

ANALYSIS, MODELING, AND SIMULATION FOR TRAFFIC INCIDENT MANAGEMENT APPLICATIONS



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16. Abstract <p>Traffic incidents are a major source of congestion in both urban and rural areas. Nationally, roughly 25 percent of total congestion is due to traffic incidents. Further, traffic incidents create unexpected congestion – congestion that occurs in times and places where travelers don't expect to be delayed – and are therefore a major source of frustration for travelers.</p> <p>Implementing Traffic Incident Management (TIM) strategies has proven to be a highly cost-effective way of treating congestion problems. However, a strong need exists to be able to predict what the impacts of TIM strategies will be at the planning stage of project development and to monitor the effects of TIM programs.</p> <p>To support modeling and evaluation of TIM strategies, this document provides a synthesis of analysis, modeling, and simulation (AMS) methods for incident impacts. The focus is on incidents effects on congestion and reliability as well as secondary incidents, for the purpose of estimating benefits and evaluating programs and proposed strategies. This document covers several specific topics including: a synthesis of AMS methods for incidents, TIM AMS application areas, data required to undertake modeling and evaluations of TIM strategies, and identification of future improvements to TIM AMS applications.</p>			
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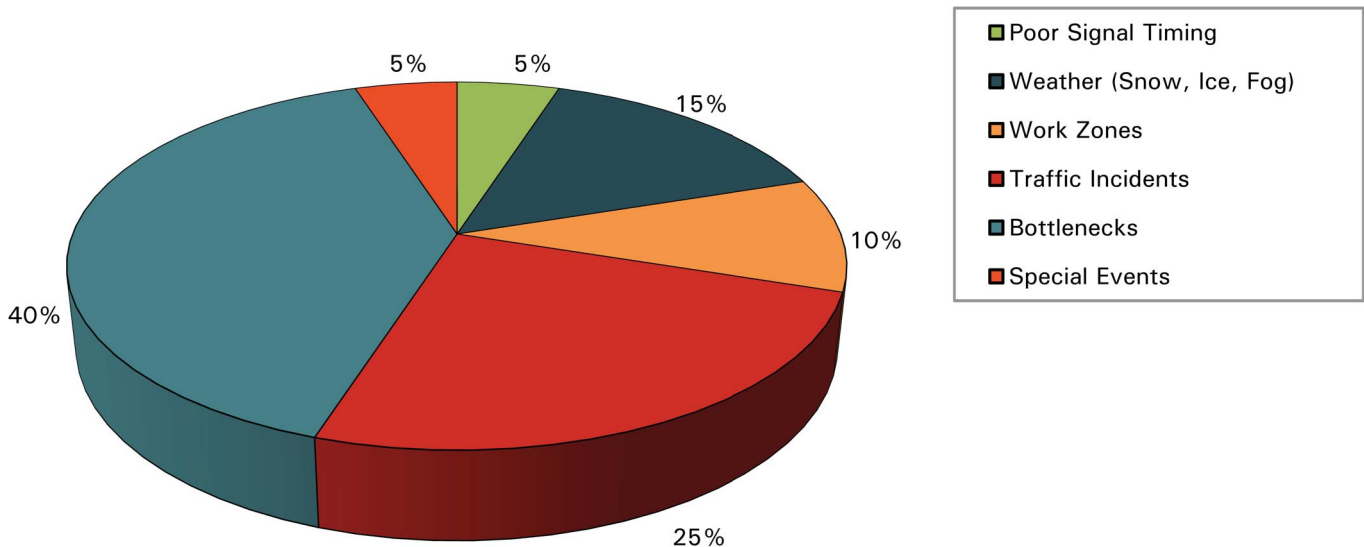


INTRODUCTION

PURPOSE OF THIS DOCUMENT

Traffic incidents are a major source of congestion in both urban and rural areas. Nationally, roughly 25 percent of total congestion is due to traffic incidents (Figure 1). Further, traffic incidents create unexpected congestion – congestion that occurs in times and places where travelers don’t expect to be delayed – and are therefore a major source of frustration for our customers.

Figure 1. Relative Sources of Congestion



(Source: Chin et al., *Temporary Losses of Highway Capacity and Impacts on Performance*, prepared for FHWA, 2004, http://www-cta.ornl.gov/cta/Publications/Reports/ORNLTM_2004_209.pdf.)

In addition to contributing to total congestion, disruptions such as traffic incidents, work zones, and inclement weather also define travel time reliability, which is the variability in congestion that occurs from day-to-day. This variability, and the uncertainty in travel conditions it causes, has been shown to have significant costs to travelers beyond “typical” or “average” congestion. It is therefore critical that the reliability component of congestion be captured when performing evaluations and economic analyses of transportation investments.

Implementing Traffic Incident Management (TIM) strategies has proven to be a highly cost-effective way of treating congestion problems. However, a strong need exists to be able to predict what the impacts of TIM strategies will be at the planning stage of project development and to monitor the effects of TIM programs.

To these ends, *this document provides a synthesis of analysis, modeling, and simulation (AMS) methods for incident impacts*. The focus is on incidents effects on congestion and reliability as well as secondary incidents, for the purpose of estimating TIM benefits and evaluating programs and proposed strategies.



The research and examples presented in this document will significantly assist practitioners in the planning and development of TIM and the evaluation of the performance of TIM strategies. By estimating the expected impacts and evaluating the performance of TIM projects, practitioners can demonstrate the value of TIM. Specifically, the research and examples can be linked with best practices in TIM in a number of ways:¹

1. Methods for measuring incident impacts from field data: these can be used to establish performance monitoring procedures based on field data. Collection of incident characteristics and the sensitivity of the estimates to the accuracy of incident data reporting also are covered. Travel time reliability metrics can be readily derived from field measurements of performance under incident conditions.
2. Methods for predicting impacts of a single incident: practitioners can choose the most appropriate tool for the analysis of the problem in hand, from simple queuing models for isolated incidents to complex simulation tools on traffic corridors with multiple bottlenecks where the incident location within the system is of great importance.
3. Methods for predicting cumulative incident impacts: systemwide impacts of incidents that can be used as a decision support tool in a TMC to trigger actions for the management of the adverse impacts of incidents is covered. These include control of ramps or signals, and rerouting of traffic.
4. Methods for predicting incident duration: given a set of incident characteristics, what is the expected duration so more accurate information can be provided in a timely manner and response and clearance activities can be deployed. These can be used in conjunction with methods for predicting cumulative impacts (#3 above) for possible corridor management and rerouting to parallel facilities.
5. Methods for predicting secondary incidents: better understanding of the occurrence of secondary incidents based on the characteristics of primary incidents, the operating conditions of the facility, and the TIM in place; guidance in developing and implementing TIM measures to reduce the occurrence of secondary incidents.

USES FOR TIM AMS METHODS

A wide variety of applications require TIM AMS methods for incidents. These applications can include:

- **Development and evaluation of TIM plans** – What is the expected impact of TIM strategies on congestion and secondary crashes as a basis for a TIM plan?
- **Analysis and evaluation of TIM strategies such as use of service patrols** – What effect have TIM strategies had after they were implemented?
- **Decision support systems used for incident management** – What is the expected duration of an incident that has just occurred, what will be its impacts on congestion, and what strategies should be deployed to manage incidents.
- **Congestion/operations performance measurement** – What are the trends in incident characteristics, how have they been affected by TIM programs, and what role do incidents play in total congestion and travel time reliability?



- **Benefit-cost analysis of TIM programs/strategies** – What congestion and safety benefits result from TIM programs?
- **Integrated Corridor Management** – How can the response of other corridor management methods be integrated with TIM strategies?

HOW WE DEVELOPED THIS DOCUMENT

In developing the material presented in this document, we reviewed the relevant technical literature as a starting point. We then conducted a survey of practitioners and researchers to identify the current state of the practice in AMS for incidents. The progress of the work was monitored by an independent three-person review panel.

SYNTHESIS OF INCIDENT ANALYSIS, MODELING, AND SIMULATION METHODS

This section describes TIM AMS methods and related applications. In each of the following subsections the current state of the practice is documented. The state of the practice (what is in current use) is discussed separately from the state of the art (that what has been researched).

SURVEY OF PRACTITIONERS ON TIM AMS METHODS

A TIM AMS survey was sent to state departments of transportation (DOT) and metropolitan planning organizations (MPO) in August 2011. The purpose of this survey was to determine current practices in TIM AMS, and to identify areas where practitioners felt that additional guidance would be valuable. The survey questionnaire included eight questions related to TIM:

1. Have you ever conducted a study of the incident impacts on congestion (e.g., delay due to incidents)? If so, please attach the relevant study in an e-mail.
2. Have you ever conducted a study of secondary crashes due to incidents? If so, please attach the relevant study in an e-mail.
3. Do you routinely measure and report secondary crashes?
4. What software tools have you either developed or used to estimate incident congestion impacts or secondary crashes?
5. In what applications that use incident data does your agency currently engage?
6. For which applications would technical guidance be most helpful to you?
7. What kind of information/data would be helpful to you in “making the case” for incident management programs internally with your agency?
8. In terms of your needs for incident information, what types of technical guidance would help you the most?



Eleven agencies responded by September 2011; they are:

- Delaware Valley Regional Planning Commission (DVRPC);
- Florida DOT, District 6;
- Indiana DOT;
- Kansas City Scout (Kansas DOT and Missouri DOT);
- Maryland State Highway Administration;
- Missouri DOT;
- New Hampshire DOT;
- Regional Transportation Commission (RTC) of Southern Nevada;
- Rhode Island DOT;
- Southeast Michigan Council of Governments; and
- Washington State DOT.

Study of Incident Impacts on Congestion

Out of the 11 agencies who responded the survey, 5 (or 45 percent) indicated that they have conducted studies of the incident impacts on congestion (e.g., delay due to incidents).

Study of Secondary Crashes

Out of the 11 response, 4 (or 36 percent) indicated that they have conducted studies of secondary crashes due to incidents.

Measuring and Reporting Secondary Crashes

Out of the 11 response, 5 (or 45 percent) indicated that they routinely measure and report secondary crashes.

Software Tools for Estimating Incident Congestion Impacts/Secondary Crashes

Out of the 11 response, 8 (or 73 percent) indicated that they have either developed or used software tools to estimate incident congestion impacts or secondary crashes.

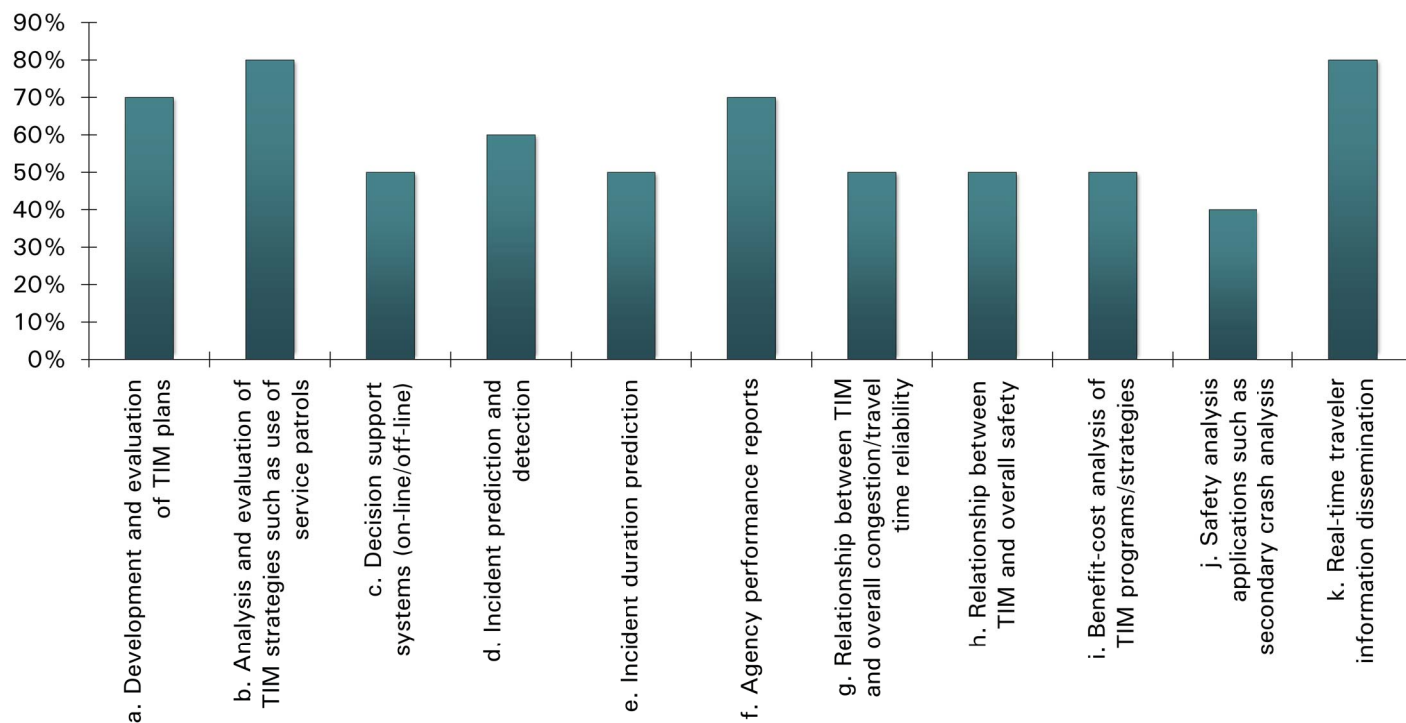
Use of Incident Data

Figure 2 shows the applications of incident data by the surveyed agencies. The top five applications are:



- Analysis and evaluation of TIM strategies such as use of service patrols;
- Real-time traveler information dissemination;
- Development and evaluation of TIM plans;
- Agency performance reports; and
- Incident prediction and detection.

Figure 2. Use of Incident Data by Agencies



(Source: Cambridge Systematics, Inc.)

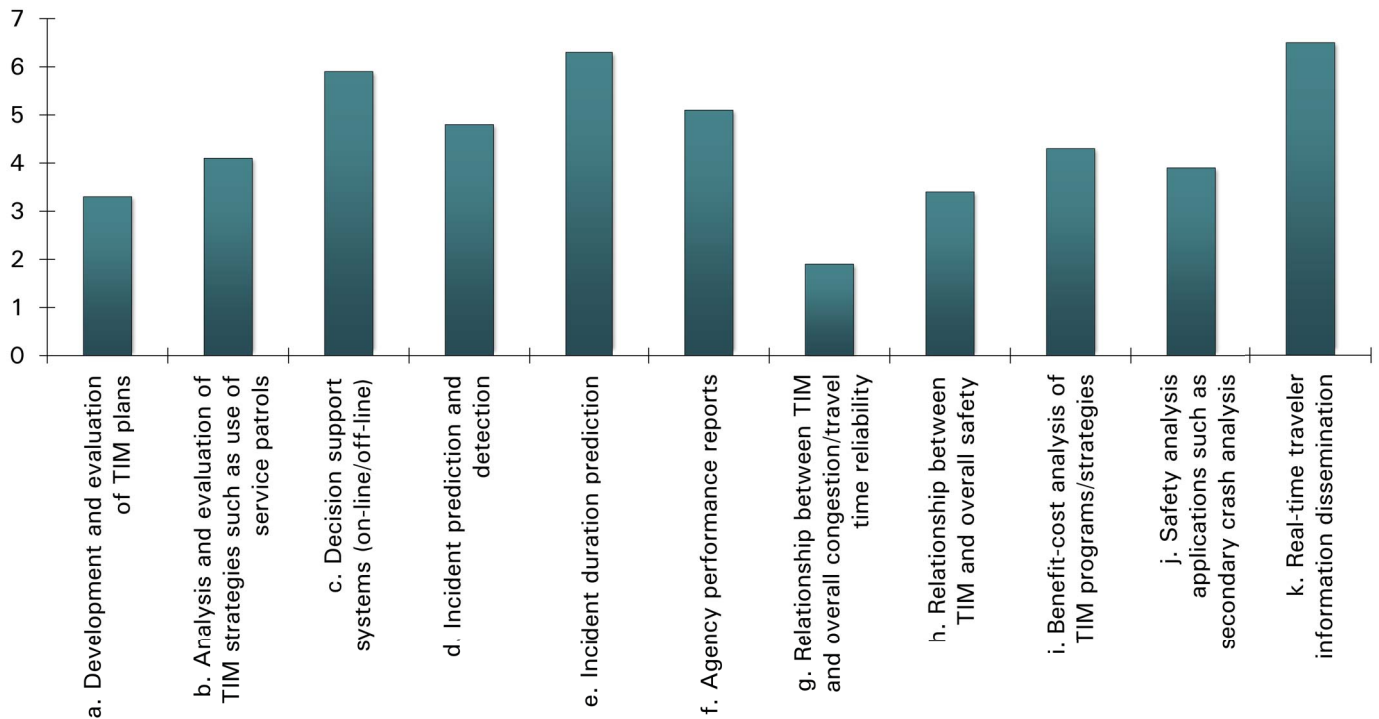
Useful Applications of Technical Guidance

Figure 3 shows the useful applications of a TIM technical guidance (with 1 being the most important for TIM AMS application). The top five areas include:

- Relationship between TIM and overall congestion/travel time reliability;
- Development and evaluation of TIM plans;
- Relationship between TIM and overall safety;
- Safety analysis applications such as secondary crash analysis; and
- Analysis and evaluation of TIM strategies such as use of service patrols.



Figure 3. Useful Applications of Technical Guidance
With “1” Being the Most Important



(Source: Cambridge Systematics, Inc.)

Information/Data Helpful for TIM Programs

When being asked what kind of information/data would be helpful for them in “making the case” for TIM programs internally with their agency, the respondents provided the following answers:

- Reliable systemwide speed data.
- Better information related to the benefits of delay/congestion management through transportation systems management and operations.
- Data for reducing congestion and improving safety and linking it with departments such as Operations, Planning, and Safety and Security.
- Injury information is collected for events in which the Service Patrol responds to within the District. But to quantify how many incidents have been averted because of Service Patrol or notification of an incident due to posting of a Dynamic Message Sign (DMS) or through the state 511 system would be helpful information.
- Benefit/cost data, and how incident management is directly tied to safety performance measures.

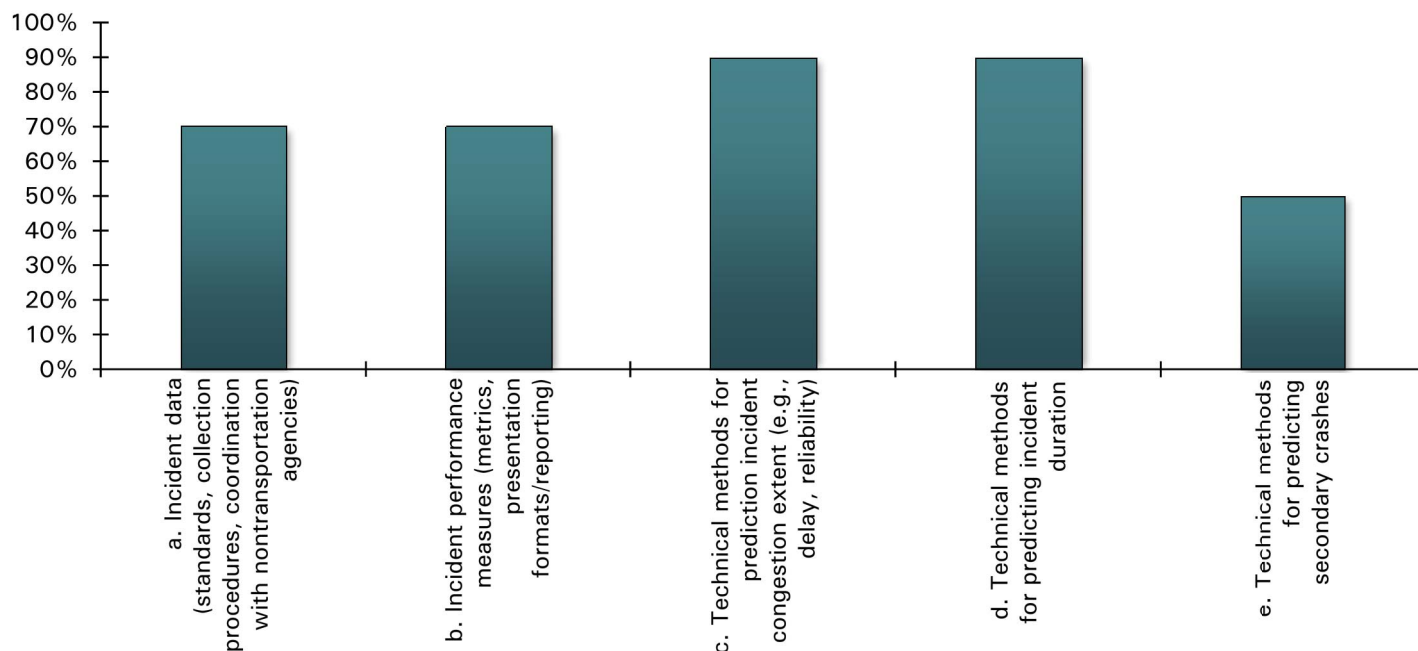


- Benefit/cost data; find a way to get public officials to understand benefits so they can communicate to media and traveling public; work with upper management so they can present benefit to their board of elected officials.
- Anything would be helpful in justifying operating and maintaining a TMC.
- What can we use to show the cost of secondary crashes and convince our planners and designers to take into consideration traffic safety/congestion/secondary crashes when they design TIM plans for projects.
- Programs to track incident clearance and closure time that can be integrated with control systems
- Documented safety and congestion improvement results of having a program in place.

Desired Technical Guidance

Figure 4 shows the types of technical guidance that would be helpful. The top two types are technical methods for predicting incident congestion extent (e.g., delay, reliability) and technical methods for predicting incident duration.

Figure 4. Type of Technical Guidance Desired for Improving TIM AMS



(Source: Cambridge Systematics, Inc.)

TIM AMS METHODS

This subsection documents the TIM AMS methods and their applications as revealed through a review of the recent literature as well as through agency contacts. It includes what currently is being used by practitioners and what is available from the research. Five types of approaches to evaluating TIM are described:



1. Methods for measuring incident impacts from field data;
2. Methods for predicting impacts of a single incident;
3. Methods for predicting cumulative incident impacts;
4. Methods for predicting incident duration; and
5. Methods for predicting secondary incidents.

Methods for Measuring Incident Impacts from Field Data

Methods for measuring in the field the impacts of incidents on delay must address three challenges:

- The definition of what constitutes delay;
- Collection of delay data over extended periods of time; and
- The parsing of the observed delay among incidents and various other possible causes of delay.

Delay is often defined as the difference between the actual travel time and the free flow travel time. Field measurement of travel time over extended periods has historically been difficult, so agencies and researchers have resorted to spot speed measurements over extended lengths of the facility to compute approximate delays.

State of the Practice

Congestion Monitoring Systems

Congestion monitoring systems and programs are either in place or being developed in the major urban areas of the U. S. Monitoring is done using permanent spot speed measurement stations on freeways, targeted field measurements using floating cars of specific facilities, and/or the use of GPS/cell phone tracking devices by commercial vendors of real-time congestion data. However, the assignment of causality to the measured congestion, and the attribution of delay to incidents are extremely rare in current practice. Assignment of causality is more often done as part of specific research efforts.

One example of how an agency defines delay over extended periods is Caltrans.² Caltrans defines two delay values: the difference between the observed spot speed and 60 mph (free-flow delay), and the difference between the observed spot speed and 35 mph (breakdown delay). The two definitions of delay are used because the agency's goal is to minimize breakdown delay.

Automated permanent vehicle detector stations approximately a half-mile apart on urban freeways are used by Caltrans to measure five-minute average spot speeds (24 hours per day, 7 days per week). The vehicle-hours of delay measured at each station is the actual volume measured at the station multiplied by the difference in travel times between detector stations at the actual speed and the delay threshold speed (either 35 mph or 60 mph):

$$\text{Delay} = \text{Volume} * [(\text{Length}/\text{actual speed}) - (\text{Length}/\text{threshold speed})]$$

Caltrans currently does not parse the observed delay into various causes, but has plans to do so in future editions of its statewide Mobility Performance Reports.



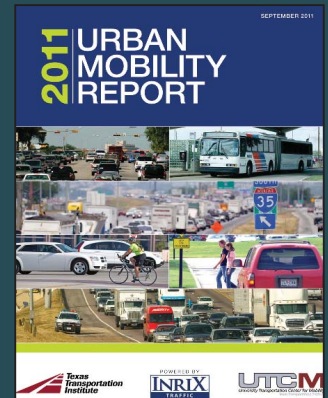
The TTI *2011 Urban Mobility Report* is an example of a national congestion monitoring report which tallies total delay associated with all causes of delay, but does not assign responsibility to any specific causes, such as incidents. Delay is measured by tracking vehicle GPS devices and comparing off-peak to peak travel times.

The Urban Mobility Report: Improved Data Leads to Better Understanding of Congestion

The Texas Transportation Institute has been publishing the Urban Mobility Report (UMR) annually since 1987. Up until 2010, congestion was estimated – rather than measured – using traffic count and roadway characteristics data with analytic methods. Starting with 2010, travel time data collected by a private vendor from GPS-equipped vehicles has been used. As noted in the 2011 UMR:

The new data and analysis changes the way the mobility information can be presented and how the problems are evaluated:

- Hour-by-hour speeds collected from a variety of sources on every day of the year on most major roads are used in the 101 detailed study areas and the 338 other urban areas.
- The data for all 24 hours makes it possible to track congestion problems for the midday, overnight, and weekend time periods.
- A new wasted fuel estimation process was developed to use the more detailed speed data.
- The effect of TIM strategies and other operational treatments on congestion are now considered.



(Source: <http://tti.tamu.edu/documents/mobility-report-2011.pdf>.)

State of the Art

Kwon et al. used quantile regression to apportion the causes of measured congestion between incidents and other causes.³ In essence, the maximum likelihood contribution of incidents to measured delay is estimated through least squares regression. No underlying traffic behavior model is required.

Skabardonis et al. used a more legalistic approach to separating out incident-related congestion from other congestion.⁴ First the incident logs were consulted to identify nonincident days. These became the baseline congestion days. These days were then compared to days with incidents. The difference in delay between incident days and incident-free days was considered to be the delay associated with incidents.

The statistical and legalistic approaches are somewhat unusual. More typical are traffic model-based approaches such as List et al. which used the classical queuing model in New York State DOT's Congestion Needs Assessment Model and updated look-up tables of key parameters to estimate the amount of congestion on arterial streets that might be attributable to incidents.⁵ This approach (like all traffic model-based approaches) requires demand volumes during the incidents and the estimated capacity of the facility before, during and after the incident is present. The estimated delays produced by all of the incidents over the year are summed to obtain incident delays for the year.



Methods for Predicting Impacts of a Single Incident

There are a variety of general purpose and incident-specific analytical tools for predicting the delay impacts of a given incident on a given facility. Since the incident is “given,” these models do not focus on predicting the time, location, and type of incident. They focus on predicting the consequences. Incident-specific analytical tools also may predict secondary incidents and the duration of the incident.

General purpose tools include traffic simulation models, and the recently published 2010 Highway Capacity Manual (HCM) method for freeways. Both facility-specific and systemwide impacts of individual incidents can be estimated using microsimulation models, and mesoscopic simulation models. The 2010 HCM currently is limited to single facility applications.

Microsimulation models require more data and will tend to produce more precise estimates of delay effects than mesoscopic models. Mesoscopic models require more precise facility design (and operations) data than demand models, and tend to produce more precise estimates of delay effects than demand models.

Some of the models specifically tailored to the evaluation of incidents can predict incident duration and secondary incident occurrence as well as delay. General purpose models require this information as input and cannot predict these parameters.

State of the Practice – General Purpose Traffic Operations Analysis Models

General purpose traffic operations analysis models are “state of the practice” for the estimation of the delay effects of specific incidents with a given duration. They do not predict incident duration or the probability of secondary incidents.

There are numerous instances in the literature of general purpose traffic operations analysis models being used in research and in practice to predict the delay effects of incidents and incident management strategies. General purpose traffic operations analysis models of specific incidents come in two basic types: Highway Capacity Manual and Simulation (micro and mesoscopic). (See Volumes 1 and 2 of the FHWA Traffic Analysis Toolbox.)⁶

HCM-Based Deterministic Macroscopic Analysis Tools

Overview of Deterministic Tools
Analytic tools predict road traffic capacity, speed, delay, and queuing at intersections and road segments of a variety of types and configurations. Many, though not all, of these tools are based on methodologies published in the Highway Capacity Manual (HCM).
The incident type, start time, location, and duration must be specified. Chapter 10 of the 2010 Highway Capacity Manual then provides special capacity adjustment factors for incidents on freeways. It covers breakdowns and collisions that occur on the shoulders, as well as incidents that block one, two, or three lanes on freeways with two to eight lanes in one direction. The methodology described in Chapter 10 is then used to predict the mean speed (and therefore travel time and delay) and density of traffic on the freeway before, during, or after an incident.
Similar information on capacity and performance effects is not available in the 2010 HCM for urban streets.
What is this tool used for?
HCM-based tools are used to evaluate the effects of traffic operations on isolated transportation facilities such as signalized and unsignalized intersections, freeway mainline segments, freeway weaving segments, freeway ramp merge/diverge areas, and others.



Overview of Deterministic Tools (continued)

Why is this tool favored for such uses?

The HCM is widely used and its results are accepted (near universally) throughout the industry as representative of actual conditions. Many jurisdictions employ performance standards and thresholds that have been developed with HCM level of service measures in mind.

The HCM is often viewed as the benchmark for evaluating traffic operations. It has a long and storied history of use and acceptance in the industry. Additionally, analysts and decision-makers appreciate the nature of its analytical procedures in terms of consistency of inputs, algorithmic calculations, and resulting output values.

What are challenges and limitations of this tool?

Many users comment that deterministic tools do not properly evaluate the relationships between adjacent or other interacting facilities/control devices, i.e., network affects are ignored. These tools assume demand is fixed and unaffected by highway improvements. Usually the demand model used to forecast demand takes into account approximate effects of highway improvements. The HCM is then used to determine more precise effects for given demand.

Deterministic methodologies are sensitive to the length of the analysis periods. HCM 2000 methodologies do not account for the variation in traffic states within an analysis time period. HCM 2010 freeway methodologies incorporate time slices in a manner similar to macroscopic simulation which addresses variations in traffic states.

Software implementations of the HCM often incorporate default values which make it easy to produce results without giving proper consideration to detailed characteristics of the conditions being evaluated.

When considering the limitations it is important to distinguish between the limitations of the various software implementations and those of the actual HCM. Additionally, certain limitations can be overcome through iterative applications of deterministic tools.

Some deterministic tools do not employ methods documented in the HCM. The comments pertaining to HCM tools apply to these tools for the most part as well, except that these tools are not as widely used and so the likelihood of inconsistency is increased with analysis tools used 'upstream' or 'downstream' in the analytic process.

What are some software implementations of this tool?

Software examples of deterministic tools include HCS, Teapac, TRAFFIX, RODEL, and SIDRA.

Example Applications:

Skabardonis, A., and M. Mauch, FSP Beat Evaluation and Predictor Models: Methodology and Documentation, Research Report UCB-ITS-RR-2003-XX, University of California Berkeley, 2003 (Updated 2010).

Hagen, L., H. Zhou, and H. Singh, "Road Ranger Benefit Cost Analysis," Center for Urban Transportation Research, University of South Florida, November 2005.

The first report describes the development and documentation of deterministic spreadsheet-based tools for estimating the benefit/cost ratio of freeway service patrols (FSP) on a freeway site ("beat"). FSP is an incident management measure designed to assist disabled vehicles along congested freeway segments and reduce nonrecurring congestion through quick detection and response to accidents and other incidents on freeways. The benefits of FSP depend on the beat's geometric and traffic characteristics, and the frequency and type of assisted incidents. The models, implemented into spreadsheets, calculate the savings in incident delay, fuel consumption and air pollutant emissions based on data that are commonly available to local agency operations staff. The report includes step-by-step instructions for applying the models and analyzing the results. The models have been independently applied by operating agencies in Virginia, Florida, and Hawaii to evaluate the effectiveness of their FSP programs.



Simulation Tools

Simulation Tools: Microsimulation Tools

Microscopic simulation models simulate speed and traffic density by tracking the instantaneous movement of individual vehicles through the network based on a statistical distribution of arrivals and driver behaviors.

The start time, location, lanes blocked, and duration must be specified for each incident. Merging effects are automatically accounted for in microsimulation models; however, distraction effects on the capacity of remaining lanes (rubbernecking) must be specified by the analyst.

What is this tool used for?

As with macroscopic tools, microsimulation tools are used to evaluate changes in operation on a facility that result from changes in demand, capacity, or traffic control. Microscopic tools simulate traffic on a quantum time scale (less than one second) based on the movement and spacing of individual vehicles. Therefore microscopic tools can be used to evaluate the interaction between different vehicles and between vehicles and individual controls and capacity constraints. Furthermore detailed microsimulation models can evaluate the instantaneous and cumulative effects of small changes to facility geometry and timing.

Why is this tool favored for such uses?

Well-calibrated microsimulation tools are superior to other tools for evaluating the sensitivity of operations to small changes. Microsimulation tools allow analysts to identify capacity constraints and opportunities for improvements more precisely. Microscopic tools permit the evaluation of assumptions about driver behavior in addition to management and operational strategies.

Microscopic tools can be incorporated in planning, design, and systems management and provide robust feedback reflecting the cumulative systemwide effects of local modifications and improvements.

Many of the microsimulation tools are packaged with state-of-the-art animation and graphics capabilities. Given the focus of microsimulation tools on individual vehicles, this provides analysts with a convenient and persuasive means of communicating the local and systemwide implications of analysis results.

What are challenges and limitations of this tool?

Microsimulation tools can be prohibitively expensive to implement. The level of detail of a microsimulation model is the direct cause of this. The input data requirements of complex microsimulation models can easily exceed data availability, resulting in the widespread use of defaults. Furthermore, microsimulation models are acutely sensitive to proper calibration and the results generated by the inappropriate use of default inputs can vary considerably from results generated using properly calibrated microsimulation models.

Effective use of microsimulation tools requires a considerable amount of training and quality control. The generation of poor quality analysis is often facilitated by the proliferation of defaults, leading to some confusion over what constitutes calibration.

Microsimulation tools treat origin-destination patterns as fixed inputs. Induced demand is not evaluated though traffic diversion can be evaluated using some microsimulation tools when complete alternate routes are represented within the geographic scope being modeled. Considerable time and training are required for the development of complex models using microscopic tools.

Microsimulation tools require multiple analyses and the results should be averaged. This requirement is due to the variations in results caused by use of random number generators for the starting point of the analysis. Even if the same starting point is used for the analysis, different results may be obtained from the use of different simulation platforms.

What are some software implementations of this tool?

Software examples of Microsimulation tools include CORSIM, VISSIM, SimTraffic, AIMSUN, Paramics, Dynasim, and Transmodeler.



Simulation Tools: Microsimulation Tools (continued)

Example Application:

Chou, C-S, and E. Miller-Hooks, "Exploiting the Capacity of Managed Lanes in Diverting Traffic Around an Incident," Transportation Research Record: Journal of the Transportation Research Board, #2229, 2011.

Evaluation of the potential benefits and detriments of diverting general traffic into a managed lane when an incident arises along the general purpose lanes using the **VISSIM** microscopic simulation tool. Continuous and access point diversion strategies were evaluated regarding their impacts on the mobility of general traffic and managed lane users along a concurrent flow lane system on I-270 in Maryland.

Simulation Tools: Mesoscopic Simulation Tools

Mesoscopic simulation models combine properties of both macro- and micro-scopc models.

Many of these models employ multiresolution demand and network modeling with dynamic traffic assignment (DTA) and selected subarea simulation to predict how system performance and traffic demand will vary in response to an incident. The analyst inputs the incident location, capacity reduction, and duration.

What is this tool used for?

Mesoscopic tools are a relatively new addition to the traffic analysis toolbox. Mesoscopic tools combine a focus on individual vehicles and drivers (as with microscopic models) with average measures of speed and density (as with macroscopic models). They are used to evaluate the systemwide effects of changes to driver behavior and performance on individual approaches and segments. Incidents can be directly coded into the network and their effect determined. As a result mesoscopic tools have been recommended for use in planning the operations over citywide or regional networks.

Why is this tool favored for such uses?

They can dynamically assign traffic based on the performance of specific facilities in a network, unlike macroscopic models, but they cannot compare to the precision of microsimulation models, which focus on the behaviors of individual drivers/vehicles.

Mesoscopic models can address a variety of traffic adaptations to network changes, including route shifts and changes in departure times. In the latter sense, mesoscopic tools come closer to addressing induced demand.

Mesoscopic models are easier to use than microscopic models in developing models of large geographic scales.

Mesoscopic models are more flexible than macroscopic tools for evaluating different facility types within the same model.

A number of software applications exist to facilitate integration between mesoscopic tools and travel demand models on the one hand, and microscopic tools on the other.

What are challenges and limitations of this tool?

The implementation of dynamic assignment in mesoscopic tools requires a considerable investment in calibration. Minor changes in origin and destination and departure-time patterns can have profound results on the simulated performance of alternative routes.

Mesoscopic tools can provide a misleading level of detail about individual link performance given that they are typically calibrated to generate analysis of large area networks. This is exacerbated by the simplistic representation of signals and other traffic controls.

The sensitivity of mesoscopic tools to default assumptions about driver behavior can be obscured somewhat by the use of average values for link-level vehicle speeds and densities.

Mesoscopic simulation models are more susceptible to failure in reaching convergence or equilibrium due to the additional interaction of dynamic route assignment with the random properties common to many simulation tools.

Considerable time and training are required for the development of complex models using mesoscopic tools.



Simulation Tools: Mesoscopic Simulation Tools (continued)

What are some software implementations of this tool?

Software examples of mesoscopic tools include DYNASMART-P, DYNAST, CUBE Avenue, Dynameq, and TRANSIMS.

Example Applications:

Fei, X., S. Eisenman, H.S. Mahmassani, and X. Zhou, “Application of DYNASMART-X to the Maryland CHART Network for Real-Time Traffic Management Center Decision Support,” **Proceedings of the 12th World Congress on Intelligent Transport Systems**, San Francisco, California 2005.

Application of **DYNASMART-X**, a simulation-based real-time network traffic estimation and prediction system based on dynamic traffic assignment (DTA) methodology, to the CHART network in Maryland. The application considers the I-95 corridor network between Washington, D.C. and Baltimore. The CHART network application allows use of the prediction and estimation procedures in conjunction with real-time information to consider multiple traffic management strategies and scenarios in real time. This can improve the ability of the traffic management center to respond to unfolding situations, including incidents, congestion and other unexpected events, through provision of traffic information to travelers and deployment of various control measures. The capabilities and benefits of the system are illustrated through scenario analysis and evaluation that considers real-time information in the context of multiple alternative management strategies in response to the occurrence of an incident on the main traffic facility.

Lili Lou, *Examination of Traffic Incident Management Strategies via Multi-Resolution Modeling with Dynamic Traffic Assignment*, 2012 Transportation Research Board Annual Conference, Conference CD-ROM, 2011.

Lou demonstrated the use of **Dynus-T** to model various traffic management strategies during a major freeway crash in the Phoenix region. In their analysis they imported their inputs from the regions travel demand model, conducted analysis in Dynus-T and then exported the output to VISSIM.

State of the Art – Incident-Specific Traffic Operations Analysis Models

Incident-specific traffic operations analysis models are “state of the art,” seeing application primarily in research settings.

The iMIT model is an example of a traffic incident-specific traffic operations analysis model (Khattak).⁷ This tool uses statistical models for incident duration and secondary incident occurrence, and uses a theoretically based deterministic queuing model to estimate associated delays. It has been tested in Hampton Roads, Virginia.

AIMSUN ONLINE is an example of a simulation model designed to support real-time incident management decision-making.⁸ AIMSUN ONLINE deduces the current traffic status on the streets and the actual demand based on data from permanent detectors. With control plans changing dynamically during the day, AIMSUN ONLINE also reads the current control plan operated at each network intersection. Parallel simulation runs are conducted to assess a variety of possible actions that might be applied in order to improve the network situation compared to the “do nothing” case.

Methods for Predicting Cumulative Incident Impacts

In addition to modeling the effect of a single incident, it also is desirable to know what the *cumulative* effect of incidents is: this accounts for the variability in incident occurrence and severity that occurs over the course of a year.

The tools for predicting cumulative benefits of incident management fall into three categories:

- Tools that predict the effects of incident management for large systems with minimal details or specifics on incident management methods. These tools are typically sketch planning models.



- Tools that predict the effects of incident management for single facilities with a great deal of detail on the specifics of the incident management methods. These tools are typically microsimulation models but with ongoing advances in Highway Capacity Manual methods, may soon include HCM analysis tools.
- Tools that predict the effects of incident management for multiple facility systems with moderate information on the specifics of the incident management methods. These tools are typically mesoscopic simulators employing dynamic traffic assignment.

Sketch planning models are designed to work at very large geographic scales and forecast the system effects of a variety of traveler information, demand management, capacity, and operational improvements, including incident management.

Overview of Sketch Planning Tools ⁹
Sketch-planning tools are typically simple, low-cost analysis techniques, employing highly aggregated and readily available data.
What is this tool used for?
Sketch planning tools are used to provide a quick analytic response to questions about planning concepts and alternatives. Sketch planning tools provide an introduction into the analytic process and can be used to communicate planning relationships and the effects of background trends. Sketch planning tools can be used to rule out scenarios.
Sketch planning tools support experimentation with alternatives and allow for comparisons between large geographic contexts with a minimum investment in set up and analysis.
Sketch planning tools are useful for screening planning alternatives. By incorporating knowledge about cause and effect, and costs-benefits into an automated framework, sketch planning tools offer analytic support for the initial stages of project development with clarity and robustness that surpasses the use of traditional 'rules of thumb.'
Why is this tool favored for such uses?
Sketch planning tools are inexpensive to develop or acquire. Knowledge of basic policy evaluation concepts and off-the-shelf software makes learning sketch planning tools and applying them easier and less expensive than most other tool types. Sketch tools provide an important benchmark for comparison with subsequent analysis results. It is not the case that sketch planning tools are always wrong and travel demand model analysis is always right when there is a disagreement in their results. Disagreement between sketch planning tools and other tools can be used to prompt a check of the assumptions used with more detailed tools.
What are challenges and limitations of this tool?
Sketch planning tools would benefit from improvements in presentation capabilities. Sketch planning tools often do not generate publishable reports and rarely generate graphical information.
Sketch planning results generally lack precision. Their simplicity is directly related to reliance on a limited number of inputs. The validity of results depends on a constrained range of variation among these inputs, which typically do not extend far beyond the central tendencies established by past experience. Alternatives and scenarios that reflect conditions not measured by the inputs can generate indefensible results. Sketch planning tools are not sensitive to operational features of the project (e.g., signal timing) because they do not represent facilities with resolution.
It should be recognized that the low cost of sketch planning tools might be lost in any tradeoff to enhance their capabilities.
What are some software implementations of this tool?
Software examples of sketch planning tools include HERS, IDAS, SMITE, SPASM, STEAM, and TELUS.



Overview of Sketch Planning Tools (continued)

Example Applications:

The Hampton Roads Planning District Commission (HRPDC) MPO used IDAS to quantify the emissions reductions due to reduced incidents as a result of ITS technologies deployed in the Hampton Road region. The IDAS tool was used in combination with the regional travel demand model to estimate the daily incremental emission impacts. The analysis results “showed a substantial decrease in the daily emissions for hydrocarbons (HC) and NO_x in the region due to the ITS deployment.”

Mesoscopic models, HCM methods, and microsimulation models are generally used to predict the impacts of specific incidents, but when combined with **scenario generators** and applied systematically to a variety of possible incident scenarios, these more computationally intensive tools can produce predictions of the cumulative benefits of incident management.

More information on these types of tools can be found in Volumes 1 and 2 of the FHWA Traffic Analysis Toolbox.¹⁰

Sketch Planning Tools

Sketch planning models such as HERS,¹¹ IDAS,¹² and TOPS-BC are designed to work at very large geographic scales and forecast the system effects of a variety of traveler information, demand management, capacity, and operational improvements, including incident management. They apply average incident frequencies, average incident durations, and relatively simple speed-flow relationships to estimate systemwide, long-term effects of incidents on system demand and system delay.

Title: *Incident Response Evaluation: Phase 3*

Objective: This study was intended to improve the understanding of the benefits from Incident Response (IR) actions by Washington State Department of Transportation (WSDOT). The key objectives of this study were to analyze the impacts of incident response service measures on traffic conditions and to develop a methodology to help WSDOT more effectively deploy the Incident Response resources.

Type of Tool/Analysis Used: A variety of statistical analyses of incident data in the Puget Sound region in Washington State were performed to investigate how incidents and incident characteristics affect roadway performance.

Results: For the 2006 study year, a conservative estimate was that crashes and other traffic incidents cost travelers 5,300,000 vehicle-hours of delay, in addition to typical congestion delay, on the Puget Sound region’s freeway system. That was roughly 30 percent of the total delay from all causes that occurred on these roadways. It was recommended that roadway segments (5- to 7-mile stretch) that produce roughly 45 crashes per year in one direction of travel would exhibit enough savings in travel time from incident response to warrant the deployment of incident response on the basis of travel time savings alone. The incident response activities were only financially warranted during times when volumes exceeded a V/C ratio of 0.6 on two-lane (in one direction) roadways or 0.7 on three-lane or larger roads.



HERS

The Highway Economic Requirements System (HERS) is a model for determining optimal highway investment programs and policies. Two versions of HERS exist, one for national-level analyses, the other, HERS-ST is targeted to state DOT-level analyses. HERS does not have a built in network traffic operations analysis module. This information must be provided to HERS from a separate model, such as a travel demand model network or a mesoscopic model network. The traffic operations effects of different investments in incident management programs are modeled off-line and the results input into HERS.

While numerous operations strategies are available to highway agencies, a limited number are now considered in HERS (based on the availability of suitable data and empirical impact relationships). The types of strategies analyzed can be grouped into four categories: arterial management, freeway management, incident management, and travel information.¹³ For incident management, HERS can evaluate the following strategies for freeways only:

- Incident detection (free cell phone call number and detection algorithms);
- Incident verification (surveillance cameras); and
- Incident response (on-call service patrols).

HERS was used to model incident management effects for FHWA's 2008 Status of the Nation's Highways, Bridges, and Transit: *Conditions and Performance Report*.¹⁴

More information on HERS can be found at:

<http://www.fhwa.dot.gov/infrastructure/asstmgmt/hersfact.cfm>.

HERS: The Oregon Experience¹⁵

In 1999, the State of Oregon developed a customized version of the FHWA Highway Economic Requirements System (HERS) tool for use in conducting investment analysis in the State. The State developed the tool so it could develop more credible estimates of user costs and benefits from transportation improvements. When controversy arose in quantifying the costs of delay in a high-profile incident on one of the state highways, the State developed additional postprocessors to produce estimates of "Unexpected Delay" and "Cost of Unexpected Delay" from the HERS-OR tool.

In a major incident that closed a portion of I-5 for 13 hours, a local newspaper cited estimates of user costs that did not match official ODOT estimates from the HERS-OR model. ODOT took the opportunity to develop additional postprocessors to HERS-OR that produced an Unexpected Delay Map and the Cost of Expected Delay that were acceptable and consistent. This information was shared with all departments and the public and now provides a single consistent source for quantifying delay within ODOT.



IDAS

The ITS Deployment Analysis System (IDAS) is software that can be used in planning for Intelligent Transportation System (ITS) deployments. State, regional, and local planners can use IDAS to estimate the benefits and costs of ITS investments – which are either alternatives to or enhancements of traditional highway and transit infrastructure. IDAS can predict relative costs and benefits for more than 60 types of ITS investments. The IDAS ITS components deployed include:

- Incident detection only; and
- Both incident detection and incident response.

IDAS was utilized to model incident management system in Hampton Roads, Virginia.¹⁶ The results showed a substantial decrease (9 to 14 percent reductions) in the daily emissions for hydrocarbons (HC) and NO_x in the region for the two options containing incident management improvements when compared with the control alternative without any improvements.

More information on IDAS can be found at:

<http://idas.camsys.com/>.

TOPS-BC

FHWA's Office of Operations sponsored this project to provide guidance on conducting benefit/cost analysis for operations projects, including incident management. The project developed an *Operations Benefit/Cost Analysis Desk Reference* as well as software to implement it (TOPS-BC). The benefits of operations projects include those related to travel time reliability. For the impacts of incident management strategies, TOPS-BC uses the IDAS procedures.

SSP-BC

Objective:

The SSP-BC Tool was developed for the I-95 Corridor Coalition and FHWA to fill the need for a comprehensive, cost-effective, and standardized Benefit/Cost (B/C) ratio estimation methodology to facilitate evaluation of existing Service Safety Patrol (SSP) programs throughout the country. The tool is based on commonly accepted assumptions and uses an updateable monetary conversion process. A major strength of the tool is not only its utility for evaluating existing programs, but also its applicability in testing numerous what-if scenarios, including the introduction of a new program or the impact of improvements in service response times.

Methodology:

Data in tables used in the tool were derived directly from simulation run results (travel delays, fuel consumption), regression-based estimates (fuel consumption), a novel hybrid statistical-simulation data methodology with improved model fitness (travel delay), computations (emissions, secondary incidents), and from publically available sources (wages, fuel costs, traffic composition, and monetary conversion



rates). Power-based equations that incorporate vehicle characteristics and modal parameters (vehicle mass, velocity, and acceleration) in computing instantaneous power demand for each vehicle type category are used in the estimation of fuel consumption and emissions produced (carbon dioxide (CO₂), carbon monoxide (CO), methane (CH₄), Nitrogen Oxides (NO_x), and Sulfur Oxides (SO_x)). The equations are responsive to roadway geometry, traffic volume, grade, and other characteristics of the traffic environment. The output of the tool includes the B/C ratio incorporating user-specified benefit measures, savings in travel delay in vehicle-hours, fuel consumed by passenger cars and light-duty vehicles in gallons, number of prevented secondary incidents, and emission pollutants in metric tons.¹⁷

Example Applications

Evaluation of Emissions Impacts of an Incident Management System in Hampton Roads, Virginia

The Hampton Roads Planning District Commission (HRPDC) MPO had invested in deploying ITS technologies in the Hampton Road region. They believed the reduced incidents due to the incident management put in place during the ITS program should logically lead to reductions in emissions. They wanted a tool that could be used to estimate and quantify the emissions reduction. The IDAS software was selected to conduct analysis to quantify the expected emissions reduction. The HDRPC also was interested in quantifying any emissions reductions to the EPA, FHWA, and Air Quality Bureaus to be used in determining the region's air quality conformity status.

Output runs for a base case and two 2021 scenarios from the regional travel demand model were fed into the IDAS tool for analysis. The IDAS tool was used to estimate the daily incremental emission impacts.

The analysis results “showed a substantial decrease in the daily emissions for hydrocarbons (HC) and NO_x in the region for the two options containing incident management improvement when compared with the control alternative.” Run 1 was the current and near-term ITS deployments, while Run 2 represented greater regional incident management, planned for the future. Though EPA did not ultimately use the results it was a first step for HRPDC to begin quantifying the benefits of their incident management program.

CHART

The Coordinated Highways Action Response Team (CHART) is a joint effort of the Maryland Department of Transportation, Maryland Transportation Authority, and the Maryland State Police. Its mission is to improve real-time operations of Maryland's highway system through teamwork and technology. From February 2001, all incident requests for emergency assistance have been recorded in the CHART information system and this has significantly enriched the available incident data.



Title: *Benefit-Cost Analysis of Freeway Service Patrol Programs: Methodology and Case Study*

Objective: The objective of this study was to estimate the benefits of a Freeway Service Patrol (FSP), the Highway Emergency Local Patrol (H.E.L.P.) program operating in New York State.

Type of Tool/Analysis Used: A CORSIM-based simulation methodology was applied for estimating the benefits of the H.E.L.P. program. The benefits assessed include savings in travel delay, fuel consumption, emissions, and secondary incidents. Using this methodology, the monetary equivalent of these savings was computed to obtain an estimate of the benefit-to-cost (B/C) ratio.

Results: This study showed that the H.E.L.P. program operated with better than two-to-one B/C ratio. If vehicle occupancy, traffic composition with commercial vehicles, and the benefit of avoiding secondary incidents were considered, the B/C ratio could be in a range of 3.4 to 4.2. If considering fatal incidents that were avoided, this ratio would increase to between 13.2 and 16.5.

The University of Maryland, as part of the ongoing CHART evaluations, developed a predictive equation model based on running experiments with microscopic simulation:

$$\text{Excess Delay Due to Incidents} = e^{-10.19 * (V)^{2.8} * (NLB/TNL)^{1.4} * (ID)^{1.78}}$$

- Where:
- TNL = Total number of lanes;
 - NLB = Number of lanes blocked;
 - V = Traffic volume; and
 - ID = Incident duration.

Using this model, it was determined in 2009 that the CHART program reduced delays by 32.43 million vehicle-hours.

More information on CHART can be found at:

<http://www.chart.state.md.us/>.

Scenario-Based Modeling Approaches

Scenario-based modeling approaches apply mesoscopic models, HCM methods, and microsimulation models repeatedly to a variety of possible incident conditions to arrive at an assessment of the cumulative effects of incident management. There are three primary examples of this approach: The Integrated Corridor Management (ICM) analysis, the FHWA ATDM Evaluation Guide, and the SHRP 2-L08 Reliability in HCM project.

Integrated Corridor Management Analyses

The evaluations of Integrated Corridor Management strategies for Minneapolis, Dallas, and San Diego used travel demand models, mesoscopic simulation models and microsimulation analysis in combination with selected incident scenarios (Table 1). The analysis of multiple incident and weather scenarios



(where a variety of incident types can occur at multiple times and locations) were strictly limited to manage analysis costs.

The analysis found significantly positive benefit/cost ratios for integrated corridor management strategies, which include incident management.

This analysis approach can evaluate a wide variety of incident management strategies but it requires a significant investment in analysis effort for the various models that must be employed.

More information on the ICM analyses methods and results can be found at:

http://www.its.dot.gov/icms/success_icme.htm.

Table 1. ICM TIM Modeling Tools

Model Type	Minneapolis	Dallas	San Diego
Regional Travel Demand Model	Metro model in TP+	NTCOG model, TransCAD	TransCAD
Mesoscopic Simulation Model	Dynus-T – supported by University of Arizona	DIRECT – supported by Southern Methodist University	None
Microscopic Simulation Model	None	None	Transmodeler/Micro

(Source: Adapted from: http://www.its.dot.gov/icms/success_icme.htm.)

FHWA ATDM Evaluation Guide

The FHWA Active Transportation and Demand Management Evaluation Guide (ATDM Guide) and future replacement for Chapter 35 of the 2010 Highway Capacity Manual currently is under preparation. The ATDM Guide recommends the creation of three different prototypical incident scenarios (no incident, one lane blocked, two lanes blocked) for each of good weather and bad weather days for a total of 6 capacity scenarios. The 6 capacity scenarios are each matched with 5 different levels of demand. The result is 30 scenarios for evaluating incident management and other ATDM strategies.

Special demand, capacity and speed adjustment factors currently are being developed to reflect the effects of incidents and various incident management strategies on these factors. The method will be sensitive to traveler information strategies, speed control strategies (VSL), and lane management strategies (temporary shoulder lane use, etc.).

Once the scenarios have been created and the demand/capacity/speed adjustment factors computed, conventional HCM methods are then used to evaluate facility performance.

The HCM predicted performance for each scenario is weighted by the probability of the scenario occurring over the course of a year to obtain average, median, and any desired percentile (e.g., 95th percentile) result.

Software to implement aspects of the ATDM methodology is being developed. The proposed ATDM evaluation methodology is being tested on the I-15 corridor in San Diego.



SHRP 2 Projects Relevant for Incident AMS

Several completed and ongoing SHRP 2 projects deal specifically with the prediction of travel time reliability, of which incident impacts are a major component. These SHRP 2 projects are discussed below.

More information on this methodology can be obtained from SHRP 2 staff.

SHRP 2-L08 Incorporation of Reliability in the HCM

The SHRP 2-L08 Reliability Analysis Guide for the Highway Capacity Manual (Reliability Guide) currently is under preparation. The Reliability Guide will recommend the creation of several hundred to several thousand demand, weather, and incident scenarios to predict future travel time reliability distribution.

Two methods for generating scenarios are being considered. One enumerates all possible scenarios and selects the ones of most interest for more extensive evaluation. The other method uses a Monte Carlo approach to generate the scenarios.

Special capacity and speed adjustment factors currently are being developed to reflect the effects of incidents (but not incident management strategies) on these factors. The SHRP 2-L08 project is focusing on predicting existing and future reliability under existing control conditions, rather than predicting how changes in operational strategies can affect reliability.

Once the scenarios have been created and the demand/capacity/speed adjustment factors computed, conventional Highway Capacity Manual (HCM) methods are then used to evaluate facility performance.

An improved HCM Urban Streets method is being developed to better support reliability analysis on arterial streets. The improved method will be able to account for the impacts of queues on upstream signal operation.

The HCM predicted performance for each scenario is weighted by the probability of the scenario occurring over the course of a year to obtain average, median, and any desired percentile (e.g., 95th percentile) result.

Software to implement the methodology is being developed. The proposed methodology will be tested on a half dozen freeway and urban street data sets.

SHRP 2 L03 Analytical Procedures for Determining the Impacts of Reliability Mitigation Strategies

SHRP 2 Project L03 produced two types of statistical equations based on empirical data for predicting reliability measures. The first set relates the mean congestion condition, as measured by the travel time index (TTI) to a variety of reliability metrics. A strong correlation was found between the mean and the rest of the reliability metrics used, including standard deviation, upper percentiles of the travel time distribution, and on-time measures. The second set relates reliability metrics to demand, capacity, incident blockage, and weather. Publication of the report is expected in late 2012.



Methods for Predicting Incident Duration

When an incident occurs, the timely estimate of its duration plays a key role in the overall incident management process. Reliable incident duration predictions can help traffic managers in providing correct and essential information to road users, applying appropriate traffic control measures at or near the incident location and evaluating the effectiveness of the incident management strategies implemented. The duration of an incident can have several definitions, depending on what is chosen for the start and end times of the incident. Generally the start time is when the incident is first detected by incident management personnel. Ideally the start time would be the time when the incident actually occurred, but this cannot be known with certainty. However, in urban areas, the time between actual start and detection is very small because most incidents are reported by travelers via cell phones within a very short time of the actual occurrence. The end time is usually selected as the time when all lanes are open to traffic or when the last responder has left the scene.

State of the Practice

In Maryland, a Rule-Based Tree Model (RBTM) was applied to develop the prediction model for freeway incident duration by Kim et al.¹⁸ The model was developed based on the Maryland State Highway (MDSHA) incident database. The overall confidence for the estimated model was over 80 percent. In cases where RBTM did not provide incident duration within a desirable range, a discrete choice model was developed as a supplemental model.

State of the Art

There are several methods that have been developed in predicting incident duration, as listed below:

- Regression model;
- Hazard-based duration regression model;
- Log-logistic model;
- Prediction/decision tree model;
- Support/relevance vector machine model; and
- Bayesian network model.

Methods for Predicting Secondary Crashes

Secondary crashes are associated with vehicles in close proximity due to a queue formed from a primary incident, the abrupt “end-of-queue” condition caused by a primary incident, collisions with emergency vehicles and personnel, and rubbernecking in both the current and opposite directions of travel. Secondary crashes can be severe, especially at night when visibility is reduced and traffic queues are unexpected. Modeling methods to predict secondary crashes would be greatly enhanced if traffic management center personnel could flag crashes that occur in the queue caused by the primary incident or from opposite direction rubbernecking. Currently, researchers must derive these items analytically.



State of the Practice

Researchers at the Virginia Center for Transportation Innovation and Research also developed a dynamic queue-based tool to identify primary incidents (Secondary Incident Identification tool – SiT). They have used SiT and iMiT together to begin to improve the state of the art in modeling secondary incidents.¹⁹

State of the Art

The following is a list of methods that have been developed and used for quantifying the occurrence and characteristics of secondary crashes.

- Regression model;
- Ordered logit model;
- Probit model;
- Logistic regression model;
- Bayesian network model; and
- Simulation-based secondary incident filtering method.

For instance, a study conducted by Zhan et al. used a comprehensive incident database on I-95 from District 4 of the Florida DOT to identify freeway secondary crashes and their contributing factors.²⁰ A method based on a cumulative arrival and departure traffic delay model was developed to estimate the maximum queue length and the associated queue recovery time for incidents with lane blockages.

Vlahogianni et al. also recently utilized neural networks and statistical approaches to study the impact of weather on secondary crashes.²¹ Their findings were that speed, volume, number of blocked lanes and vehicles involved in a crash significantly influence the probability of a having a secondary incident.

A compendium of how transportation agencies are dealing with secondary incidents can be found in the document: *Traffic Incident Management Performance Metric Adoption Campaign*.



Title: *Primary and Secondary Incident Management: Predicting Durations in Real Time*

Objective: The main objectives of this study were to analyze the occurrence and nature of secondary incidents in the Hampton Roads (HR) area in Virginia, and develop tools that can analyze primary and secondary incidents at the planning and operational levels.

Type of Tool/Analysis Used: A dynamic queue-based tool, Secondary Incident Identification Tool (SiT), was developed to identify primary and secondary incidents from historical incident data. An on-line tool, iMiT, was developed to predict the remaining duration of an existing incident, the chances of a secondary incident based on the characteristics of the primary incident, and the associated delays.

Results: This study found that secondary incidents account for nearly 2.0 percent of Transportation Operations Center (TOC)-recorded incidents, using the 2006 data. Of all accidents, 7.5 percent had associated secondary incidents, 1.5 percent of disabled vehicles had secondary incidents, and 0.9 percent of abandoned vehicles had secondary incidents. The average duration of secondary incidents in Hampton Roads was 18 minutes, which was 4 minutes longer than the mean duration of other incidents, indicating that secondary incidents were not necessarily minor “fender benders.” The study also found that a 10-minute increase in primary incident duration was associated with 15 percent higher odds of secondary incidents.

Predicting Incident Characteristics (Independent Variables)

Incident models are built using indicators of incident performance as the predictor variables (e.g., incident duration, lane-hours lost due to incidents). Knowing how TIM strategies affect these independent variables is therefore of utmost importance. A number of studies have been done over the past two decades that can be used for this purpose. SHRP 2 L03 assembled the most recent studies in this area.

EVALUATION OF TIM AMS METHODS

This subsection provides a qualitative assessment of incident modeling methods based on selected criteria.

Qualitative Assessment Based on Selected Criteria (Review Matrix)

Table 2 shows a comprehensive assessment of incident modeling methods.



Table 2. TIM Review Matrix

Category	Application														Data Requirements	Ease of Use	Amount of Applications in Practice	Validation Efforts	Consistency with Traffic Flow Theory	Known Shortcomings	Qualitative Assessment of Validity of Results	Document Used/Reference	
	Development and Evaluation of TIM Plans	Analysis and Valuation of TIM Strategies	Decision Support Systems (On-line/Off-line)	Incident Prediction and Detection	Incident Duration Prediction	TIM Performance Measures	Relationship between TIM and Overall Congestion/Travel Time Reliability	Benefit-Cost Analysis of TIM Programs/Strategies	Safety Analysis Applications	Real-Time ATIS	Integrated Corridor Management	Appropriate for Long-Range Planning	Appropriate for Corridor Planning	Appropriate for Deployment Planning									Appropriate for Benefit/Cost Analysis
Measuring Impacts of Incidents on Traffic Flow																							
Data Collection and Archiving (Incident and Travel Time Data)																							
Roadway Sensors/ Detectors	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Extensive	Easy	Many	Unknown	N/A	<ul style="list-style-type: none"> • Detector health • Spot measurement (not continuous) 	Good for Empirical-Based Statistical Analysis	<ul style="list-style-type: none"> • Decomposition of Travel Time Reliability into Various Sources: Incidents, Weather, Work Zones, Special Events, and Base Capacity, Kwon, J. et al., TRB Annual Meeting, January 2011. • Freeway Travel Time Forecasting Under Incident, Xia, J. et al., Transportation Research Record: Journal of the Transportation Research Board, Issue 2178, 2010. • Decision Support Tools to Support the Operations of Traffic Management Centers (TMC), Hadi, M. et al., January 2011. • Modeling Travel Time Variability on Urban Links in London, Hasan, S. et al., European Transport Conference, 2009. • A Cellular Automata Approach to Estimate Incident-Related Travel Time on Interstate 66 in Near Real Time, Wang, Z. et al., Virginia Transportation Research Council, 2010. • Modeling Incident-Related Traffic and Estimating Travel Time with a Cellular Automaton Model, Murray-Tuite, P, Transportation Research Board 89th Annual Meeting, 2010.
Freeway Service Patrol (FSP)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Extensive	Moderate	Many	Unknown	N/A	<ul style="list-style-type: none"> • Not all incidents are included as FSP does not respond to all incidents 	Good for Empirical-Based Statistical Analysis	<ul style="list-style-type: none"> • iMiT: A Tool for Dynamically Predicting Incident Durations, Secondary Incident Occurrence, and Incident Delays, Khattak, A. et al., TRB Annual Meeting, January 2011. • Benefit-Cost Analysis of Freeway Service Patrol Programs: Methodology and Case Study, Chou, C. et al.
Accident Logs	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Extensive	Moderate	Many	Unknown	N/A	<ul style="list-style-type: none"> • Not all incidents are included in accident logs and some of the records are not accurate 	Good for Empirical-Based Statistical Analysis	<ul style="list-style-type: none"> • Structure Learning for the Estimation of Non-Parametric Incident Duration Prediction, Demirogluk, S. et al., Transportation Research Board 90th Annual Meeting. • Development of a Hybrid Model for Freeway Incident Duration: A Case Study in Maryland, Kim, W. et al., 17th ITS World Congress, Busan, 2010. • Are Incident Durations and Secondary Incidents Interdependent, Khattak, A. et al., Transportation Research Record: Journal of the Transportation Research Board Issue Number: 2099, 2009. • Identifying Secondary Crashes and Their Contributing Factors, Zhan, C. et al., Transportation Research Record: Journal of the Transportation Research Board Issue Number: 2102, 2009. • Analysis of Freeway Incident Duration for ATIS Applications, Kim, W. et al., 15th World Congress on Intelligent Transport Systems and ITS America's Annual Meeting, 2008. • Dynamic Incident Progression Curve for Classifying Secondary Traffic Crashes, Journal of Transportation Engineering, December 2010.
TMC Data	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Extensive	Moderate	Many	Unknown	N/A	<ul style="list-style-type: none"> • May contain incomplete information 	Good for Empirical-Based Statistical Analysis	<ul style="list-style-type: none"> • Incident Duration Prediction for In-Vehicle Navigation System, Hu, J. et al., Transportation Research Board 90th Annual Meeting, 2011. • What Is the Role of Multiple Secondary Incidents in Traffic Operations, Zhang, H. et al., Journal of Transportation Engineering Volume: 136, 2010. • Decision Support Tools to Support the Operations of Traffic Management Centers (TMC), Hadi, M. et al., January 2011.



Table 2. TIM Review Matrix (continued)

Category	Application														Data Requirements	Ease of Use	Amount of Applications in Practice	Validation Efforts	Consistency with Traffic Flow Theory	Known Shortcomings	Qualitative Assessment of Validity of Results	Document Used/Reference		
	Development and Evaluation of TIM Plans	Analysis and Valuation of TIM Strategies	Decision Support Systems (On-line/Off-line)	Incident Prediction and Detection	Incident Duration Prediction	TIM Performance Measures	Relationship between TIM and Overall Congestion/Travel Time Reliability	Benefit-Cost Analysis of TIM Programs/Strategies	Safety Analysis Applications	Real-Time ATIS	Integrated Corridor Management	Appropriate for Long-Range Planning	Appropriate for Corridor Planning	Appropriate for Deployment Planning									Appropriate for Benefit/Cost Analysis	
Data Collection and Archiving (Incident and Travel Time Data) (continued)																								
Simulation	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Extensive	Difficult	Many	Unknown	N/A	<ul style="list-style-type: none"> Resource intensive (cost, expertise, analysis time) 	Good if the simulation model is developed and calibrated well	<ul style="list-style-type: none"> Use of Simulation-Based Forecast for Real Time Traffic Management Decision Support: The Case of the Madrid Traffic Centre, Torday, A. et al., European Transport Conference, 2008. Measurement of Uncertainty Costs with Dynamic Traffic Simulations, Marchal, F. et al, Transportation Research Record: Journal of the Transportation Research Board, 2008. On-line Microscopic Traffic Simulation to Support Real Time Traffic Management Strategies, Barcelo, J. et al. Benefit-Cost Analysis of Freeway Service Patrol Programs: Methodology and Case Study, Chou, C. et al. Estimation of Nonrecurring Post-incident Traffic Recovery Time for Different Flow Regimes: Comparing Shock Wave Theory and Simulation Modeling, Jeihani, M. et al., Transportation Research Board 90th Annual Meeting, 2011. Regional Emergency Action Coordination Team (REACT) Evaluation, by Battelle, July 2002.
Automatic Number Plate Reader (ANPR)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Extensive	Difficult	Rare	Unknown	N/A	<ul style="list-style-type: none"> Resource intensive (cost and analysis time) 	Good for Empirical-Based Statistical Analysis	<ul style="list-style-type: none"> Modeling Travel Time Variability on Urban Links in London, Hasan, S. et al., European Transport Conference, 2009.
Web-based Data Collection and Archiving System	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Extensive	Easy	Some	Unknown	N/A	<ul style="list-style-type: none"> Unknown 	Good if the quality of data feeding into the system is good	<ul style="list-style-type: none"> Freeway and Arterial System of Transportation (FAST) Dashboard (Regional Transportation Commission (RTC) of Southern Nevada).
Analytical Methods																								
Coordinated Highways Action Response Team (CHART, University of Maryland, Model-Based Stochastic Approach)	Y	Y	Y					Y					Y	Y	Y	Y	Minimal	Easy	One	Unknown	N/A; Statistical-based	<ul style="list-style-type: none"> Only includes a volume term – should include a V/C term instead 	Will overestimate delay at low volumes	<ul style="list-style-type: none"> Performance Evaluation and Benefit Analysis for CHART in Year 2009, Chang, G. et al.



Table 2. TIM Review Matrix (continued)

Category	Application														Data Requirements	Ease of Use	Amount of Applications in Practice	Validation Efforts	Consistency with Traffic Flow Theory	Known Shortcomings	Qualitative Assessment of Validity of Results	Document Used/Reference	
	Development and Evaluation of TIM Plans	Analysis and Valuation of TIM Strategies	Decision Support Systems (On-line/Off-line)	Incident Prediction and Detection	Incident Duration Prediction	TIM Performance Measures	Relationship between TIM and Overall Congestion/Travel Time Reliability	Benefit-Cost Analysis of TIM Programs/Strategies	Safety Analysis Applications	Real-Time ATIS	Integrated Corridor Management	Appropriate for Long-Range Planning	Appropriate for Corridor Planning	Appropriate for Deployment Planning									Appropriate for Benefit/Cost Analysis
Analytical Methods (continued)																							
Quantile Regression (Empirical-Based Statistical Method)	Y	Y	Y			Y	Y	Y				Y	Y	Y	Y	Extensive	Easy	One	Unknown	N/A; Statistical-based	<ul style="list-style-type: none"> It is site specific and hard to make generalization to other facilities 	Results are valid as long as data input is reasonably accurate	<ul style="list-style-type: none"> Decomposition of Travel Time Reliability into Various Sources: Incidents, Weather, Work Zones, Special Events, and Base Capacity, Kwon, J. et al., TRB Annual Meeting, January 2011.
Simulation	Y	Y	Y			Y	Y	Y				Y	Y	Y	Y	Extensive	Difficult	One	Unknown	N/A; Simulation-based	<ul style="list-style-type: none"> Unknown 	Moderate	<ul style="list-style-type: none"> Measurement of Uncertainty Costs with Dynamic Traffic Simulations, Marchal, F. et al., Transportation Research Record: Journal of the Transportation Research Board, 2008. On-line Microscopic Traffic Simulation to Support Real Time Traffic Management Strategies, Barcelo, J. et al. Regional Emergency Action Coordination Team (REACT) Evaluation, by Battelle, July 2002. Estimation of Incident Delays on Arterial Streets, Yang, S. et al., Transportation Research Board 87th Annual Meeting, 2008.
Predicting Impacts of Incidents on Traffic Flow																							
Regression Model	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Y	Extensive	Easy	Two	Unknown	N/A; Statistical-based	<ul style="list-style-type: none"> N/A 	Good	<ul style="list-style-type: none"> Estimation of Nonrecurring Postincident Traffic Recovery Time for Different Flow Regimes: Comparing Shock Wave Theory and Simulation Modeling, Jeihani, M. et al., Transportation Research Board 90th Annual Meeting, 2011. Estimation of Incident Delays on Arterial Streets, Yang, S. et al., Transportation Research Board 87th Annual Meeting, 2008.
Shock Wave Model	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Y	Moderate	Moderate	One	Unknown	Yes	<ul style="list-style-type: none"> Tend to report shorter recovery time as it only calculates queue dissipation time which does not necessarily equate with the time to return to pre-incident normal traffic flow condition 	Moderate	<ul style="list-style-type: none"> Estimation of Nonrecurring Postincident Traffic Recovery Time for Different Flow Regimes: Comparing Shock Wave Theory and Simulation Modeling, Jeihani, M. et al., Transportation Research Board 90th Annual Meeting, 2011.



Table 2. TIM Review Matrix (continued)

Category	Application													Data Requirements	Ease of Use	Amount of Applications in Practice	Validation Efforts	Consistency with Traffic Flow Theory	Known Shortcomings	Qualitative Assessment of Validity of Results	Document Used/Reference	
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Predicting Impacts of Incidents on Traffic Flow (continued)																						
Queuing Analysis	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Moderate	Easy	Three	Moderate validation efforts	Yes	• Unknown	Moderate	<ul style="list-style-type: none"> • Primary and Secondary Incident Management: Predicting Durations in Real Time, Khattak, A. et al., Final Report VCTIR 11-R11, Virginia Center for Transportation Innovation and Research, April 2011. • Decision Support Tools to Support the Operations of Traffic Management Centers (TMC), Hadi, M. et al., January 2011. • Comprehensive Analysis of Important Questions Related to Incident Durations Based on Past Studies and Recent Empirical Data, Yazici, A. et al., TRB 89th Annual Meeting, January 2010.
Adjustment Method Based on Queuing Analysis	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Extensive	Moderate	One	Moderate validation efforts	Yes	• Unknown	Moderate	<ul style="list-style-type: none"> • Freeway Travel Time Forecasting Under Incident, Xia, J. et al., Transportation Research Record: Journal of the Transportation Research Board, Issue 2178, 2010.
Difference-in-Travel-Time Method	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Moderate	Moderate	One	Moderate validate efforts using a case study	N/A; Statistical-based	• Unknown	Moderate	<ul style="list-style-type: none"> • Empirical Method for Estimating Traffic Incident Recovery Time, Zeng, X. et al., Transportation Research Record: Journal of the Transportation Research Board, Issue 2178, 2010.
Marginal Incident Computation (MIC) Model	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Moderate	Difficult	One	Unknown	N/A; Statistical-based	<ul style="list-style-type: none"> • Model is complicated • Should be refined to consider other causes of variable travel times, such as demand fluctuations and capacity fluctuations 	Moderate	<ul style="list-style-type: none"> • Stochastic Dynamic Network Loading for Travel Time Variability Due to Incidents, Corthout, R. et al., New Developments in Transport Planning: Advances in Dynamic Transport Assignment, 2010.
IDAS	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Moderate	Moderate	N/A	Unknown	Partly (Combined analytical model and empirical data)	<ul style="list-style-type: none"> • Do not consider spatial characteristics of incident delay 	Moderate	• N/A



Table 2. TIM Review Matrix (continued)

Category	Application													Data Requirements	Ease of Use	Amount of Applications in Practice	Validation Efforts	Consistency with Traffic Flow Theory	Known Shortcomings	Qualitative Assessment of Validity of Results	Document Used/Reference		
	Development and Evaluation of TIM Plans	Analysis and Valuation of TIM Strategies	Decision Support Systems (On-line/Off-line)	Incident Prediction and Detection	Incident Duration Prediction	TIM Performance Measures	Relationship between TIM and Overall Congestion/Travel Time Reliability	Benefit-Cost Analysis of TIM Programs/Strategies	Safety Analysis Applications	Real-Time ATIS	Integrated Corridor Management	Appropriate for Long-Range Planning	Appropriate for Corridor Planning									Appropriate for Deployment Planning	Appropriate for Benefit/Cost Analysis
Predicting Impacts of Incidents on Traffic Flow (continued)																							
Genetic Neural Network (GNN)	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Y	Moderate	Difficult	One	Unknown	N/A; Statistical-based	<ul style="list-style-type: none"> Difficult to understand the model parameters (blackbox) 	Moderate	<ul style="list-style-type: none"> Prediction of Freeway Travel Time in Incident Management Evaluation Based on Genetic Neural Network, He, D. et al., Seventh International Conference on Traffic and Transportation Studies, 2010.
Cellular Automata	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Y	Moderate	Difficult	Two	Moderate validation efforts	Yes	<ul style="list-style-type: none"> Computation resource intensive May give poor results if input detector data is not accurate 	Moderate	<ul style="list-style-type: none"> A Cellular Automata Approach to Estimate Incident-Related Travel Time on Interstate 66 in Near Real Time, Wang, Z. et al., Virginia Transportation Research Council, 2010. Modeling Incident-Related Traffic and Estimating Travel Time with a Cellular Automaton Model, Murray-Tuite, P, Transportation Research Board 89th Annual Meeting, 2010.
Simulation	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Y	Extensive	Difficult	Five	Unknown	N/A; Simulation-based	<ul style="list-style-type: none"> Resource intensive (data, cost, expertise, analysis time) 	Good	<ul style="list-style-type: none"> Estimation of Non-recurring Post-incident Traffic Recovery Time for Different Flow Regimes: Comparing Shock Wave Theory and Simulation Modeling, Jeihani, M. et al., Transportation Research Board 90th Annual Meeting, 2011. Estimation of Traffic Recovery Time for Different Flow Regimes on Freeways, Saka, A. et al., Maryland State Highway Administration, Report No. MD-09-SP708B4L, July 2008. Use of simulation-based forecast for real time traffic management decision support: the case of the Madrid traffic centre, Torday, A. et al, European Transport Conference, 2008. On-line Microscopic Traffic Simulation to Support Real Time Traffic Management Strategies, Barcelo, J. et al. Non-Recurrent Congestion Simulation And Application, Jiang, Z. et al., 15th World Congress on Intelligent Transport Systems and ITS America's Annual Meeting, 2008. Development of a Traffic Simulator for the Baltimore Beltway for Traffic Operations and Incident Management (MD-10-SP808B4M). Management and Analysis of Michigan Intelligent Transportation Systems Center Data with Application to the Detroit Area I-75 Corridor, Grand Valley State University and Wayne State University, Detroit, Michigan, Report No: MIOH UTC TS21p1-2 2011.



Table 2. TIM Review Matrix (continued)

Category	Application													Data Requirements	Ease of Use	Amount of Applications in Practice	Validation Efforts	Consistency with Traffic Flow Theory	Known Shortcomings	Qualitative Assessment of Validity of Results	Document Used/Reference	
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Predicting Incident Characteristics (e.g., Duration)																						
Regression Model	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Moderate	Easy	Three	Moderate validation efforts	N/A; Statistical-based	<ul style="list-style-type: none"> The explanatory power of the model may be poor 	Moderate	<ul style="list-style-type: none"> A Comparative Study of Models for the Incident Duration Prediction, Valenti, G. et al., European Transport Research Review, 2010. Are Incident Durations and Secondary Incidents Interdependent, Khattak, A. et al., Transportation Research Record: Journal of the Transportation Research Board Issue Number: 2099, 2009. Primary and Secondary Incident Management: Predicting Durations in Real Time, Khattak, A. et al, Final Report VCTIR 11-R11, Virginia Center for Transportation Innovation and Research, April 2011.
Log-Logistic (Accelerated Failure Time, or AFT) Model	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Moderate	Moderate	One	Out-performed other naïve predictors	N/A; Statistical-based	<ul style="list-style-type: none"> Unknown 	Moderate	<ul style="list-style-type: none"> Incident Duration Prediction for In-vehicle Navigation System, Hu, J. et al., Transportation Research Board 90th Annual Meeting, 2011.
iMiT - Incident Management Integration Tool (On-line Tool Based on Statistical Regression)	Y	Y	Y ^a			Y		Y		Y	Y ^b	Y	Y	Y	Moderate	Easy	One	Empirically validated by comparing the model's predicted incident durations in year 2007 against the observed incident durations	N/A; Statistical-based	<ul style="list-style-type: none"> The model was based on Safety Service Patrol (SSP) data, but SSP did not respond to all incidents; therefore, the data used for the model may be biased 	Good (Considering it was able to predict incident duration with root mean squared error (RMSE) within 16.4%)	<ul style="list-style-type: none"> iMiT: A Tool for Dynamically Predicting Incident Durations, Secondary Incident Occurrence, and Incident Delays, Khattak, A. et al., TRB Annual Meeting, January 2011.
Shock Wave Model	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Moderate	Moderate	One	N/A	Yes	<ul style="list-style-type: none"> Unknown 	Moderate	<ul style="list-style-type: none"> Stochastic Incident Duration: Impact on Delay, Knoop, V. et al., Transportation Research Board 89th Annual Meeting, 2010.
Hazard-Based Duration Regression Model	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Moderate	Moderate	One	N/A	N/A; Statistical-based	<ul style="list-style-type: none"> Unknown 	Moderate	<ul style="list-style-type: none"> An Information-Based Time Sequential Approach to On-line Incident Duration Prediction, Qi, Y. et al., Journal of Intelligent Transportation Systems Volume: December 2008.
Prediction/Decision Tree (DT)	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Moderate	Moderate	One	Moderate validation efforts	N/A; Statistical-based	<ul style="list-style-type: none"> Unknown 	Moderate	<ul style="list-style-type: none"> A Comparative Study of Models for the Incident Duration Prediction, Valenti, G. et al., European Transport Research Review, 2010.



Table 2. TIM Review Matrix (continued)

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Predicting Incident Characteristics (e.g., Duration) (continued)																						
Rule-Based Tree Model (RBTM)	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Moderate	Moderate	One	N/A	N/A; Statistical-based	<ul style="list-style-type: none"> May need to use together with supplemental models for more accurate prediction 	Moderate	<ul style="list-style-type: none"> Analysis of Freeway Incident Duration for ATIS Applications, Kim, W., S. Natarajan, and G-L Chang, 15th World Congress on Intelligent Transport Systems and ITS America's Annual Meeting, 2008. An Integrated Knowledge Based System for Real-Time Estimation of Incident Durations and Nonrecurrent Congestion Delay for Freeway Networks (MD-09-SP708B4C).
Support/Relevance Vector Machine (RVM) Model	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Moderate	Difficult	One	Moderate validation efforts	N/A; Statistical-based	<ul style="list-style-type: none"> Tend to underestimate the prediction values for the long duration incident cases 	Moderate	<ul style="list-style-type: none"> A Comparative Study of Models for the Incident Duration Prediction, Valenti, G. et al., European Transport Research Review, 2010.
Hybrid Model (Rule-Based Tree Model (RBTM), Multinomial Logit Model (MNL), and Naïve Bayesian Classifier (NBC))	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Moderate	Difficult	One	N/A	N/A; Statistical-based	<ul style="list-style-type: none"> Model is complicated 	Moderate	<ul style="list-style-type: none"> Development of a Hybrid Model for Freeway Incident Duration: A Case Study in Maryland, Kim, W. et al., 17th ITS World Congress, Busan, 2010.
K-Nearest-Neighbor (KNN)	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Moderate	Difficult	Two	Moderate validation efforts	N/A; Statistical-based	<ul style="list-style-type: none"> Tend to overestimate the prediction values for the short duration incident cases 	Moderate	<ul style="list-style-type: none"> A Comparative Study of Models for the Incident Duration Prediction, Valenti, G. et al., European Transport Research Review, 2010. Decision Support Tools to Support the Operations of Traffic Management Centers (TMC), Hadi, M. et al., January 2011.
Artificial Neural Network (ANN)	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Moderate	Difficult	One	Moderate validation efforts	N/A; Statistical-based	<ul style="list-style-type: none"> Tend to overestimate the prediction values for the short duration incident cases 	Moderate	<ul style="list-style-type: none"> A Comparative Study of Models for the Incident Duration Prediction, Valenti, G. et al., European Transport Research Review, 2010.



Table 2. TIM Review Matrix (continued)

Category	Application													Data Requirements	Ease of Use	Amount of Applications in Practice	Validation Efforts	Consistency with Traffic Flow Theory	Known Shortcomings	Qualitative Assessment of Validity of Results	Document Used/Reference		
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Predicting Incident Characteristics (e.g., Duration) (continued)																							
Bayesian Network	Y	Y	Y			Y		Y		Y	Y	Y	Y	Y	Moderate	Moderate	Two	Unknown	N/A; Statistical-based	<ul style="list-style-type: none"> It is site specific and hard to make generalization to other facilities 	Good	<ul style="list-style-type: none"> Structure Learning for the Estimation of Non-Parametric Incident Duration Prediction, Demirogluk, S. et al., Transportation Research Board 90th Annual Meeting. Traffic Incident Duration Prediction Based on the Bayesian Decision Tree Method, Yang, B. et al., The First International Symposium on Transportation and Development – Innovative Best Practices, 2008. 	
Quantifying Occurrence and Characteristics of Secondary Crashes																							
Regression Model								Y				Y	Y	Y	Y	Moderate	Moderate	One	The model was validated against 640 sample data set and the result showed that the methodology reduced Type I error by 24.38% and Type II by 3.13%	N/A; Statistical-based	<ul style="list-style-type: none"> Unknown 	Moderate	<ul style="list-style-type: none"> Dynamic Incident Progression Curve for Classifying Secondary Traffic Crashes, Journal of Transportation Engineering, December 2010.
Ordered Logit Model and Heckman Model	Y	Y	Y					Y	Y			Y	Y	Y	Y	Moderate	Moderate	One	N/A	N/A; Statistical-based	<ul style="list-style-type: none"> Model has limited goodness of fit due to the complexity and randomness of secondary incident occurrence 	Moderate	<ul style="list-style-type: none"> What Is the Role of Multiple Secondary Incidents in Traffic Operations, Zhang, H. et al., Journal of Transportation Engineering Volume: 136, 2010.



Table 2. TIM Review Matrix (continued)

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Quantifying Occurrence and Characteristics of Secondary Crashes (continued)																						
Simulation-Based Secondary Incident Filtering (SBSIF) Method	Y	Y	Y				Y	Y			Y	Y	Y	Y	Moderate	Difficult	One	Validated using 6-month data along a segment of I-287 in the New York State	N/A; Simulation-based	<ul style="list-style-type: none"> Model needs to be recalibrated for use for other locations Additional factors, such as weather, could be considered 	Moderate	<ul style="list-style-type: none"> Simulation-Based Secondary Incident Filtering Method, Chou, C. et al., Journal of Transportation Engineering Volume: 136, 2010.
Probit Model	Y	Y	Y		Y		Y	Y			Y	Y	Y	Y	Moderate	Moderate	Two	N/A	N/A; Statistical-based	<ul style="list-style-type: none"> Model has limited goodness of fit due to the complexity and randomness of secondary incident occurrence 	Moderate	<ul style="list-style-type: none"> Are Incident Durations and Secondary Incidents Interdependent, Khattak, A. et al., Transportation Research Record: Journal of the Transportation Research Board Issue Number: 2099, 2009. Primary and Secondary Incident Management: Predicting Durations in Real Time, Khattak, A. et al, Final Report VCTIR 11-R11, Virginal Center for Transportation Innovation and Research, April 2011.
Logistic Regression Model	Y	Y	Y		Y		Y	Y			Y	Y	Y	Y	Moderate	Moderate	Two	Unknown	N/A; Statistical-based	<ul style="list-style-type: none"> Unknown 	Moderate	<ul style="list-style-type: none"> Identifying Secondary Crashes and Their Contributing Factors, Zhan, C. et al., Transportation Research Record: Journal of the Transportation Research Board Issue Number: 2102, 2009 Decision Support Tools to Support the Operations of Traffic Management Centers (TMC), Hadi, M. et al., January 2011.
Bayesian Network	Y	Y	Y		Y		Y	Y			Y	Y	Y	Y	Moderate	Moderate	One	Moderate validation efforts	N/A; Statistical-based	<ul style="list-style-type: none"> Unknown 	Moderate	<ul style="list-style-type: none"> Freeway Operations, Spatiotemporal-Incident Characteristics and Secondary-Crash Occurrence, Vlahogianni, E. et al., Transportation Research Record: Journal of the Transportation Research Board Issue Number: 2178, 2010.

^a On-line.
^b Predict secondary incident occurrence.

- Notes
- A: Development and evaluation of TIM plans.
 - B: Analysis and valuation of TIM strategies such as use of service patrols.
 - C: Decision support systems (on-line/off-line).
 - D: Incident prediction and detection.
 - E: Incident duration prediction.
 - F: TIM Performance Measures.
 - G: Relationship between TIM and overall congestion/travel time reliability.
 - H: Benefit-cost analysis of TIM programs/strategies.
 - I: Safety analysis applications such as secondary crash analysis.
 - J: Real-time ATIS.
 - K: Integrated Corridor Management.
 - L: Most appropriate uses of the method (e.g., long-range planning, corridor planning, deployment planning, benefit/cost analysis).



INCIDENT DATA REQUIRED TO SUPPORT TIM AMS APPLICATIONS

TIM PERFORMANCE MEASURES

Monitoring trends in performance leads to sound investment in transportation strategies and policies. Performance programs have evolved over the years to include many types of performance measures that are used to manage incident programs. Recently, there has been a move to developing a few core measures that can be used as indicators of program performance for all transportation agencies, while recognizing that additional measures are needed at the agency level. In TIM, a national effort²² has produced three of these core measures:

- **Roadway clearance time** is the time between first recordable awareness of an incident (detection/notification/verification) by a responsible agency and first confirmation that all lanes are available for traffic flow.
- **Incident clearance time** is the time between the first recordable awareness and the time at which the last responder has left the scene.
- **Secondary crashes** are those that occur with the time of detection of the primary incident where a collision occurs either a) within the incident scene or b) within the queue, including the opposite direction, resulting from the original incident.

Additional TIM performance measures are of use to agencies beyond the core measures. Monitoring other parts of the incident “timeline” also can lead to identifying and correcting program deficiencies. Incident locations are used to identify hotspots. Identifying types of incidents (e.g., crashes, vehicle disablement, hazardous material release, large truck involvement) also produces actionable information.

DATA COLLECTION

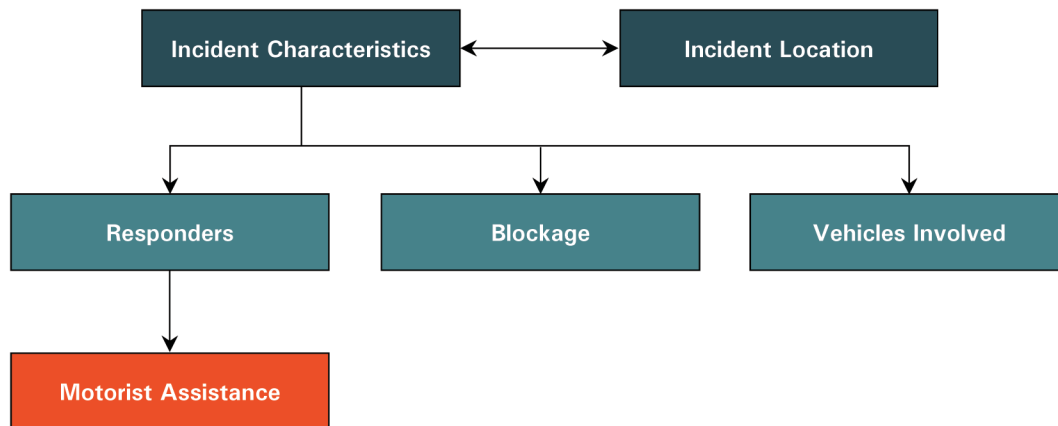
The incident data to support the development of performance measures are the same that are required to support TIM modeling applications and includes the types of data shown in Figure 5.

Incident Characteristics – This data type includes elements that describe the number, location, characteristics, and duration of incidents. The most important data elements for the research are:

- Incident type (crash, disabled vehicle, fire, debris, abandoned vehicle).
- Incident collision type (fixed object, overturn, vehicle/side, vehicle/head-on, vehicle/rear-end).
- Incident “timeline” data (time stamps for: start of incident, detection, verification, on-scene arrival, lane/shoulder open, all clear).
- Incident severity (KABCO injury scale).



Figure 5. Incident Data Model for Performance Monitoring



(Source: Cambridge Systematics, Inc.)

- Incident location (route, travel direction, milepost or GPS coordinates).
- Incident blockage.²³
 - » Cross section feature affected (lane, partial lane, right shoulder, left shoulder, median, off maintained way);
 - » Lane type (through/GP, through/HOV, auxiliary, on-ramp, off-ramp); and
 - » Begin/end time.
- Number of involved vehicles.

The duration of the blockages caused by incidents is the most important piece of information needed for research, but others also affect traffic flow conditions. Also, some incident data may be incomplete and the type of incident may be used as an indicator of the lane closure impacts (e.g., for data checking purposes).

Possible sources of data include the following:

- Service Patrol/Incident Response Team Data Entry – PDAs/laptops in the vehicles;
- Automated sensors (for detecting incident start times);
- Freeway service patrols (on-scene reporting);
- Law enforcement officer on-scene reports;
- TMC Operator Data Entry – Automate the conversion of web information to database entries; and
- Police Computer-Aided Dispatch (CAD) files.



Incident Activity Data – This data type relates to the nature of how incidents are managed by an agency. Having this type of data is not strictly necessary for doing incident modeling, as they are rarely used as direct input variables to modeling procedures. However, incident activity data can influence incident characteristics. For example, increasing the number of service patrols can reduce incident response and on-scene management times. Many past studies have established links between incident activities and incident characteristics; the Joint Program Office’s ITS benefits database has a compilation of these relationships: <http://www.itsbenefits.its.dot.gov/>.

Examples of the incident activity data include:

- Incident detection algorithms (used with traffic sensors);
- Method of incident notification to all responders (communication between agencies);
- CCTV coverage (percent of study segment capable of being viewed with CCTV);
- Degree of wireless communication for on-scene management;
- Service patrol vehicles per centerline mile by time period;
- Quick clearance laws or policies;
- Length of time abandoned vehicles are allowed to remain on a freeway shoulder (assuming they are not an imminent hazard);
- Laws or policies regarding the removal of stalled or abandoned vehicles from freeway shoulders;
- Policies and procedures to facilitate quick removal of heavily damaged vehicles and nonhazardous cargoes; and
- Procedures for removing crash victims from incident scene.

Other data inputs to models and analytic procedures – Table 3 lists some of the other data inputs needed to run the various scales of AMS procedures.



Table 3. Input Requirements of TIM AMS Procedures

Model Type	Network	Demands	TIM	Calibration
Sketch Planning Models	Minimal. Generally deals with regional VMT and VHT.	Minimal. Generally regional VMT.	General categories of TIM strategies. No specific implementation details.	Not applicable.
Deterministic (HCM Type Macroscopic) Models	Link and intersection-specific lane geometry, speed limits, controls (signal timing).	Link and intersection-specific hourly demands by vehicle type (usually just peak hour).	Incident types (number of lanes blocked, specific links affected, and average duration). Strategies to be tested and expected effects on average lane blockage durations.	Not generally done.
Mesoscopic Simulation Models	Same as deterministic HCM.	OD tables by hour of day for peak periods.	Same as for deterministic HCM.	Observed flows and link speeds.
Microscopic Simulation Models	Same as HCM plus signal detector locations, signal controller settings, turn pocket lengths.	Same as mesoscopic or link and intersection-specific demands by vehicle type.	Incident start/end times, longitudinal location within link. Expected effect of strategies on specific incident duration.	Observed flows and link speeds.

DEFAULT DATA FOR TIM AMS APPLICATIONS

In the absence of agency-specific data, data developed from other areas may be used for TIM AMS applications, especially for forecasting purposes. Some of these data represented below. SHRP 2 Project L08 is developing a larger library of these data.

A major caveat in the use of these data is that they were developed from areas where active incident management programs already exist. Thus, the incident duration data in particular may not be representative of a “before” case where active TIM does not exist.

For planning applications, it is often necessary to predict the number of future incidents. This can be done in a number of ways, including the following methods:



- Use of Incident Rates. If the analyst has the current incident rates (incidents per vehicle-miles of travel, VMT), either for a specific facility or as an areawide default, the number of incidents can be estimated simply by multiplying the incident rate by the forecasted VMT.
- If overall incident rates are not available, but a crash rate is, the crash rate can be factored up to total incident rates using agency-developed default values. If these default values are unavailable, the national default factors being developed by SHRP 2 Project L08 can be used. In the interim, a factor of 5.0 can be used, based on analysis of Atlanta data that showed crashes are roughly 20 percent of all incidents.
- If accident rates are not available, the analyst should use the procedures in the *Highway Safety Manual* to estimate the number of crashes, convert this to a crash rate, then factor up to a total incident rate.

Table 4. Lateral Locations of Incidents
Atlanta, Georgia

Incident Type	Frequency		Row Percent		Col Percent		Total
	1 Lane	2 Lanes	3+ Lanes	Off Roadway	Shoulder	Total	
Accident	2,566	1,451	1,052	41	712	5,822	
	44.07	24.92	18.07	0.70	12.23		
	28.32	69.19	84.77	21.47	4.39		
Stall	4,411	261	100	101	15,349	20,222	
	21.81	1.29	0.49	0.50	75.90		
	48.68	12.45	8.06	52.88	94.72		
Debris	2,047	382	87	47	85	2,648	
	77.30	14.43	3.29	1.77	3.21		
	22.59	18.22	7.01	24.61	0.52		
Roadkill	37	3	2	2	59	103	
	35.92	2.91	1.94	1.94	57.28		
	0.41	0.14	0.1	1.05	0.36		
Total	9,061	2,097	1,241	191	16,205	28,795	



Table 5. Incident Duration by Incident Type
Atlanta, Georgia

	Lateral Location	Frequency	Duration (Minutes)			
			Mean	Standard Deviation	Median	95 th Percentile
Accident	1 Lane	2,566	38.942	28.526	34.700	89.367
	2 Lanes	1,451	46.279	30.697	41.283	96.450
	3+ Lanes	1,052	66.718	56.219	56.233	149.767
	Off Roadway	41	14.377	20.580	4.267	71.817
	Shoulder	712	40.112	34.306	34.375	91.800
	TOTAL	5,822	46.287	38.129	40.033	106.067
Stall	1 Lane	4,411	29.055	31.382	24.100	72.083
	2 Lanes	261	40.650	44.884	33.917	109.883
	3+ Lanes	100	40.002	23.263	38.850	76.800
	Off Roadway	101	30.753	28.419	25.050	97.533
	Shoulder	15,349	41.506	29.356	35.483	96.300
	TOTAL	20,222	38.996	30.337	32.917	93.350
Debris	1 Lane	2,047	16.588	21.955	11.408	49.000
	2 Lanes	382	17.789	23.002	11.833	51.067
	3+ Lanes	87	45.448	62.059	22.833	183.633
	Off Roadway	47	5.027	4.091	2.717	10.567
	Shoulder	85	35.713	46.699	19.958	175.883
	TOTAL	2,648	18.797	27.375	11.833	61.433
Roadkill	1 Lane	37	47.064	57.934	32.650	226.883
	2 Lanes	3				
	3+ Lanes	2	2.325	1.473	2.325	3.367
	Off Roadway	2	20.650		20.650	20.650
	Shoulder	59	33.922	63.202	8.575	121.850
	TOTAL	103	36.292	60.359	13.858	135.317



FUTURE IMPROVEMENTS IN TIM AMS APPLICATIONS

Based on the current state of the practice, several areas are ripe for further development in Traffic Incident Analysis Modeling and Simulation (TIM AMS). We have developed the following problem statements that should be considered for further research.

Project statements that are based on the priority area topics identified in the practitioner survey include the following:

- Incident Data (Standards, collection procedures, coordination with transportation agencies, etc.) – *Covered in Topic 1;*
- Incident Performance Measures (metrics, presentation, formats/reporting) – *Covered in Topic 1;*
- Technical Methods for Predicting Incident Congestion Extent (delay, reliability) – *Topic 2 covers estimating incident delay and its contribution to total delay;*
- Technical Methods for Predicting Incident Duration – *Covered in Topic 3;* and
- Technical Methods for Predicting Incident Crashes – *Secondary Crashes covered in Topic 4.*

Additional Topics were identified based on a review of current practice and research.

TOPIC 1 – DATA MANAGEMENT/DATA DICTIONARY FOR ARCHIVING THE DATA NEEDED TO COMPUTE INCIDENT PERFORMANCE MEASURES

This effort would cover data collection and processing so that all agencies are calculating the same measures, ensuring that agencies could be compared meaningfully. One of the key items is the ability to track changes in a single incident over its duration – blockages and response characteristics can change – and capturing this allows more detailed analysis of strategies and more realistic estimates of delay to be modeled. This effort could be extended to cover other forms of disruptions, primarily work zones.

Purpose: The aim is to ensure a consistent process of data collection and archiving in order to enhance analysis and comparison of data across agencies.

Impact on practice: A consistent dictionary of terms and data collection procedures will significantly enhance and ease the level of effort involved in conducting analysis using incident-related data. Practitioners also will be able to communicate with each other more effectively as key words and terminology will mean the same across agencies.

Action: A series of reports modeled in a manner similar to the FHWA Traffic Analysis Toolbox to develop terminologies, criteria to be used in collecting data, and guidelines for archiving the data will be effective in setting up guidelines for archiving incident data.

How topic was developed: This topic was developed based on responses from the TIM survey. Agencies surveyed identified incident data standards, collection, and coordination as one of the top five priorities for which technical guidance would be helpful.



TOPIC 2 – LINKING INCIDENT MANAGEMENT STRATEGIES TO INCIDENT MODEL INPUTS

The ATDM/HCM project will lay out a conceptual framework for evaluating the traffic performance benefits of various incident management strategies, however; this work is based on very limited data to calibrate and validate the specific parameters and sensitivities included in the framework. Additional work is required to add additional strategies to the framework and to calibrate and validate the specific models in the framework. This type of information is valuable for all levels of modeling, including the new work under SHRP 2 L08, which is not carrying the analysis back to this level.

The need to understand how actions affect the inputs to the modeling process is heightened by the emergence of ATDM strategies. Some of these strategies are relatively new (e.g., lane control) while some have a longer history (e.g., ramp metering and incident management). These strategies are implemented dynamically and in combinations. Determining the conditions under which the strategies are triggered is key to modeling their effect. That is, having a “control plan” that replicates how operators will deploy ATDM strategies is required for effective modeling.

Purpose: To improve the confidence of the profession in the ATDM/HCM tools for evaluating TIM strategies and to increase the variety of TIM strategies that can be evaluated using the ATDM/HCM tools.

Impact on practice: This research will enable agencies to better understand the performance benefits of implementing various levels of TIM strategies and be able to make better decisions as to investments in TIM.

Action: This topic may take advantage of the SHRP 2 research database to obtain data on traffic performance during incident conditions. Developing data on more advanced TIM strategies, not in the SHRP 2 database may require field data collection, preferably as “before/after” studies.

How topic was developed: This topic was developed based on relevant information gathered from ongoing research on ATDM and travel time reliability (SHRP 2).

TOPIC 3 – REAL-TIME MANAGEMENT AND PREDICTION METHODS

The ability to forecast an incident impact immediately after an incident occurs, given its location and the state of the network, is crucial to advanced operational control strategies. This study will develop methods to predict short-term impacts of a range of incident scenarios and develop recommended mitigation strategies of each scenario. The combined forecasting and mitigation models should be designed so they can be integrated into operational incident management programs.

Purpose: The aim is to give operators of incident management programs and traffic management centers (TMC) tools they can use to improve their response to incidents.

Impact on practice: This project will help develop clear procedures that operators of incident programs can apply to effectively respond to incidents. It also will ensure a more consistent response pattern for day-to-day operations of TMCs.



Action: This project should be conducted in two phases. The first phase should be a state-of-the-practice study on how incident management programs currently are predicting impacts of incidents and the steps they take in responding to incidents. The second phase should use historical data to develop the models that forecast incident impacts and develop mitigation strategies. The models developed in Phase 2 should be tested in real-time scenarios at TMCs.

How topic was developed: This topic was developed based on responses from the TIM survey. Incident prediction and prediction of incident duration were the two top items for technical guidance identified by agencies participating in the TIM survey that wanted technical guidance.

TOPIC 4 – IDENTIFY KEY FACTORS THAT CAUSE SECONDARY CRASHES

This effort would define a standard methodology for identifying secondary crashes based on identifying the key mechanisms that would cause secondary crashes. These include queue location at the time of crash, rubbernecking in the vicinity of the crash for both directions, and crashes involving emergency vehicles on their way to manage the primary incident.

Purpose: This method would abandon crude assumptions of where and when a queue is present and use travel time and volume data to identify the queue empirically.

Impact on practice: The improved and more credible process of identifying secondary crashes will make it easier to conduct analysis on the impact of TIM programs on secondary crashes and also assess the impacts of secondary crashes (delay, queuing etc.).

Action: This will involve extensive historical or real-time data at crash sites with secondary crashes. The data collection should involve the factors that are likely to contribute to the secondary crashes, geometric location of the crash and secondary crash, queue length, flow of traffic in opposite direction of travel (rubbernecking), emergency vehicles are a few. Microsimulation modeling could be used to validate the models developed.

How topic was developed: Agencies participating in the TIM survey identified the need for improved technical methods for predicting secondary incident crashes.

TOPIC 5 – MODELING PROGRESSIVE LANE OPENING

It is very common for the lane blockage characteristics of an incident to change over the course of its duration. This can go both ways: responders may close additional lanes to facilitate clearance and involved vehicles may be moved. Recently, the idea of systematically opening lanes as clearance progresses, rather than waiting to open all lanes at once, has gained acceptance as a TIM practice. How this practice can be modeled remains an open question, and data on what are reasonable values for the duration of each successive-lane opening need to be developed.

Purpose: Develop improved approach to implementing progressing-lane opening strategies.



Impact on practice: Practitioners will have improved tools to assess the impacts of progressive-lane opening strategies and will be able to better assess the performance of such implementations and whether it is having the intended impact of improving traffic flow.

Action: Given that some agencies already are implementing the practice, an NCHRP Synthesis study is suggested to survey the agencies and find out their current practices and analysis methods. This could be followed up with a full NCHRP study.

How topic was developed: This topic was developed because the literature scan showed a few agencies have begun implementing progressive lane opening after incident response. A synthesis of current practice will be useful in assisting other agencies that may be interested in implementing this strategy.

TOPIC 6 – UPDATE OF HCM SECTIONS REGARDING INCIDENT MANAGEMENT AND CAPACITY LOSS

The data presented in the HCM on capacity loss is based only a few older studies and is not sensitive to any incident management strategies. These values are in need of updating with the improved traffic and incident data now available.

Purpose: Provide practitioners with more credible information and factors for conducting incident analysis.

Impact on practice: The updated values will ensure analyses conducted with the HCM are more acceptable to all stakeholders and analysts will be more confident about their results.

Action: Given the TRB Highway Capacity and Quality of Service Committee is responsible for the HCM it will be best to develop an NCHRP problem statement to conduct the study to update the factors in the HCM.

How topic was developed: This update is needed because the Highway Capacity Manual is a key resource and practice reference for all transportation professionals. Having the Manual address Incident Management will be critical in ensuring techniques and best practices are adopted by the professional transportation community.

TOPIC 7 – ESTIMATING INCIDENT DELAY AND ITS CONTRIBUTION TO TOTAL DELAY

Past studies attempting to do this are somewhat limited and need to be extended. In addition to a methodology that could be applied on a case-by-case basis, simple predictive equations could be developed that relate incident delay to traffic and basic incident characteristics.

Purpose: Improve the state of the practice in quantifying and analysis of incident impacts.

Impact on practice: Ability to better quantify delay impacts due to incidents will create an opportunity to develop more targeted and effective measures to address these delays.



Action: This will work well as an NCHRP research project. A key issue when modeling incident delay – as well as other nonrecurring causes of congestion – is how to account for recurring congestion. On facilities where a significant amount of recurring congestion occurs, the effect of incidents on total congestion is complex. If a lane-blocking incident occurs upstream of a bottleneck, the incident will meter flow into the bottleneck, reducing or eliminating the congestion it causes. In other words, the congestion cause has moved from the bottleneck to the incident location, i.e., “delay migration” has occurred. It is true that the incident-caused delay can be greater than the bottleneck-caused delay (depending on the number of lanes blocked), but accounting for the recurring delay that would have been there without the metering effect of the incident needs to be addressed.

How topic was developed: Agencies surveyed indicated incident prediction and duration were top on their list of topics for which they wanted additional technical guidance. This topic was developed to help analyze the impact of incident characteristics (location, severity, and duration) on delay.

TOPIC 8 – USE OF SIMULATION IN TABLETOP EXERCISES

This topic consists of customizing the user interfaces and analysis methods of one or more simulation models to facilitate their use by nonsimulation experts in the testing of TIM strategies in a tabletop exercise format.

Purpose: To provide operators with tools for self-training and development of cost-effective TIM strategies tailored to their agency’s capabilities, objectives, and the characteristics of the incidents on their facilities.

Impact on practice: This would result in a significant improvement in the day-to-day quality and effectiveness of agency responses to incidents. The agency also would have a greater depth of experienced personnel to place in charge of incident management. Agencies also would be able to use the tabletop exercises to explore various “what-if” scenarios.

Action: Candidate simulation tools that can be readily modified into a tabletop exercise format must be identified. Speed of operation, sensitivity to TIM strategies, adaptability to tabletop exercise, and ease of use by nonexperts would be primary considerations. One or more cooperative simulation model developers may be partnered with to develop and test the necessary user interface modifications to facilitate rapid execution by personnel more familiar with incident management than simulation. Finally, the resulting model(s) must be tested with operations personnel to verify their ease of use by nonexperts and their ability to accurately reflect real world results.

How topic was developed: This topic was developed based on the review of the example application of TIM AMS strategies. The review showed that due to limited tools for incident analysis, most studies involve postprocessing data from a combination of simulation tools, travel demand models, and sketch planning programs (HERS/IDAS). Developing customized user interfaces and postprocessors will make it easier for nonexperts of the tools to understand TIM applications.



TOPIC 9 – FRAMEWORK DEVELOPMENT FOR TIM PROGRAM EVALUATION

Framework development for TIM program evaluation is necessary to assist operating agencies in correctly identifying and quantifying the costs and benefits of TIM programs. A structured framework also will ensure more consistent information reporting which will enable more collaboration and knowledge exchange and sharing between agencies.

Purpose: To identify the inputs required and appropriate tools and analytical procedures for accurately evaluating the costs and benefits of TIM programs.

Impact on practice: The accurate assessment of TIM costs and benefits will support the development and implementation of cost-effective TIM programs.

Action: The primary and secondary benefits and costs of TIM and the variables affecting them must be identified. An economic, traffic operations, safety, and environmental assessment framework must then be developed.

How topic was developed: This topic was developed based on responses from the survey.

TOPIC 10 – EXPAND BENEFIT/COST ANALYSIS TO INCLUDE SECONDARY IMPACTS

This topic is an extension of the analysis framework discussed under the Topic 9. This topic expands primary B/C analysis to include secondary impacts of TIM programs, particularly the reduction in secondary crashes that can be a significant benefit of good TIM programs.

Purpose: To identify and quantify the secondary impacts of TIM programs for use in benefit/cost analyses.

Impact on practice: Significantly improved assessment of the benefits of TIM programs, and improved decision-making regarding investments in TIM programs by considering a full range of expected impacts is expected.

Action: The research would involve gathering data on the effects of TIM on secondary crashes, travel behavior, lost productivity, environment (emissions), insurance costs, etc. Data gathering would cover much longer periods to capture the likelihood of secondary accident occurrence. Models relating TIM strategies to secondary effects would be developed. A primer on the assessment of primary and secondary effects of TIM (such as the AASHTO Red Book – *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements*) would be produced to guide agencies in the benefit/cost assessment of TIM.

How topic was developed: This topic was developed because the TIM survey identified the need for improved technical methods for predicting secondary incidents and crashes. A more structured process is needed to include the secondary incidents in benefit/cost analysis.



TOPIC 11 – RESOURCE OPTIMIZATION FOR TIM PLANS

Incidents are, to an extent, random in nature. Planning to respond to them involves an element of estimating the number of incidents that will occur, where they will occur, the type of incident, and the level of severity. Agencies will deploy and position response teams based on estimates of these variables (probably from historical information) and the amount of resources (personnel, vehicles, tow trucks, etc.) they have. The TIM objectives will largely determine the incident response team, subject to the agency budget constraints. For example, the number of required patrol units at a given freeway section can be determined by the desired response time. Even in the case where there are adequate budgets, the process of determining the optimal location to position resources in order to respond effectively is not trivial.

Purpose: To develop procedures, analytical tools, and best practices that agencies rely on to plan, deploy, and coordinate their traffic incident management teams so they can respond effectively and clear the highest number of incidents with the minimal amount of resources.

Impact on practice: A well-developed planning tool and a guidebook with best practices will significantly ease the burden and reduce the level of guesswork smaller agencies and those with limited budgets face in running TIM programs.

Action: A guidebook should be developed that includes an optimization tool and synthesis of best practice from agencies that have effective TIM programs.

The theoretical research needed to solve analytical resource allocation problems already exists in various branches of transportation literature and fields like industrial systems engineering. What is needed is the translation of the problem: the resources (service patrol staff and equipment, law enforcement agencies, first responders, etc.), constraints (limited budgets, area to be patrolled, communication staff) into an optimization system. The resource allocation tool developed should be developed in standard off-the-shelf commercial software like Microsoft Excel. A user interface should be included to make it easy to use, including GIS and mapping software to facilitate deployment.

The best practice guidelines should cover practices at agencies in large metropolitan areas, suburbs, and rural areas to make the content useful to the diverse set of agencies that might use it.

How topic was developed: This topic was based on some of the challenges identified during the development of the report. We found agencies are still struggling with basic problems like the most optimal location for dispatching a freeway service patrol truck, or whether to have the truck drive up and down a corridor or position it. Such problems have already been solved in several areas and a guidebook will bring the solutions together in one place for managers of TIM programs.



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1200 New Jersey Ave, SE
Washington, DC 20590

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