessed 20th July 2008.
13. VISSIM. (2007) Product Information. Available from McTrans Website http://mctrans.ce.ufl.edu/store/description.asp?itemID=662, Date Accessed 20th July 2008.
14. Breheret, L., Hounsell, N. B. and McDonald, M. The simulation of route guidance and traffic incidents. *Presented at 22nd Annual Universities Transport Studies Group Conference, Hatfield, U.K*, 1990.
15. Ha, Dong-Ik, Jung J.-H. and Baik H. An application of the simulation model to evaluate dynamic route guidance systems. *Proceedings of the 1994 Korea-U.S.A. Symposium on IVHS and GIST, Seoul, Korea*, 1994.
16. Hounsell, N., McDonald, M. and Breheret, L. Models and strategies for dynamic route guidance. In *Advunced Telematics in Road Transport*, pp. 89-98, Elsevier, Brussels, 1991.

17. Smith, M. J. and Ghali, M. New dynamic model to evaluate the performance of urban traffic control systems and route guidance strategies. *Transportation Research Record***,** 1306, 33-39, 1989.
18. Smith, 1. C. and Russam, K. Some possible effects of autoguide on traffic in London, vehicle navigation and information systems (VNIS). Conference record, pp. 288-29, 1989.
19. Koutsopoulos, H. H., Polydoropoulou A. and Ben-Akiva, M. The use of driving simulators to investigate the response to traffic information. Center for Transportation Studies, Massachusetts Institute of Technology, 1993.
20. Abdel-Aty, M, Vaughn, K.M., Kitamura, R., and Jovanis, P.P. Impact Of ATIS On Drivers' Decisions And Route Choice: A Literature Review. *Research Report: Institute of Transportation Studies California Partners for Advanced Transit and Highways (PATH)*, 1993.
21. Khattak, A.J., Schofer, J.L., and Wang, M. A Simple Time Sequential Procedure For Predicting Freeway Incident Duration. *Research Report: Institute of Transportation Studies California Partners for Advanced Transit and Highways (PATH)*, 1994.
22. Cragg, C.A. and Demetsky, M.J. *Simulation Analysis of Route Diversion Strategies for Freeway Incident Management*, Final Report. Published by the Virginia Transportation Research Council. February 1995.
23. Madanat, S., and Feroze, A. Prediction Models for Incident Clearance Time for Borman Expressway. *Joint Transportation Research Program, Purdue University, Indiana*, 1996.
24. FHWA. Regional Traffic Incident Management Programs, *Federal Highway Administration, US Department of Transportation*, 2001.
25. Balke, K.N., Fenno, D.W., and Ullman, B. Incident Management Performance Measures. Texas Transportation Institute, Prepared for Federal Highway Administration U.S. Department of Transportation Contract Number: DTFH61-01-C-000182, 2002.
26. Hidas, P., and Awadalla, E. Modelling driver response to variable message signs for incident management. *Road and Transport Research*, v 12, n 2, p 15-30, 2003.
27. FHWA. Alternate Route Handbook. Alternate Route Handbook. *Federal Highway Administration, US Department of Transportation*, 2006a.
28. FHWA. Simplified Guide to Incident Command System for Transportation Professionals. *Federal Highway Administration, US Department of Transportation*, 2006b.
29. Wirtz, J.J., Schofer, J.L., and Schulz, D.F. Using Simulation to Test Traffic Incident Management Strategies The Benefits of Preplanning. *Transportation Research Record*. 1923, 82-90, 2005.
30. R. Doughty, "Traffic signs and markings". In W. S. Homburger, , L. E. Keefer, and W. R. McGrath (Ed.). *Transportation and Traffic Engineering Handbook* (Second Edition). Englewood Cliffs, New Jersey: Prentice-Hall, Inc, 1982.
31. Hourdakis, J ; Michalopoulos, P G; Kottommannil, J. *Practical Procedure For Calibrating Microscopic Traffic Simulation Models*. Transportation Research Record, 1981, pp. 130-139, 2003.
32. Kleijnen, J.P.C. *Verification and validation of simulation models; Theory and methodology*. European Journal of Operational Research 82, pp. 145-162, 1995.

33. Hellinga, B.R. *Requirements for the calibration of traffic simulation models*, Proceedings of the Canadian Society for Civil Engineering, Vol IVB, pp. 211-222, 1998.
34. Rao, L., Owen, L. *Development and application of a validation framework for traffic simulation models*, Proceedings of the 1998 Winter Simulation Conference, 1079-1086, 1998.
35. Rakha, H., Hellinga, B., Van Aerde, M., Perez, W. *Systematic verification, validation and calibration of traffic simulation models*, Paper presented at the 1996 Transportation Research Board Annual Meeting, 1996.
36. Jayakrishnan, R., Oh, J., Sahraoui, A. *Calibration and path dynamic issues in microscopic simulation for advanced traffic management and information systems*, Paper presented at the 80th Transportation Research Board Meeting, 2001
37. MIOH. http://mioh-utc.udmercy.edu