***AN APPLICATION OF ITS FOR INCIDENT MANAGEMENT***

***IN SECOND-TIER CITIES***

Shawn Birst
Ayman Smadi

Upper Great Plains Transportation Institute
North Dakota State University
Fargo, North Dakota

August 1999

## Acknowledgments

The authors would like to thank the many individuals from various agencies who have provided valuable information for this study, including Rick Lane and Richard Sutter (City of Fargo); Cindy Gray and Brian Shorten (Fargo-Moorhead Metropolitan Council of Governments); Mark Berg, Kevin Gorder, and Bruce Nord (North Dakota Department of Transportation); Ed Gritchella (North Dakota Highway Patrol); Dennis Walaker (Fargo Street Department); Dave Rogness and Maureen Nelson (Fargo Police Department); John Gordon (Fargodome); and Rick Hessinger (North Dakota State Radio). Thanks also is extended to Dr. Michel Van Aerde, the developer of INTEGRATION, for assisting the authors during the simulation analysis.

# ABSTRACT

Congestion on urban freeways, which adversely affects the economy, environment, and quality of life, continues to be a major problem in the United States. Minor incidents, such as minor traffic accidents, stalled vehicles, and special events, account for the majority of urban freeway congestion. Due to the problems associated with freeway incidents, many large metropolitan areas have implemented Incident Management Systems (IMS) to alleviate congestion and safety problems associated with incidents. These systems provide motorists with timely and accurate information to avoid incident locations. These systems have been implemented mainly in large urban areas; however, little is known about the possible benefits in smaller urban areas (second-tier cities).

This study examined the feasibility of implementing IMS in small/medium size urban areas. It used a case study of the I-29 corridor in Fargo, ND. The INTEGRATION simulation model was used to estimate the potential benefits of an IMS which employs Advanced Traveler Information Systems (ATIS) and Advanced Traffic Management Systems (ATMS). The case study analysis revealed that the combination of ATIS and ATMS provided the most favorable network benefits under a 20-minute incident. The IMS reduced incident travel times by 12 percent (city arterials), 26 percent (freeways), and 16 percent (overall network); average trip times were reduced by 16 percent (overall network); and average speeds increased by 19 percent (overall network). Therefore, using ITS in IMS can potentially alleviate incident conditions in small/medium size urban areas.

## TABLE OF CONTENTS

## LIST OF TABLES



## LIST OF FIGURES

# CHAPTER 1. INTRODUCTION

The purpose of this study is to examine the benefits of using Intelligent Transportation Systems (ITS) for incident management in second-tier cities. ITS incorporates existing and emerging technologies in areas including telecommunications, computer sensing, and electronics that provide real-time transportation information (U.S. Department of Transportation, 1997b). These ITS technologies provide information to manage transportation, resulting in increased efficiency and safety of the surface transportation system and dramatically improving the travel options and experiences of the motorists (ITS, 1998).

Incident management is a coordinated and planned program that controls, guides, and warns the motorists of traffic problems in order to optimize the safe and efficient movement of people and goods (U.S. Department of Transportation, 1998). Incident management programs address congestion problems caused by incidents on either freeways or city arterials, and attempt to restore traffic to normal operation as quickly as possible.

## Background

Traffic congestion on urban freeways continues to be a major problem in the United States, which has negative impacts on the economy, the environment, and quality of life. Although freeways account for less than three percent of the total roadway mileage in the United States, they provide 31 percent of the total vehicle-miles of travel in the nation (Lindley, 1987). In 1992, the Texas Transportation Institute (TTI) estimated that the 50 largest urbanized areas in the United States lost over $48 billion due to congestion, a 9 percent increase from 1991. About 89 percent of the $48 billion was attributed to delay time, while the remaining 11 percent consisted of wasted fuel (U.S. Department of Transportation, 1997a). In 1975, nearly 40 percent of the peak hour traffic occurring on urban interstate flowed at an average speed of less than 35 mph. By 1990, that percentage had risen to nearly 70 percent (Cragg and Demetsky, 1995). This increase has the following negative implications:

- Lost productivity and less personal time with family, hobbies, etc.
- Increased pollution levels and wasted fuel consumption from slower vehicles and stop-and-go conditions.
- Safety issues related to increases in crashes due to driver frustration, aggressive driving, risky maneuvers, etc.

Traffic congestion, which occurs on the transportation system, may be divided into two main categories: recurring and nonrecurring. Recurring congestion occurs on a roadway when the number of vehicles during a certain time period is greater than the capacity. The delay experienced from recurring congestion occurs on a daily basis in many urban cities across the nation during peak hour periods. Traffic engineers attempt to reduce recurring congestion by adding capacity and/or employing traffic management measures, such as ramp metering, optimized signal timings, reversible lanes, and high occupancy vehicle (HOV) lanes.

Nonrecurring congestion, on the other hand, occurs from a temporary surge in demand, a reduction in roadway capacity, or a combination of two. Nonrecurring congestion can be described as unpredicted delays caused by incidents including traffic accidents, stalled vehicles, material spills, construction and maintenance, special events, and adverse weather conditions. Incident or nonrecurring congestion accounts for nearly

60 percent of all traffic congestion in the United States (Cambridge Systematics, 1990). The Federal Highway Administration (FHWA) estimates that, by 2005, congestion caused by incidents will comprise 70 percent of all urban freeway congestion, costing road users approximately $35 billion annually (Mannering, Hallenbeck, and Koehne, 1992).

Major incidents, such as major traffic accidents or hazardous material spills, can cause severe disruptions in the flow of traffic; however, minor incidents, including stalled vehicles, are responsible for the majority of the total delay caused by incidents. One study, conducted by the FHWA, stated that minor incidents accounted for 65 percent of the total delay caused by incidents, while the remaining 35 percent consisted of major incidents (Reiss and Dunn, 1991). A second study sponsored by the Trucking Research Institute determined that 80 percent of urban freeway congestion is caused by vehicle disablements, which include stalled vehicles, flat tires, cars that ran out of gas, etc. (Cambridge Systematics, 1990).

Driver safety is also an important issue when dealing with nonrecurring congestion. In addition to the individuals directly involved in the incident, emergency/medical personnel and other drivers are also at risk. Twenty percent of all crashes occur upstream from an incident (Walters, 1999).

## Research Objectives

The objective of this study is to examine the benefits of using ITS technologies for incident management in second-tier cities (populations ranging from 50,000-400,000). Intelligent Transportation Systems (ITS) have the potential to improve the performance of an existing transportation system by allowing the current transportation infrastructure to be more efficient, effective, and safer, in addition to preventing increased land-use and environmental pollution (Maas, 1998).

The case study analysis will compare key Measures of Effectiveness (MOE) values between the base cases (current conditions and policies) and ITS enhanced cases. The study will implement ITS components to portions of Fargo's I-29 and I-94 to reduce the traffic congestion that occurs from an incident occurrence. Two main elements of ITS will be implemented into the case study corridor: Advanced Traveler Information Systems (ATIS) and Advanced Traffic Management Systems (ATMS). These two components provide real-time traveler information regarding the incident, such as approximate delay time, possible alternative routes to utilize, and real-time traffic management strategies along the alternative routes, such as signal optimization, to accommodate the additional flow from the freeway.

## Proposed Methodology

This study will utilize the INTEGRATION simulation model which was developed by Dr. M. Van Aerde. INTEGRATION is an analytical tool that analyzes and simulates both freeway and arterial networks. The model computes statistical output (MOE) that provides insight on the performance of a particular design strategy and allows multiple strategies to be compared to determine the optimal strategy. This study will focus on the MOEs that are related to congestion, such as average total travel time (seconds per vehicle), average trip time (seconds per vehicle), and average fuel consumption (gallons).

The case study analysis will compare the effectiveness of six different scenarios. The first two scenarios consist of base cases (existing conditions). The first base case employs the current geometric design, traffic management strategies, and traffic volumes under incident-free conditions. The second base case differs from the first base case by implementing a freeway incident, thus, is referred to as the incident base case. The remaining four scenarios will implement various levels of ITS deployment, pertaining to traveler information and traffic management technologies.

## Organization

Chapter 2 of this study describes traffic flow dynamics, a description of incident management systems and components of such systems, the possible ITS components of incident management, and the benefits of existing incident management systems. Chapter 3 discusses the types and uses of traffic simulation models, describes several case studies that have used traffic simulation to evaluate incident management ITS deployment in large metropolitan areas, and addresses the literature gap of evaluating ITS for incident management in smaller metropolitan areas (second-tier cities). Chapter 4 provides a discussion and illustration of the methodology of this study. Chapter 4 also describes the evaluation tool (INTEGRATION), the data requirements for INTEGRATION, and a description of the validation plan. Chapter 5 describes the case study corridor, the current incident management practices of the metropolitan area, and the evaluation scenarios. Chapter 5 also reports the case study results and validation of the results. Chapter 6 provides a summary of the findings, addresses some the problems/limitations of conducting the simulation analysis, and provides some suggestions on implementing incident management systems in second-tier cities.

# CHAPTER 2. INCIDENT MANAGEMENT

This chapter briefly describes the traffic flow dynamics associated with incident occurrences. Then, it provides an overview of incident management, including the need, the major components, and possible uses of ITS technologies in incident management systems. This chapter also discusses some benefits of existing incident management systems.

## Traffic Flow Dynamics

It is important to understand the characteristics of traffic flow before, during, and after an incident has occurred on a roadway (Figure 2-1). The traffic flow prior to an incident can be described as the demand flow. The demand flow consists of the traffic volume that is normally present on the roadway at a given time. After an incident has occurred on the roadway, the traffic flow, now referred to as incident flow, is significantly decreased because of physical reductions (lane blockages) and the effects of rubbernecking, which is a term describing drivers passing the incident and slowing down to observe the incident scene. The reduction in traffic flow results in added delay and increased travel times. The amount of delay that results from the incident depends on the duration of the incident and the timeliness of its detection, response, clearance, and recovery to normal flow. The amount of delay experienced during an incident is shown in Figure 2-1 and is normally expressed in vehicle-hours.

After the traffic passes the incident, motorists attempt to regain some of the lost time and tend to increase their speed. This increase in speed causes an increase in traffic

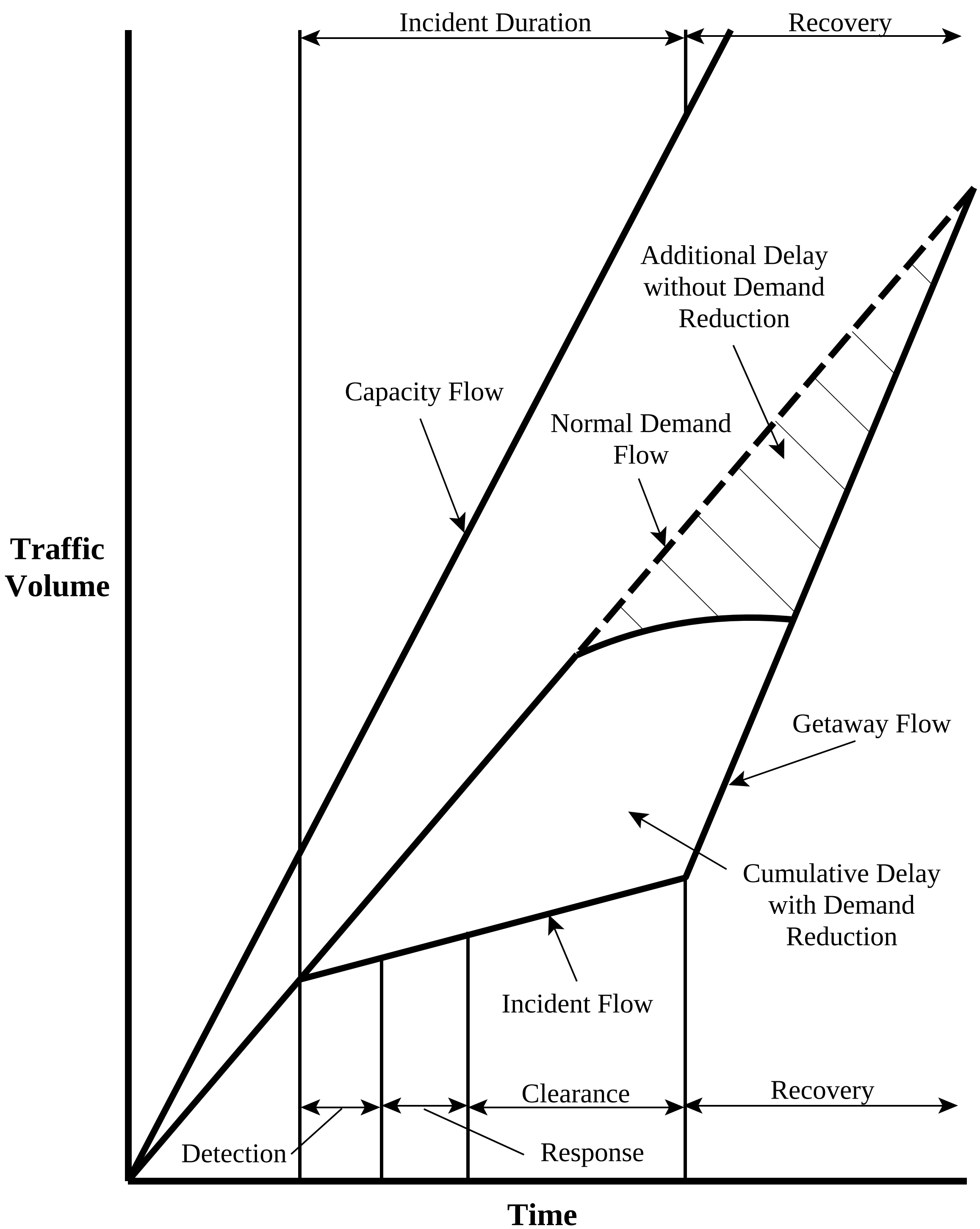


Figure 2-1. Traffic flow dynamics during an incident (Cambridge Systematics, Inc., 1990).

flow levels, commonly referred to as getaway flow. Finally, after the recovery period is over, traffic will resume to its original demand flow.

The intent of an IMS is to reduce the negative effects caused by an incident occurrence. Incident management systems attempt to reduce the detection, response, and clearance times of incident duration, thereby reducing the delay time experienced by motorists passing through the incident location. Incident management will also provide traveler information to warn motorists that an incident is ahead and to take an alternative route if one is available. The diverted traffic will reduce the demand on the road segment where the incident occurred, causing less delay to the motorist on this segment.

## Incident Management

Incident management is a coordinated and planned program that controls, guides, and warns the motorists of traffic problems in order to optimize the safe and efficient movement of people and goods. Incident management involves the cooperation of multiple agencies, such as government officials, police, highway patrol, fire and rescue, emergency medical services, hazardous material crews, and towing services, to facilitate nonrecurring congestion problems on freeway systems (U.S. Department of Transportation, 1998).

### *Incident Management Components*

Incident management can be described as an array of activities that take place during four main stages: detection, response, clearing, and recovery (Reiss and Dunn, 1991). The main elements of incident management include the following:

- Incident detection
- Incident verification
- Response selection
- Incident removal
- Traffic management
- Traveler information

Each of these elements, individually and collectively, impacts the efficiency and success of the IMS. Detailed, well-organized management systems or plans have proven beneficial in communities that implement them by reducing delay and creating more predictable travel times (Fink, 1993).

*Incident Detection*

The early detection of incidents is very important to the effectiveness of an IMS. Typically, major incidents are detected within 5-15 minutes of the occurrence. On the other hand, minor traffic accidents, which comprise of a majority of the total traffic incidents, may go undetected for up to 30 minutes (Grenzeback and Woods, 1992). During off-peak traffic conditions, each minute that a lane is blocked due to an incident causes four-to-five minutes of additional travel delay. During peak hour traffic, the additional delay created by an incident is much greater. One report stated that when traffic flow is near capacity, an incident that causes a 40 percent reduction in capacity will create a backup of traffic at a rate of 8.5 miles per hour. Therefore, by the time even a minor accident is removed from the freeway, a traffic backup of 6.5 to 8.5 miles can occur (Judycki and Robinson, 1992).

The decrease in capacity caused by an incident is mainly attributed to lane blockages, however, rubbernecking can lead to further congestion and delays (Cambridge Systematics, 1990). For example, if one lane of a three-lane freeway is blocked, the reduction in capacity should only be 33 percent. However, a study conducted on the Gulf Freeway in Houston, TX, determined that a stalled vehicle and a non-jury accident, which both blocked one lane of a three-lane freeway, would reduce the capacity of the roadway by 48 percent and 51 percent, respectively, as shown in Table 2-1 (Reiss and Dunn, 1991). Therefore, rubbernecking can significantly contribute to the capacity reduction caused by an incident and reinforces the need for early detection of an incident.

Table 2-1. Effects of Incidents on Traffic Flow on a Three-Lane (1 Direction) Freeway.

| CONDITION | # OF LANES BLOCKED | VOLUME REDUCTION (%) |
|---|---|---|
| Stall | 1 | 48 |
| Non-injury Accident | 1 | 51 |
| Accident | 2 | 79 |
| Accident on Shoulder | -- | 28 |

Source: Reiss and Dunn. *Freeway Incident Handbook*, FHWA-SA-91-056, July 1991.

Incidents may be detected using a variety of methods including reports by motorists using communication means (emergency call boxes, cellular phones, citizen-band (CB) radios, etc.), automatic vehicle detectors (loop detectors, video-image detectors, closed-circuit television, etc.), or patrolling units (law enforcement, service patrols, etc.).

Motorists' calls to report incidents to either law enforcement agencies or traffic operation centers (TOC) usually precede other detection methods (Fink, 1993). The high growth in cellular phone use has provided an excellent source of incident detection. In fact, a study conducted in Hayward, CA, reported that cellular phones provide the highest incident detection rate of any detection source (Skabardonis, Chavala, and Rydzewski, 1998). Some incident management programs provide travelers with free cellular numbers to report incidents that they encounter on the freeway.

Automatic vehicle detectors have also been implemented and have proven to be successful at detecting slow downs in traffic (i.e., due to an incident). These technologies include inductive loop detectors and video-image detectors (VID). Loop detectors consist of wires that are embedded into the road surface and sense vehicle presence, speed, gap, etc. Video-imaging detectors consist of video cameras overlooking the roadways that utilize predetermined vehicle detection zones for a camera's view. These systems are becoming more popular since they do not involve damaging the road surface during installation, and they are fairly easy to install. Both the loop detectors and VIDs are connected to computers that analyze real-time traffic volumes to detect sudden changes in flow between observed stations.

Closed circuit television (CCTV) can be used at TOCs to detect and verify traffic incidents. Operators at the TOC can monitor several camera images at a time from cameras that have been strategically placed throughout the freeway system.

The last method used for incident detection utilizes patrolling units. These units are comprised of vehicles that drive the road network in search of traffic incidents and other traffic problems. One example of a patrolling unit is the state highway patrol. Highway patrol officers can detect and report incident functions. Service patrols, such as towing services and dedicated roving units, also provide incident detection. Service patrols have been referred to as the most effective component of an incident management system for reducing incident detection time and incident duration (Wei, Hsu, and Leung, 1995). Over

50 service patrols have been implemented in the largest urban areas of the U.S. to aid in incident management programs (Fenno and Ogden, 1998).

### *Incident Verification*

After an incident has been detected and reported, it must be verified before formulating a response. This confirmation is necessary because some reports may not be true or may not be severe enough to justify a response. Verification can be made by CCTV and patrolling units. Specific and accurate reports are important for the selection of the appropriate response strategy.

### *Response Selection*

Response can be defined as “the activation, coordination, and management of the appropriate personnel, equipment, communication links, and motorist information” (Reiss and Dunn, 1991, p. 9). The time needed to formulate a response of an incident is very important for the recovery of the traffic flow to its original state. Studies have shown that even if an incident blocks just one lane of traffic, a two minute decrease in response time can cause a savings of over 400 vehicle-hours of delay (Dudek, 1987).

Depending on the severity of the incident, various responses may be implemented. Minor incidents, such as flat tires, loss of vehicle fluids, and fender benders, can be dealt with by service patrols or by law enforcement agencies who contact the appropriate service requesting assistance at the site of the incident.

On the other hand, major traffic incidents require the coordination of several agencies for an effective response. Therefore, it is essential to have preplanned protocols and procedures for specific types and severities of incidents. Each agency involved in the management team must be aware of its responsibility and role in each situation. Typical agencies that may be involved in major traffic incidents include the following:

- Department of Transportation
- Law Enforcement Agencies
- Fire Departments
- Emergency Medical Services
- Towing Services

If severe incidents occur (i.e., hazardous material spills), additional agencies, such as the Environmental Protection Agency (EPA) and hazardous material control teams, will need to be involved in the response process (Fink, 1993). All organizations that are involved with major and severe incidents must meet regularly to develop an understanding of each member's role and responsibility, and to coordinate the necessary activities to produce the quickest and most effective response to a given situation. A report conducted by the Federal Emergency Management Agency (FEMA) determined that, generally, the problems occurring with incident removal involve poor coordination and confusion between different agencies, not the lack of technology or resources (McDade, 1992).

*Incident Removal*

The removal process involves the safe and timely handling of the incident, which restores the traffic flow to its normal conditions (Judycki and Robinson, 1992). This operation may include tow truck operations, the removal of wreckage, the cleanup of material spills and debris, rerouting of traffic, etc. The removal process should implement the preplanned procedures of the response selection. As stated earlier, it is essential that effective communication and cooperation are conducted prior to and during an incident occurrence. This practice will also determine the authoritative responsibilities during the removal process.

Another factor in expediting the removal of an incident is driver cooperation in promptly moving their vehicles off the road after being involved in an incident. Roadways are often blocked after incidents occur because drivers feel they should not move their vehicles until law enforcement arrives.

*Traffic Management*

Traffic management is the process of implementing traffic control measures at or near incident locations. Roadway capacity can be increased by allowing traffic to use the road shoulder as a lane; adjusting upstream ramp meter timings or closing them down; or diverting the traffic before it is allowed to approach the incident site. Diversion schemes are often an effective method to move traffic past an incident and should be a preplanned part of the incident management plan. Different scenarios on each road section should be evaluated to achieve the possible or recommended alternative routes for traffic diversions. Steps must be taken on the alternative routes, such as changing the signal timing plans to allow the effective passage of diverted traffic. If these additional steps are not taken, freeway congestion and delay will be passed onto another route and will not benefit the traffic network as a whole.

Information regarding the diversion schemes must be presented to the motorists entering the incident location. The information should in a format that is easily understood and provides them with ample time to decide how they will use the information, such as diverting to alternative routes or maintaining on their current path.

*Traveler Information*

A major element of an incident management program is to inform the motorists that an incident has occurred. Motorists' response to the provided traffic information is crucial for successfully diverting traffic. Therefore, correct and timely information is needed to give the motorists adequate time to choose an alternative route (if one is provided) or to plan for additional travel time on their current travel path. Studies have shown that motorists are likely to have a greater tolerance for delay when they are kept informed of the current traffic situation (Reiss and Dunn, 1991). Studies have shown that a significant number of incidents occur as a result of previous incidents. Therefore, it is important to provide quick and accurate information to the motorists to limit the amount of secondary accidents. There are several methods or techniques for providing information to motorists including electronic signs, highway advisory radio, commercial radio, citizen-band (CB) radio, television and Internet, print media, and cellular phones.

An effort should be made to use as many methods to inform the motorists as possible. This task is important because not every motorist has access to a CB radio, a cellular phone, the Internet, etc. When using electronic signs and highway advisory radios, it is important to provide information that allows motorists adequate time to react to the changing road conditions. It is also importation to provide updated and accurate traveler information to the motorists. If motorists encounter a situation when traveler information is wrong, they may be less responsive or receptive to the provided traveler information.

## Using ITS in Incident Management Systems

ITS technologies were developed to increase the efficiency and safety of the transportation system. Several ITS components are available for implementation, however, incident management systems primarily deal with two components: Advanced Traffic Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS).

### *Advanced Traffic Management Systems*

The ultimate goal of ATMS is to provide real-time traffic control strategies that are capable of adjusting to the existing traffic demands through surveillance technologies, data processing, and communications (U.S. Department of Transportation, 1998). ATMS can detect an incident occurrence on the freeway through detection technology, such as inductive loop detectors, or VID. Based on the incidents' characteristics, data processing will aid in the response selection. The incident response may include diverting upstream traffic away from the incident location to reduce the traffic congestion caused by the incident occurrence. Therefore, communication means, which are utilized by ATIS, can provide traveler information to the motorists so that they can adjust their travel route. To accommodate the additional traffic flow from the diversion strategies, ATMS traffic control capabilities will provide optimal signal timing plans that reflect the current traffic flow.

### *Advanced Traveler Information Systems*

ATIS collects and distributes real-time traffic information for both "pre-trip" and "en-route" travelers (USDOT, 1998). Several forms of communication technologies can be used including variable message signs (VMS), highway advisory radios (HAR), local radio and television broadcasts, websites, and kiosks. ATIS provides current and near future traffic conditions, which allow the motorists to change their plans or routes to optimize their travel times.

## Benefits of Incident Management Systems

Incident Management Systems have proven to be effective in reducing travel time, secondary accidents, and environmental impacts, while increasing speeds and capacity during an incident. According to the Institute of Transportation Engineers (ITE), incident management programs have reduced travel time by 10-41 percent during congested conditions (Meyer, 1989). Successfully implemented and operated incident management programs in metropolitan areas have shown to be cost effective. Cost savings typically consist of reductions in travel time, fuel consumption, and secondary accidents. Some examples of IMS that have experienced positive benefit/cost ratios include the following (Mitretek Systems and PB Farradyne, Inc., 1998; Fink, 1993):

- Minneapolis, MN, Highway Helper Program — 4.8:1
- Maryland, Chesapeake Highway Advisories Touting Traffic — 7:1
- Charlotte, NC, Motorist Assistance Patrol — 7.6:1
- California Department of Transportation (Los Angeles) — 15:1
- Illinois Department of Transportation — 17:1
- New York, NY, service patrols — 35:1
- Houston, TX, Motorist Assistance Programs — 7-36:1

Several intangible benefits are also demonstrated by IMS, including reduced driver frustration and driver inconvenience, improved safety to the motorists and emergency response personnel, improved inter-jurisdictional relationships, and better public relations.

# CHAPTER 3. SIMULATION EVALUATION OF ITS APPLICATIONS

This chapter provides a background of traffic simulation models and how such programs can be used in developing incident management systems. This chapter also discusses several case studies that have used simulation models for incident management in large metropolitan areas. Finally, the literature gap regarding incident management in second-tier cities will be discussed.

## Traffic Simulation Models

Since their first development in the 1950s, traffic simulation models have greatly increased in number and capability. These models may be capable of analyzing arterial networks, freeway networks, or both. Simulation models can be classified into three main categories: macroscopic, microscopic, and mesoscopic.

Macroscopic models treat traffic flow as one continuous composition where the average traffic characteristics (i.e., flow, speed, and density) are calculated for the given traffic volume. Therefore, macroscopic models do not provide detailed information for individual vehicles. Microscopic models, on the other hand, provide detailed information about individual movements and interactions. Each vehicle's position, acceleration, speed, number of stops, lane changing maneuvers, etc. are assigned stochastically. The stochastic nature of microscopic models provides a more realistic simulation. Due to the individual vehicle-tracking nature of microscopic models, they require significantly more computing power than macroscopic models. The third category of traffic simulation, mesoscopic models, incorporates concepts from both macroscopic and microscopic simulation models.

These  models "simulate individual vehicles based on macroscopic flow relationships, and include dynamic traffic assignment (DTA) capabilities" (Skabardonis and May, 1997, p. 3).

Simulation models, primarily those capable of analyzing both arterial and freeway networks, provide effective tools for analyzing the performance of existing and proposed corridors.  These models offer great flexibility for evaluating various infrastructure and operational alternatives under different conditions — all without altering existing facilities or disrupting traffic.

## Freeway Corridor Simulation Applications

Numerous freeway corridor applications have been performed across the nation to examine freeway operations.  This section focuses primarily on application related to freeway incident management.  These applications allow the analysis of many responses and strategies for various incident severities and at different locations throughout the freeway corridor.  The simulation analysis can also be used to develop effective protocols for operating traffic management and traveler information systems.  The following sections discuss five simulation applications on freeway corridors found to be most relevant to this research.

### *Santa Monica, CA*

This study examined the potential benefits of Intelligent Vehicle Highway Systems (IVHS) on the Santa Monica Freeway (I-10) corridor and was conducted by Gardes and May in 1993.  The evaluation consisted of simulating traffic under normal conditions and during an incident with various ATIS and ATMS strategies during the morning peak hour.

ATIS and ATMS strategies included various combinations of freeway ramp metering, traffic signal optimization, and route guidance systems. The analysis utilized INTEGRATION, a microscopic simulation model, to perform the traffic simulation on the I-10 corridor.

The study investigated the effects of implementing various ATIS and ATMS strategies under recurring congestion conditions and incident conditions. A base case (without incidents, ATIS, or ATMS) was established to act as a baseline for comparing the effectiveness of different ATIS and ATMS strategies along the corridor. Six modeling cases were analyzed under recurring congestion conditions utilizing the same network configuration and traffic demand, but changing the types and level of ATIS and ATMS deployment, including

1. Base conditions (without ATMS or ATIS);
2. Ramp metering;
3. Real-time traffic signal optimization;
4. Combined ramp metering and signal optimization;
5. Route guidance; and
6. Combined ramp metering, signal optimization, and route guidance.

The sixth strategy (the combination of ramp metering, traffic signal optimization, and route guidance) resulted in the best overall network performance. The improvements under this strategy included increasing the average network speed by 6.3 percent and increasing the average freeway speed by 11.6 percent (Gardes and May, 1993).

For the incident congestion conditions, an incident was simulated in both directions of the freeway. Each incident occurred between 7:00 A.M. and 7:30 A.M. and blocked two lanes of traffic. The analysis used the previous six strategies, in addition to a seventh strategy which combines signal optimization and route guidance systems. This seventh strategy was added because of problems encountered with optimizing ramp metering plans during an incident.

After analyzing the seven control strategies, the combination of signal optimization and route guidance (Strategy 7) provided the best system performance for the corridor. When compared to not implementing ATIS or ATMS under incident conditions, the average speed for freeway links increased by 15.3 percent and the average speed for arterial links increased by 10.1 percent with the implementation of Strategy 7 (Gardes and May, 1993). The ITS technologies optimized the corridor to such an extent that the travel time for the corridor using Strategy 7 was actually lower than Strategy 1 without an incident occurrence.

***Houston, TX***

A study conducted by the Texas Transportation Institute (TTI) analyzed the Southwest Freeway (US-59) corridor in Houston, TX, using CORFLO. The CORFLO program consists of three submodels: FREFLO, a macroscopic freeway simulation model; NETFLO, a macroscopic arterial street simulation model; and TRAFFIC, an equilibrium traffic assignment model. The purpose of the study was to evaluate traffic management alternatives, such as the location, time period, and the quantity of traffic that should be diverted away from an incident by means of traffic simulation (Lee and Krammes, 1994).

The analysis was conducted in two stages. The first stage consisted of a small network comprised of US-59, two frontage roads, and five cross streets. The site of the small network was part of the second stage of the US-59 Southwest Freeway corridor network. The second stage, commonly referred to as the large network, consisted of a

12-mile section of US-59 (having four lanes in each direction), 6 parallel arterials, I-610, and 10 cross streets. The simulations for both stages were performed using off-peak traffic conditions and had a duration of two hours. Several simulation scenarios were developed and analyzed for both networks. The base case consisted of normal traffic conditions without an incident, while the other scenarios included a 30-minute incident, various lane blockages, and multiple diversion strategies.

The optimal diversion percentages for one-and two-lane blockages caused by incidents were analyzed in the small network. When compared to the base case, total network delay increased by 10 percent for a 1-lane-blocking incident and 53 percent for a 2-lane-blocking incident. The optimal diversion percentage for a 1-lane-blocking incident was determined to be 4 percent. When compared to the strategy that used no diversion during a 1-lane-blocked incident, diverting 4 percent resulted in a 27.4 percent decrease in total network delay. For a 2-lane-blocking incident, the optimal diversion percentage was determined to be 10 percent, when combined with optimized signal timings, reduced the total network delay by 22.9 percent. The efficiencies of several strategies were also calculated by the following equation (Lee and Krammes, 1994):

$$Efficiency(\%) = (\Delta D_D / \Delta D_I) \times 100 \qquad \textbf{(Equation 3-1)}$$

where

$\Delta D_1$ = Delay induced by the incident = (Delay with the incident) - (Delay in normal condition)

$\Delta D_D$ = Delay reduced by diversion = (Delay with the incident) - (Delay with the diversion strategy)

The study determined that the efficiency of the diversion strategies significantly improved when signal optimization was implemented. When compared to diversion with existing signal plans, diversion along with signal optimization increased the efficiencies for the 1-lane-blocking and 2-lane-blocking incidents from 58.5 to 298.0 percent and 13.2 to 66.3 percent, respectively (Lee and Krammes, 1994). Since the efficiency of the 1-lane-blocking incident was over 100 percent, the diversion strategy with signal optimization under incident conditions is more efficient than normal conditions with existing signal timing plans.

The second stage of the US-59 Southwest Freeway corridor consisted of analyzing the more comprehensive, large network. The large network analyzed 2-lane-blocking and 3-lane-blocking incident occurrences during off-peak conditions. The TRAFFIC assignment model provided the optimal travel patterns for the O-D trip table based on incident severity. Total network travel time savings for the 2-lane-blocking and 3-lane-blocking incidents were 14 percent and 16 percent, respectively (Lee and Krammes, 1994). Due to the increased size of the large network, the percentage increase in network travel time savings was not as significant as the small network.

The diversion efficiencies for the large network were also determined; however, the efficiencies for both local and network-wide diversions were evaluated. For a 2-lane-blocking incident, the efficiency increased from 5.8 (local) to 32.3 (network-wide) percent, while a 3-lane-blocking incident increased from 24.4 (local) to 79.0 (network-wide) percent (Lee and Krammes, 1994). The analysis showed that the efficiency values for both local and network-wide diversions increased as the incident severity increased.

***Arlington County, VA***

In 1995, the Virginia Transportation Research Council conducted a study to determine whether simulation models could aid in the decision process for diversion strategies for incident management. The study analyzed two sites on westbound I-66, which are located inside the I-495 Capital Beltway, and utilized CORSIM, a microscopic simulation model.

The first site analyzed pertains to the Lee Highway, which runs parallel with westbound I-66. When an incident occurs on I-66, traffic would be diverted onto Lee Highway and transferred back to the interstate past the incident. The second site diverted traffic off I-66 onto North Glebe Road, which consists of several signalized intersections to bypass the incident. Both sites were analyzed using several simulation runs with various traffic volumes and lane blockages with a 45-minute incident duration.

A base case (current conditions) analysis of both sites was conducted to determine the effectiveness of various incident management strategies. The results of the base case analysis were verified by field observations of queue lengths and delay times along the corridors. For the Lee Highway site, a one-lane blockage on the three-lane interstate (one direction) did not warrant a diversion strategy until traffic volumes were increased by 1,000 vehicles. However, when two lanes were blocked by an incident, diversion along with signal optimization greatly benefitted the corridor. When compared to diversion without signal optimization, this strategy reduced total system delay by 63 percent (Cragg and Demetsky, 1995).

Diversion to the North Glebe Road was warranted for an incident blocking only one lane of traffic. A modification to the CORSIM network was made to accommodate the diversion strategies. If a large percentage of vehicles was instructed to divert under congested conditions, the vehicles could not find an acceptable gap to perform the merge maneuver; thus, they would miss their destination and be removed from the simulation. Therefore, a dummy link was created to supply the vehicles onto the exit ramp. When 50 percent of the vehicles were diverted off I-66 to the arterial system, the total delay was approximately 500 vehicle-hours less than the non-diversion analysis (Cragg and Demetsky, 1995).

***Fort Worth, TX***

A study conducted by Campana (1996) analyzed diversion strategies for I-35W near downtown Forth Worth, TX. The study evaluated rerouting traffic off the interstate due to an incident during morning peak hour traffic and signal optimization along two diversion routes. The incident consisted of blocking two of the four lanes of I-35W and lasted 20 minutes. The simulation analysis was performed using CORSIM, while the signal optimization was performed using PASSER2 and PASSER3. Several scenarios were analyzed and include the following:

- Base case (existing conditions without an incident);
- Incident case (without diversion);
- Incident, diversion on Route 1;
- Incident, diversion on Route 2;
- Incident, diversion on Route 1, signals optimized; and
- Incident, diversion on Route 2, signals optimized.

The first diversion strategy (Route 1) consisted of rerouting a percentage of the freeway traffic to a frontage road that runs parallel to I-35W. Fifty percent of the rerouted traffic was diverted back to the interstate on the next on ramp, while the remaining 50 percent traveled on the frontage road and did not return to the freeway until after they left the study area. The amount of traffic that was diverted from the freeway was obtained by calculating the physical reduction due to lane blockage and the reduction due to rubbernecking. The analysis determined that 1,000 vehicles should be diverted off the interstate. The second diversion strategy (Route 2) diverts 50 percent of the traffic to the same frontage road in strategy one, while rerouting the other 50 percent to an arterial street.

The total delay time for the freeway and the entire network was evaluated for each scenario. Under incident conditions, all of the diversion scenarios benefitted both the freeway and the total network. Compared to the incident case without diversions, the total network delay reductions ranged from approximately 1 percent to 11 percent (Campana, 1996). The diversion strategies had a greater impact on the freeway delay. When compared to no diversion, the savings in total freeway delay ranged from over 300 percent to almost 500 percent (Campana, 1996). Therefore, the study shows that the given incident management strategies dramatically improve freeway traffic flow, while providing moderate improvements to the overall network.

***Orlando, FL***

A study, conducted by the University of Central Florida, simulated the I-4 Central Corridor in Orlando, FL, to guide strategies for the Management Information System for Transportation (MIST) (Al-Deek et al., 1997). Four simulation models were evaluated: FRESIM, FREQ, KRONOS, and FREFLO/CORFLO. The evaluation considered several criteria that included freeway modeling capabilities, input requirements, output capabilities, limitations, user documentation, distribution and support, popularity and usage, licensing, and comparison and evaluation. From the evaluation criteria, the FREQ macroscopic simulation model was considered to be the most appropriate for the I-4 study.

An extensive data collection effort was implemented to obtain accurate field traffic volumes at various times of the day throughout the corridor. Loop detection data from the network and videotaped footage of the freeway ramps were analyzed to determine the current traffic demand. Next, the simulation model was calibrated to provide output which was very similar to observed field output. After the necessary adjustments were made, the simulated travel times, while under an incident event on I-4, only varied three percent from the observed travel times of the corridor (Al-Deek et al., 1997).

Results from the simulation analysis were mainly used for guiding the managers who oversee the Management Information System for Transportation (MIST). MIST uses surveillance and loop detectors to detect vehicle presence, however, failures in hardware/software and adverse weather conditions create problems in vehicle detection. Therefore, the simulation could provide the traffic manager with reasonable information about current traffic conditions, and traveler information may be relayed to variable message signs (VMS) throughout the corridor.

## Conclusions of Freeway Corridor Simulation Applications

The freeway simulation studies, which were discussed in the previous section, varied in case study location, incident occurrence and duration, and optimization strategies. However, each study determined that various forms of ITS in incident management systems benefitted the transportation network. The studies evaluated several forms and combinations of ATIS and ATMS, such as route guidance, VMS devices, ramp metering, and signal optimization. In addition, all of these studies were conducted in large metropolitan areas.

The quantitative improvements to the transportation system, as determined in these studies, may be primarily grouped into speed and delay. The Santa Monica, CA, analysis was the only study that provided speed output. The optimal ITS enhanced case provided increased average speeds of both freeway and arterial links at 15.3 and 10.1 percent, respectively. The remaining studies focused on evaluating the delay time or travel time encountered by motorists. The Houston, TX, study reported reductions in total network delay time ranging from 22.9-27.4 percent for the small network and 14.0-16.0 percent for the large network. The diversion efficiencies for the Houston, TX, study varied upon incident severity and network size. The efficiencies were as high as 298 percent for the small network and 79 percent for the large network. The Arlington, VA, study also displayed a significant delay reduction. The study reported a total system delay reduction of 63 percent. After incorporating ITS strategies, the Santa Monica, CA, study resulted in network travel time lower than the travel time experienced during normal conditions. The least savings in network delay occurred in the Fort Worth, TX, study. This study demonstrated a network delay savings of 1-11 percent. However, the savings in freeway delay were determined to be 300-500 percent. In addition to these numerical results, the simulation programs also provided effective visual representations of various traffic scenarios and conditions.

Every study in this chapter listed a few obstacles and limitations that are evident in freeway analysis studies. The problems associated with these simulation applications can be classified into data acquisition and model limitations. Data must be obtained by field counts or planning models. Field counts may be obtained by vehicle detectors placed throughout the network, however, detailed data for all lanes and roadways are normally not readily available. Therefore, additional data collection may be needed, which may require large amounts of personnel.

Planning models, which are used by metropolitan planning organizations (MPO), may provide link traffic volumes and O-D demands. Traffic demands can be extracted from the planning models through complicated computer tasks, however, the agency must have personnel who are capable of performing such tasks. Other data, such as roadway geometry, must be gathered from state or local agencies in the form of electronic or paper media.

Limitations within the simulation models were also discussed in most of the case studies. The limitations are typically program specific, however, some of the downfalls are common for most simulation programs. Several of the simulation models are not capable of optimizing signal timing plans, coordination offsets, and ramp metering rates. Therefore, external optimization must be performed using other traffic software and inputted back into the simulation model. Models that only use link volumes are not capable of time-varying flow rates or turning percentages. The user must manually adjust the turning percentage for many diversion scenarios to determine the optimal turning percentages. Simulation models provide abundant amounts of output to the user, however, it is often in a difficult form to analyze.

## Freeway Corridor Simulation in Second-Tier Cities

The case studies in the previous section analyzed freeway corridors in several large urban areas across the United States. However, there were no applications in smaller urban areas (second-tier cities). The studies compared various traffic management and traveler information scenarios to the existing conditions of the freeway corridor and determined that optimizing signal timing plans, ramp metering, and diversion strategies provides system benefits including decreases in travel time, fuel consumption, and vehicle emissions. It is expected that similar benefits may be realized in small-to-medium size metropolitan areas. However, these benefits must be quantified and accurately examined. Therefore, this study addresses this need by examining the benefits of using ITS in incident management for small-to-medium urban areas using a case study in the Fargo, ND, metropolitan area.

# CHAPTER 4. METHODOLOGY

This chapter provides an overview of the methodology developed to evaluate the implementation of an incident management system in a second-tier city. The methodology specifically focuses on using two ITS services: ATIS and ATMS. The selected evaluation tool, INTEGRATION simulation program, and its data requirements are also discussed.

## Overview of the Methodology

Developing a complete and functional incident management system requires extensive planning, communication, and coordination among several entities to determine proper protocols for possible incident scenarios throughout the implementation area. Further, deploying ITS components generally requires significant up-front expenditures that must be carefully analyzed to justify their implementation. Therefore, this study develops a methodology to evaluate potential user benefits that can be used in a benefit-cost analysis of IMS utilizing ITS technologies.

Past studies have evaluated ITS in incident management in large urban areas, however, little is known about the possible benefits of ITS deployment in small-to-medium size urban areas. A flowchart of the proposed methodology is shown in Figure 4-1. The methodology is applied to a case study in Fargo, ND, which is presented in Chapter 5. Similar to previously conducted studies, this study will compare a few key MOEs, such as travel time, trip time, and speed. The MOEs of several cases or strategies will provide insight to the effectiveness of various types and levels of ITS deployment. The simulation cases or scenarios will utilize the same transportation configuration, however, an incident

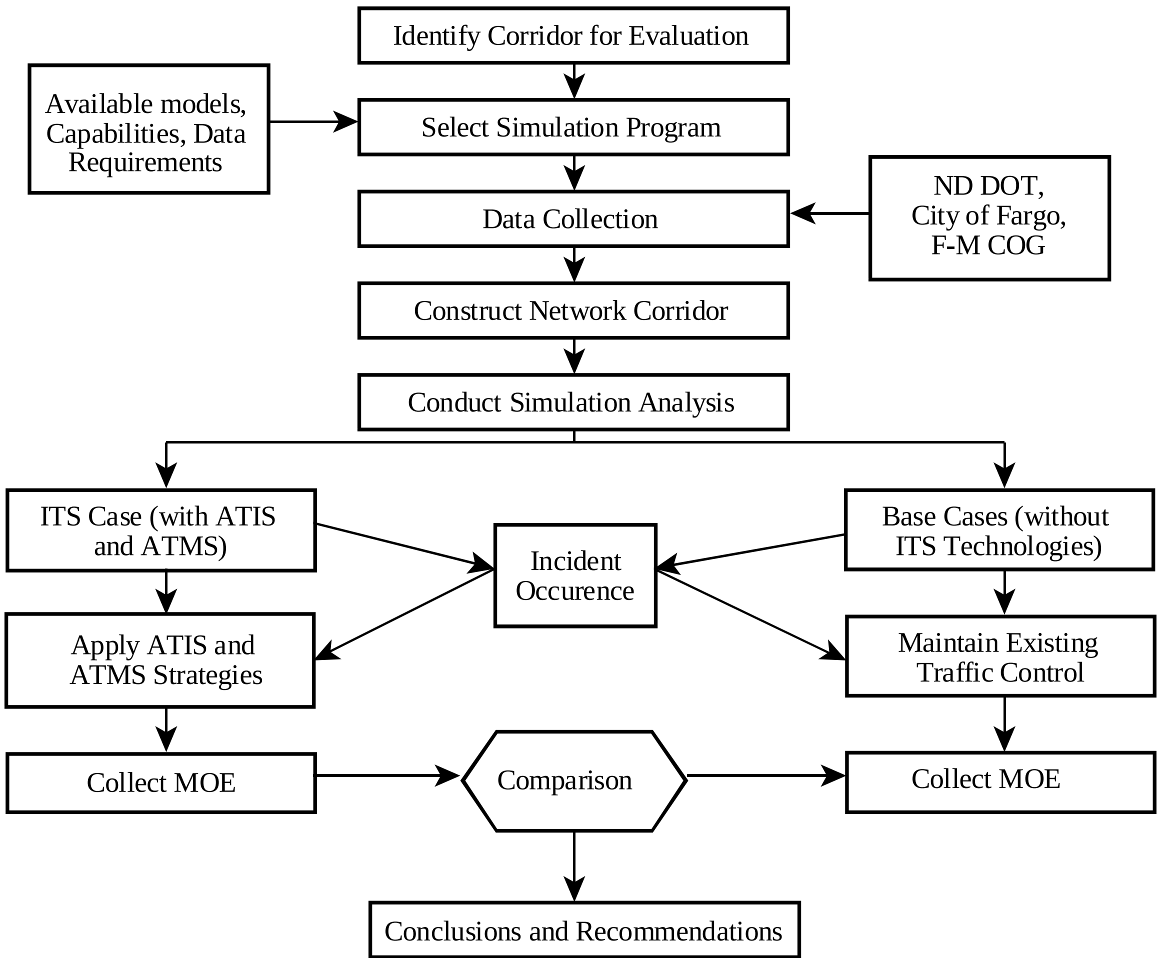


Figure 4-1. Proposed methodology flowchart.

occurrence along with different levels of ATIS and ATMS implementation will be analyzed.

The base cases represent the case study's current or existing conditions (road geometry, traffic volumes, turning movements, and signal timing plans). The ITS cases use the base case network and traffic levels, but employ various ATIS and ATMS elements to encourage drivers to take alternative routes and to implement adequate signal timing plans adequate for the new distribution of traffic. An illustration of the major components of an IMS are shown in Figure 4-2. The different ITS cases are distinguished by the level of motorist participation (i.e., diversion percentage) and the deployment level of ITS infrastructure.

The focus of the analysis will be the operational efficiency gained by using ITS. These gains can easily be converted to dollars of benefits. However, it is difficult to perform a benefit-cost analysis for this study since an ITS design has not been conceptualized yet. If ITS technologies were implemented for incident management, they would encompass a much greater area than the case study network. The level of deployment (i.e., number of vehicle detectors, cameras, number of computers, traffic management/operation facilities, etc.) would greatly influence the costs for the system. Additionally, some existing infrastructure, such as fiber optics, could be shared by multiple companies or agencies. ITS technologies used in IMS, such as VMS, can also be used to provide other services including road, weather, and tourism information; hence, the cost will be spread over more systems.

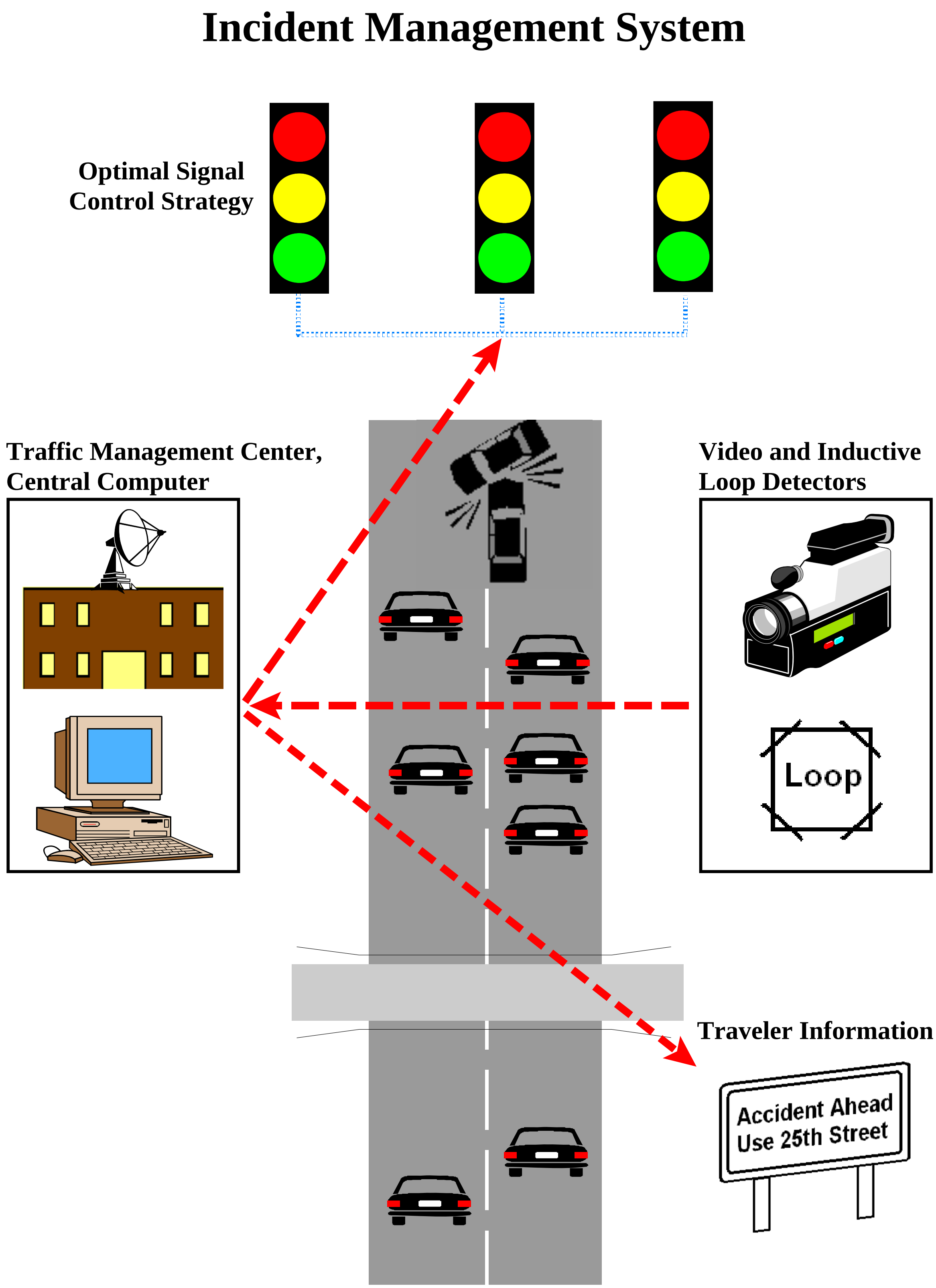


Figure 4-2. Illustration of incident management system implementation.

## Description of Evaluation Tool (INTEGRATION)

Traffic simulation will be used to evaluate the benefits of implementing an ITS-based incident management system for Fargo, ND. Many simulation programs are available on the market, however, the INTEGRATION simulation model was selected for this case study for a number of reasons, which include the following:

- It is capable of modeling ITS components, such as ATIS and ATMS.
- It provides several types of quantitative output, such as travel time, trip time, speed, vehicle emissions, and fuel consumption.
- It provides graphical output, which allows the user to "fine-tune" or adjust the model to reflect actual traffic conditions and shows the associated problems or characteristics of several scenarios.

INTEGRATION was developed in the mid-1980s by Dr. M. Van Aerde as an "integrated simulation and traffic assignment model" (Van Aerde, 1998a, p.5). It is a microscopic simulation model, which can track the longitudinal and lateral movements of vehicles at a resolution up to one deci-second (Van Aerde, 1998a). The model explicitly allows for modeling dynamic traffic events, such as shock-waves, gap acceptance, and weaving. The model allows great flexibility to the user by accepting unrestricted values for traffic flow attributes, such as departure rates, signal timing plans, incident occurrences and severities, or traffic routings. These attributes may be altered on nearly a continuous time basis (Van Aerde, 1998a). Although INTEGRATION is primarily microscopic, it should be noted that the model has been calibrated to capture most of the important macroscopic traffic relationships that are familiar to traffic engineers, such as "link speed-flow relationships; multi-path equilibrium traffic assignment; uniform, random, or over-saturated delay; as well as weaving and ramp capacities" (Van Aerde, 1998a, p. 7). Therefore, it is often referred to as a mesoscopic simulation model. The following sections discuss the main elements of the model.

### *Traffic Generation/Distribution*

Since INTEGRATION uses dynamic traffic assignment (DTA), it requires the traffic demand data to be in the form of O-D demands. Traffic demand may be represented as "a time series histogram of O-D departure rates" for every O-D pair within the network (Van Aerde, 1998a, p. 8). The duration of each histogram cell may vary from 1 second to 24 hours, and is independent of other O-D pairs and other time periods (Van Aerde, 1998a). If the same O-D pair is replicated in the departure list during overlapping time periods, the vehicle departures will have a cumulative effect. As a vehicle departs for its ultimate destination, it is tagged with its corresponding departure time, origin-destination, and a unique vehicle identification number. The vehicle identification number can be used to trace a vehicle's path from its origin to its final destination (Van Aerde, 1998a).

The traffic stream may consist of up to five driver classes or vehicle types. The user assigns the fraction of demand, which can consist of several or all O-D pairs, to be associated with each driver class. Different driver classes allow the user to track specific vehicles, such as heavy vehicles and vehicles that are provided with traveler information. After a vehicle has been generated, it is stochastically assigned a driver class based on the inputted probabilities of each driver class. Vehicle probes can also be assigned to any vehicle type. Information related to these vehicle probes is provided by unique output files, in addition to the aggregate output files based on network links and vehicle types (Van Aerde, 1998a).

### *Travel Characteristics*

Once a vehicle enters a link, it will select the lane that typically has the greatest amount of headway (distance between itself and downstream vehicles). After lane selection has occurred, the vehicle computes its preferred speed based on headway between itself and the vehicle immediately downstream within the same lane (Van Aerde, 1998a). This calculation is determined by a "link specific microscopic car-following relationship that is calibrated macroscopically" to achieve the appropriate combined speed-flow attributes for each link (Van Aerde, 1998a, p. 9). The vehicle's position, relative to other vehicles, will be updated every deci-second to calculate new headways and speeds (Van Aerde, 1998a). The macroscopic calibration of the microscopic car-following logic assures that the vehicle will travel each link consistently according to the "links desired free-speed, speed-at-capacity, capacity, and jam density" (Van Aerde, 1998a, p. 9).

### *Route Selection/Traffic Assignment*

The calculation of vehicles' shortest paths is conducted by INTEGRATION's internal routing logic, which uses a combination of static, dynamic, stochastic, and deterministic techniques (Van Aerde, 1998a). The two main types of routing logic are static traffic assignment and dynamic traffic assignment. The static traffic assignment uses link free-speed to calculate travel times. Provided that the free-speed traffic assignment accurately distributes traffic within the network, it is beneficial to use this method to evaluate the base case conditions of a traffic network since traffic will not be allowed to change course due to an incident occurrence. The second routing logic is referred to as dynamic traffic assignment (DTA) since it allows vehicles to reroute according to the current traffic conditions of the network. The DTA process provides a listing of next links to use for each vehicle class and is stored in a look-up table. When a vehicle completes a link, it queries the look-up table to determine the next appropriate link to reach its final destination in the most efficient means (minimum travel time path). The process is repeated after traversing each link until the vehicle arrives at its ultimate destination (Van Aerde, 1998a).

The frequency at which vehicle types 1-5 re-compute their minimum paths is determined by the program user. Therefore, one vehicle type may receive real-time traveler information on a continuous basis, while another vehicle type may not receive information as often or at all. As new travel paths are computed, the previous minimum paths are replaced for the given vehicle type. Higher update frequencies basically provide target vehicles with real-time traveler information to simulate the implementation of route guidance systems (RGS) or variable message signs (VMS). Less frequent travel time updates do not allow vehicles to respond to the changing traffic conditions. This experience occurs since the DTA uses the minimum paths from the last update interval until the new interval values are accumulated. Vehicles that utilize RGS receive real-time traveler information on a continuous basis, while the VMS devices provide traveler information for a time period of 180 seconds (Van Aerde, 1998b). After the 180-second time period, the minimum paths of the vehicles that temporarily received traveler information will return to their default routing logic.

### *Incident Simulation*

The INTEGRATION simulation model allows for incidents to occur at any time, have any duration, and have a severity ranging from blocking 0 percent to 99 percent of the capacity. Also, the incident may block only one lane or a group of lanes on a link, and the blockage can be any practicable length (Van Aerde, 1998a). Multiple incidents may be simulated to occur at the same time at different locations, or at different times and same locations. Typically, an incident occurrence reduces traffic flow, link speed, and the availability of a specific lane. Rather than directly reacting to an incident occurrence, INTEGRATION's current routing logic responds to the indirect delays that are caused by an incident's flow or speed restrictions. As a result, the indirect response causes diversions to occur only when the delay experienced by the vehicles is large enough to make an alternative route more appealing. Traffic may also be diverted away from links that do not have an incident, but are congested as a result of an incident on another link in the network (Van Aerde, 1998a).

### *Traffic Control*

INTEGRATION is capable of modeling different traffic control strategies, such as yield signs, stop signs, and traffic signals. Several time-of-day signal timing plans may be implemented into INTEGRATION. Each signal plan incorporates the appropriate cycle length, offset (if applicable), number of phases (up to eight), green interval per phase, and lost time per phase (Van Aerde, 1998a).

INTEGRATION is capable of conducting internal signal optimization as it runs (i.e., creates signal timing plans adaptive to traffic conditions at a given time period). The model optimizes the cycle length, phase splits, and offsets and is very similar to Split Cycle Offset Optimization Techniques (SCOOT). The user must define the frequency of the optimization, and the minimum and maximum cycle lengths. The only limitation in this process is that the optimization frequency must be a multiple of 60 seconds (Van Aerde, 1998a). The green allocation for each phase is determined on the approach's volume/saturation flow rates based on the procedures of the Canadian Capacity Guide (Van Aerde, 1998a). The model also provides some flexibility in the optimization process, by optimizing phase splits while keeping cycle lengths and offsets constant. This flexibility would be beneficial during signal coordination. Moreover, the model is not constrained to have all signals participate in either the automatic cycle length or the phase split optimizations (Van Aerde, 1998a).

***Measures of Effectiveness***

INTEGRATION collects several types of helpful statistics including link travel time, fuel consumption, and vehicle emissions. This information may be used as MOEs to evaluate the improvement in traffic conditions due to using ITS in IMS. Link travel time is obtained by the weighted sum of the vehicle speeds for each link (Van Aerde, 1998a). When a vehicle enters each link, it is provided with a "time card." Upon leaving the link, the "time card" is returned. The vehicle's link travel time would be the difference between the entry and exit times (Van Aerde, 1998a).

The model computes vehicle speed at the deci-second time level (Van Aerde, 1998a). Therefore, steady state fuel consumption rates are computed for each vehicle based on its instantaneous speed. By knowing a vehicle's speed on a second-by-second basis, additional fuel consumption that occurs from acceleration or deceleration can be determined (Van Aerde, 1998a). The default vehicle used to obtain the fuel consumption is the 1992 Oldsmobile Toronado (Van Aerde and Baker, 1993; Baker and Van Aerde, 1995).

Several vehicle emission models are integrated with the fuel consumption model. The estimated emission levels, which include hydrocarbons, carbon monoxide, and nitrous oxide emissions, are also computed on a second-by-second basis (Van Aerde, 1998a). Similar to fuel consumption, vehicle emissions are related to vehicle speed, ambient air temperature, and the magnitude that the vehicle's catalytic converter has been warmed up (Van Aerde, 1998a).

***Description of INTEGRATION Data Requirements***

INTEGRATION requires detailed information about the study area, including roadway geometry, traffic control, and traffic volumes. The information needed to develop the case study analysis was obtained from several sources, including Fargo-Moorhead Metropolitan Council of Governments (F-M COG), the City of Fargo, ND, and the North Dakota Department of Transportation (NDDOT). This information is summarized in the following section.

Roadway geometry is coded in the form of a link-node representation, where links represent road segments of the network and nodes represent points or origin or destination and intersections of links. Information related to roadway geometry includes 1) the number and location of city through and turning lanes, and left/right turn bays; and 2) the number and location of freeway through lanes, entrance and exit ramps, and auxiliary lanes.

Traffic control devices include yield signs, stop signs, traffic signals. Signalized intersection data include type of controller (pretimed, semi-actuated, or actuated), cycle length, number of phases, phase sequence, phase timings or splits, and offsets (if implementing coordination).

Traffic volumes are measured in O-D demands (i.e., the number of vehicular trips between every O-D pair). Origin-Destination demands allow INTEGRATION to use DTA in routing vehicles throughout the network while taking the service levels on network links and nodes into consideration. The required information includes 1) peak hour O-D traffic volume (defined as the highest hourly vehicular flow rate within a single hour of the day) and 2) the percentage of heavy vehicles, such as trucks, buses, and recreational vehicles, for each O-D pair.

## Description of Validation Plan

Validation of simulation results is an important task in the analysis, but it is often influenced by the availability of field data. Generally, it is necessary to ascertain that the simulation produces traffic levels and conditions similar to real-world conditions. Therefore, one method of validating simulation results is to compare traffic volumes. The link volumes from the base case (without an incident) obtained by INTEGRATION can be compared to those obtained from the latest available (1996) average annual daily traffic (AADT). Most previous studies indicated that a difference within 10 percent between the available traffic volumes and simulation volumes is acceptable. Once the incident-free base case is validated, it will be assumed that the other simulation scenarios also provide valid or realistic values.

# CHAPTER 5. CASE STUDY

Fargo, ND, was chosen as the study area to evaluate the effectiveness of using ITS technologies for IMS in second-tier cities. Fargo is located in the eastern side of the North Dakota and is the state's largest city. Fargo is a major part of a metropolitan area consisting of West Fargo, ND; Moorhead, MN; and Dilworth, MN. The projected population of the metropolitan area, commonly referred to as the Fargo-Moorhead (F-M) metropolitan area, was approximately 166,000 in 1996 and is expected to grow to approximately 214,000 by 2025 (Fargo-Moorhead Metropolitan Council of Governments, 1998).

Numerous freeway incidents occur within the F-M metropolitan area, as a result of special events, traffic accidents, inclement weather, and material spills. A majority of the incidents that occur in the F-M area are traffic accidents. An average of 108 crashes per year, which consisted of property damage, personal injury, and fatalities, occurred on the freeway system within the F-M metropolitan area between 1994-1996 (North Dakota Department of Transportation, 1999). This information may be used for examining potential benefits of IMS.

The analysis will be conducted on a portion of Interstate 29 (I-29) and Interstate 94 (I-94), where an incident occurrence will be simulated on a northbound segment of I-29. Four city arterials are included in the corridor, which will provide motorists with diversion routes during the incident occurrence. The corridor runs approximately 3.2 miles from north to south and 3.5 miles from east to west. The remainder of this chapter discusses the case study corridor, the existing incident management committees and practices in the F-M metropolitan area, the proposed use of ITS technologies in the corridor, and the results of the IMS implementation.

## Case Study Corridor

The case study corridor consists of two freeways, I-29 and I-94, and four city arterials, Main Avenue, 13$^{th}$ Avenue South, 25$^{th}$ Street, and 45$^{th}$ Street (Figure 5-1). These roadways are six of the heaviest traveled in the F-M area. The two interstates serve the community by providing access to local traffic, as well as serving through traffic. Local traffic makes up the majority of traffic carried by the interstate system within the metropolitan area (about 75%), while the through traffic accounts for 25% of the AADT (Fargo-Moorhead Council of Governments, 1996a).

The city arterials included in the analysis corridor accommodate large volumes of traffic connecting multiple employment centers, shopping malls, retail, convenience, and industrial supply stores, as well as serving many dwelling units located within or near the study area. Fargo-Moorhead contains three universities; therefore, many dwelling units, such as apartment buildings, are available throughout the metropolitan area. A large quantity of these apartment complexes are located near 13$^{th}$ Avenue South and 45$^{th}$ Street.

### *Geometry Data*

The geometric data for the case study corridor were obtained from the F-M COG, the NDDOT, and by direct field observations. Both interstate highways are primarily classified as four-lane freeways, however, I-94 is a six-lane facility for approximately three miles in the metropolitan area. Main Avenue, 13$^{th}$ Avenue South, 25$^{th}$ Street, and 45$^{th}$

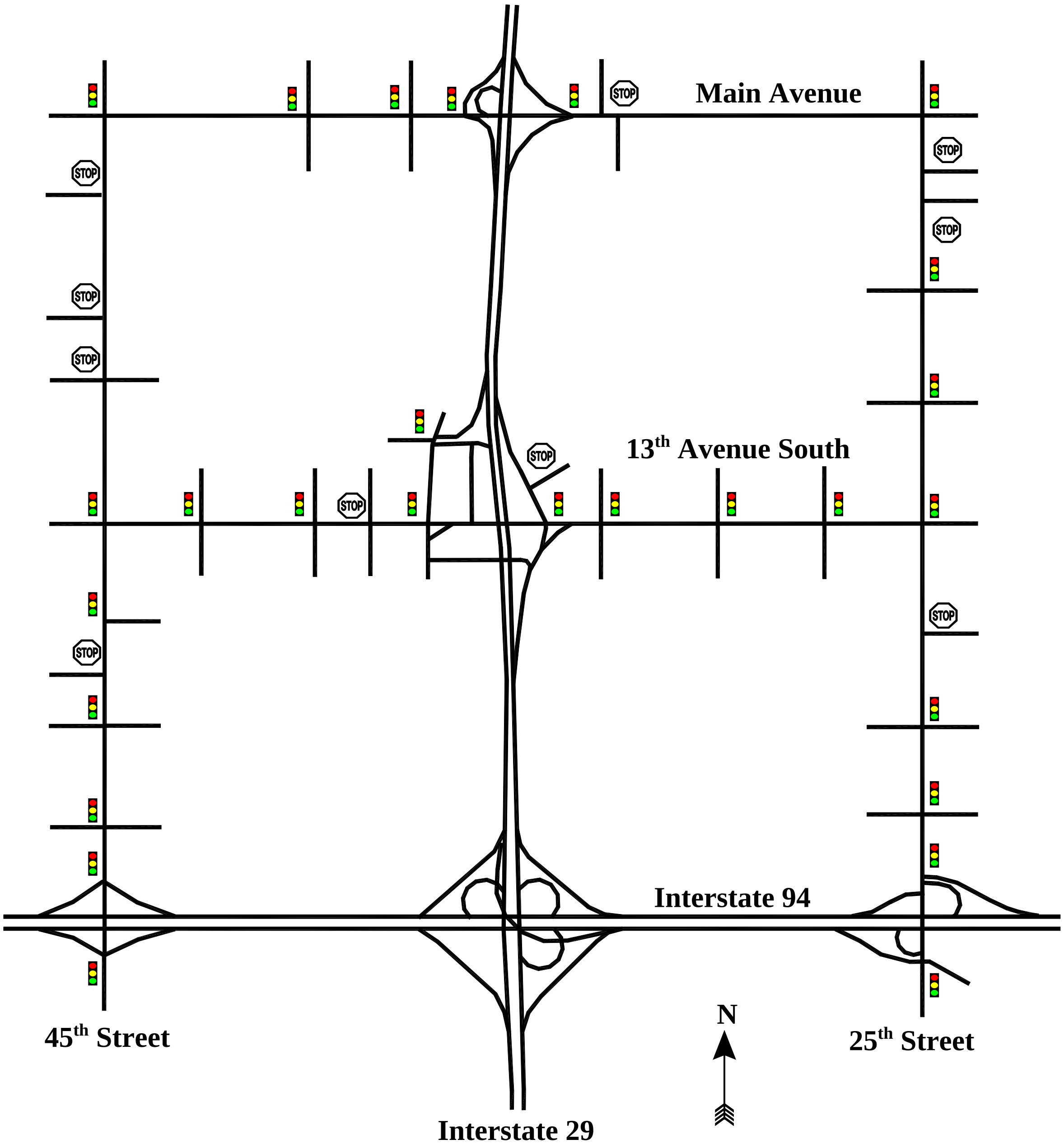


Figure 5-1.  Case study corridor.

Street are mostly defined as four-lane arterials, while a small portion of 13th Avenue South is a six-lane arterial.

Due to the lack of complete data, most of the freeway acceleration and deceleration lane lengths were assumed to be 600 feet. This length was selected since it provided adequate acceleration length for the vehicles to reach the link's free-flow speed. The storage lengths for the auxiliary lanes at arterial intersections were assumed to be 250 feet for the main movements or where two arterials intersected, while the side streets (minor movements) had storage lengths of 200 feet. The actual values for storage lengths vary from intersection to intersection, however, the assumed values are reasonable for Fargo. Overall, the case study network for running the INTEGRATION simulation model consisted of 447 directional links and 329 nodes.

***Traffic Volume***

Traffic information was primarily obtained by the F-M COG and the City of Fargo. The traffic volumes used for this study were based on 1996 AADT and signalized intersection counts. These volumes had to be in the form of O-D demands, as required by INTEGRATION. The O-D demands were obtained for the interstate links from the F-M COG's TRANPLAN model and were calibrated using the 1996 AADT map. Arterial O-D demands only accurately represent the traffic volumes on the arterials and will be discussed in further detail later in this section. The network traffic volumes for both interstates range from 22,000 to 41,300 vehicles per day, while the arterial traffic ranges from 11,800 to 35,000 vehicles per day (Fargo-Moorhead Council of Governments, 1996a).

The F-M COG updates the model when necessary, however, a consultant must run the model to get the necessary output. A "selected link analysis" was performed at four strategic locations to determine the appropriate O-D demands affected by the incident. The four locations included the incident location and three freeway sections that feed traffic into the incident. An O-D table was also provided for the whole F-M metropolitan area, which estimates the total productions and attractions throughout the whole metropolitan transportation network. An AADT map, which was created by the TRANPLAN model, along with traffic counts obtained at the signalized intersections will also be used in the traffic distribution process.

Next, a method to determine the traffic volumes for the city arterials had to be derived. Currently, the F-M COG's TRANPLAN model is comprised of 222 traffic analysis zones (TAZ), 14 of which are within the case study location. Therefore, it was almost impossible to transform aggregate demands from 222 zones into the 14 zones included for this study. Moreover, the TAZs distribute traffic from the zonal centroid to one or several roadways and may not use other roads, which would result in an underestimation of traffic on many side streets and intersections.

One possible solution was to synthesize O-D tables from street traffic volumes. Several formal methods to estimate O-D trip tables from link volumes have been developed over the past 20 years. However, they are very time consuming, especially for developing a target trip table to calibrate the model. Therefore, a less formal method to estimate the O-D demands for city links was developed. The method uses the AADT map and traffic counts at all of the signalized intersections within the case study. The AADT map provided the appropriate traffic volumes for the arterials and collectors, while the traffic counts provided the turning percentages for the intersections. Each arterial was analyzed by starting at an entry node and tracing the traffic to the next node on the arterial. At each node the approaching volume was adjusted based on the turning movement to estimate a departure volume (Figure 5-2). If needed, adjustments to the initial O-D pair loadings were performed. The process described above was carried out for the three remaining arterials.

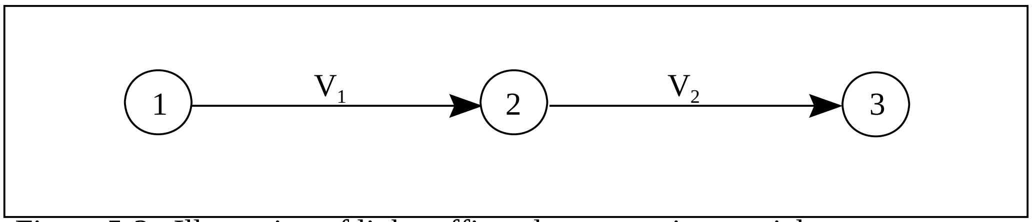

Figure 5-2. Illustration of link traffic volumes on city arterials.

The traffic distribution process used for this study may not be suitable for large networks that include many city streets since it may not provide accurate O-D demands. Since the arterials will not be able to utilize diversion strategies in this study, the traffic distribution for the city arterials is used only to assess the conditions of the arterials in evaluating freeway traffic diversions.

***Traffic Control***

The traffic control devices included in the case study consisted of 5 yield signs, 10 stop signs, and 27 traffic signals. The signal timing plans were obtained form the City of Fargo and the NDDOT. The timing plans correspond to the AM peak period. Signal coordination is implemented along portions of Main Avenue, 13th Avenue South, and 25th Street.

AM-8:30 AM), mid-day (8:30 AM-3: 30 PM), PM peak (3:30 PM-6: 30 PM), and PM off-peak, which is the same as the mid-day program (6:30 PM-11: 00 PM or 2:00 AM). Signal controllers located at major intersections operate on a "free status" during off-peak periods. Free status is a term given to a controller that operates as a volume density controller. A volume-density controller is similar to a full-actuated controller except it provides additional demand responsive capabilities. Minor signalized intersections operate on a flash mode during off-peak periods, typically from 2:00-6:30 AM.

### *Other Model Input Data*

INTEGRATION requires link information, such as free-speed, speed-at-capacity, capacity, and jam density. The free-speed was set as the posted speed limits. The freeway speed limit within the metropolitan area (excluding ramps) is 55 mph, while the city arterial speeds range from 30-40 mph. The capacity and speed-at-capacity values were estimated based on the facility type or section in accordance with the 1997 Highway Capacity Manual (HCM). The jam densities were estimated using the Greenshields relationship, as twice the density at capacity (McShane, Roess, and Prassas, 1998). The density at capacity values were also obtained by the HCM.

## Incident Management Plans Currently in Place

The F-M metropolitan area does not have an official incident management system or plan, however, all of the components of such a system are implemented to some degree. The following sections discuss the current committees involved in incident management, and the protocols and available equipment used for incident management.

### *Committees Related to Incident Management*

The F-M metropolitan area has a Metropolitan Incident Management Committee. The committee meets on an annual basis to discuss current or potential issues of emergency management, however, it was primarily organized to manage long-term incidents. The incident management committee is made up of representatives from several agencies including the North Dakota Department of Transportation (NDDOT), Minnesota Department of Transportation (MNDOT), City of Fargo, City of West Fargo, City of Moorhead, City of Dilworth, Cass County, and Clay County. In 1996, the committee purchased two trailers through cooperative funding by the agencies involved.
The trailers are equipped with Incident Management Command Signs (IMCS) which provide traffic control during severe incidents within the previously mentioned jurisdictions.

Standard operating procedures (SOP) for using the IMCS were also established by the committee, and provide guidance for securing and using these signs in times of emergency. The IMCS were designed to be used for serious unplanned incidents, which include the following (Fargo-Moorhead Council of Governments, 1996b):

- Major accidents (require more than three hours to clear the incident),
- Natural disasters (concrete blow-ups, flooding streets, tornados, etc.),
- Major structural failures (bridge or roadway collapse),
- Spills (hazardous materials), and
- Man-made disasters (construction failures).

A second committee, known as the Metro ITS Development Committee, was organized in 1998 to evaluate and prioritize potential ITS projects within the Fargo-Moorhead metropolitan area. Representatives from a variety of federal, state, county, and city agencies meet to discuss traffic safety and mobility issues that are evident in the F-M area. The committee has evaluated several short-range and long-range ITS applications that can be grouped into ATMS, ATIS, Advanced Public Transit Systems (APTS), emergency response, and infrastructure applications. The committee plans to deploy some of the higher priority projects as funds are available. Although the committee was not created specifically to deal with incident management issues, it has recognized a number of potential ITS projects related to incident management. In fact, one of the ITS committee's first projects will be to implement VMS technologies along the freeway system.

***Current Procedures for Incidents***

Numerous types of freeway incidents occur within the F-M metropolitan area, such as traffic accidents, special events, inclement weather, and material spills. The following sections discuss the current practices and procedures of managing incidents in the metropolitan area.

*Traffic Accidents*

Accidents may be detected on I-29 by motorist or highway patrols. When a motorist reports an incident via a cell phone or telephone, the call is received by the Fargo Dispatch Center. If no injuries occurred, the call is transferred to State Radio which will dispatch the appropriate emergency personnel. State Radio is North Dakota's statewide communications system that acts as a centralized dispatching center primarily for highway patrol units and DOT personnel, however, local police, fire departments, and emergency response agencies can communicate with State Radio dispatchers.

If injuries occur on the interstate, the Fargo Dispatch Center will dispatch F-M Ambulance and Fargo Fire Department units (one unit each) and call for NDHP units in the area to respond. If no highway patrol units respond, Fargo Dispatch will contact State Radio since it knows where the state patrol units are located.

Freeway incidents are often detected by highway patrol units. When a patrol officer encounters an accident, he or she will report it to State Radio. State Radio will contact the local fire and ambulance personnel. The highway patrol may also request other equipment, such as front end loaders, from the Fargo District DOT. Traffic management is conducted by the highway patrol officers on the interstate system. The traffic management plan is determined by the investigating officer at the accident scene.

*Special Events*

Special events in F-M metropolitan area frequently occur at the Fargodome, a multipurpose arena that is utilized for sporting events, musical concerts, and special shows or festivals. When the Fargodome is configured to its maximum concert configuration, 28,120 fixed seats are available to the pubic. Large Fargodome events cause significant traffic problems on I-29 and several city streets near the facility. During dome events, Fargodome event personnel (Fargodome employees, event police, on-duty local police officers, and sheriff deputies) and the NDHP implement traffic management strategies and provide information to the motorists traveling to or near the facility.

Fargodome officials, the Fargo Police Department, and City Engineers have developed several protocols for various sized dome events to reduce the amount of congestion arriving and departing from the dome. The categories for determining the traffic control measures are based on vehicle peak hour rates and include 0-5,000 vehicles, 5,000-12,000 vehicles, and 12,000+ vehicles. These three categories determine the locations and strategies for Fargodome event personnel at 18 intersections around the dome.

Since I-29 is a major connector to the Fargodome, it experiences heavy traffic congestion due to large dome events. Excessive queues on ramps, decreased freeway travel speeds, and dangerous lane changing maneuvers are typical during large events. The NDHP, as a result and without coordination with dome personnel, provides some traffic management and guidance to motorists during dome events. The Fargodome sends a monthly event schedule to the state patrol. The NDHP uses two electronic signs to regulate traffic on I-29 along major interchanges that provide access to the dome. The electronic signs are placed near the two interchanges that are on the north and south sides of the Fargodome interchange (19$^{th}$ Ave. S.). One sign uses a static message to inform dome event motorists to use a specific alternative route. The second sign uses a dynamic message that is operated by an NDDOT employee. Two state troopers or county deputies with two patrol cars perform traffic control at the ramp/street intersection at the Fargodome interchange and communicate to the NDDOT employee to change the message of the sign in accordance with the traffic congestion levels at their location. When traffic congestion causes spill back onto the interstate, the message is changed to request dome motorist to divert to a preceding ramp. As traffic congestion subsides, the troopers/deputies radio the NDDOT employee to change the message that informs the dome event motorist to use the Fargodome interchange.

*Inclement Weather*

The motorists in the region often encounter poor driving characteristics due to different atmospheric conditions. Icy conditions or excessive rains, which may lead to flooding, cause travelers to change their driving habits, detour around road closures, and prohibit travel on some road sections. Road closures due to icy conditions occur frequently in the F-M metropolitan area and often cause queues at the freeway gates by vehicles that are anticipating the road to re-open. The NDHP and the NDDOT are the two main agencies that are involved with the highway system. NDHP officers report to State Radio when they encounter unsafe road conditions on the interstate system and personally contact the district DOT offices to request snow plows and sand trucks. State Radio gathers road condition data from both highway patrol and DOT personnel, and provides road reports to the public via television and radio stations, telephone and cellular numbers, and the DOT's web site.

*Material Spills*

Material spills consist of various chemicals or equipment that is accidentally released onto the roadway. These spills may be dangerous from a toxic standpoint or by reducing the capacity of a roadway. Typical material spills in the region consist of agricultural products, such as grain or manure. The highway patrol and DOT will provide traffic management and cleanup at the material spill sites; however, if a toxic spill occurs, hazardous material teams and/or the EPA will also assist in the cleanup effort.

## Evaluation Scenarios

This study will simulate an incident along a portion of Fargo's I-29 corridor. The simulation analysis can be grouped into two cases: 1) base cases and 2) ITS enhanced cases. Comparing the simulation output of the two groups will determine whether using ITS technologies can benefit motorists during incidents in second-tier cities. The scenarios that were used in this study are as follows:

1. Base Case (without incident occurrence, ATIS, or ATMS),
2. Incident Base Case (without ATIS or ATMS),
3. ATIS - 20% (20% of motorists use traveler information),
4. ATIS - 50% (50% of motorists use traveler information),
5. ATIS - 20% combined with ATMS (signal optimization), and
6. ATIS - 50% combined with ATMS (signal optimization).

### *Incident Duration*

Incident duration varies upon the severity of the incident and the timeliness of detection, verification, and clearing of the incident. Lindley (1989) performed a study that examined incidents on four-lane highways. The study evaluated average detection and clearance times for various types of incident severities, and determined that a one-lane accident would have a 10-minute detection time and a 10-minute clearance time (Lindley, 1989). Therefore, this study will use a 20-minute incident blocking one lane for simulation Scenarios 2-6.

### *Simulation Period*

The simulation period for all cases will have a duration of 1 hour and 40 minutes. The following list describes the simulation time line:

- The network is "loaded" with off-peak traffic demands (five minutes).

- Traffic demands increase to simulate AM peak hour traffic conditions (60 minutes).
- A one-lane-blocking incident occurs on a northbound segment of I-29 at the beginning of AM peak hour traffic demands (20 minutes).
- Traffic returns to normal conditions (recovery period). The recovery period was determined by inspecting the on-screen graphics of the simulation model (63 minutes for the incident base case). Although the recovery period will be shortened by implementing ITS strategies, for comparative purposes, the simulation length for all of the scenarios will remain the same.
- All generated vehicles are allowed to reach their final destination (12 minutes).

***Base Cases***

The base cases utilize 1996 traffic volumes, road geometry, and traffic control. Two base cases will be simulated for this case study. The first base case, Scenario 1, will simulate current traffic conditions within the corridor during the AM peak hour without an incident and is primarily used for validation. The incident base case, Scenario 2, simulates current conditions with an incident, but without providing traveler information or traffic management. Scenario 2 will serve as a base line for comparing the effectiveness of the other scenarios (i.e., the effectiveness of the ITS enhancements).

***ITS Enhanced Cases***

The ITS enhanced cases will examine the operational benefits of different levels of ATIS and ATMS deployment for the base network with the same traffic conditions as the incident base case. Traveler information regarding the incident will be provided to freeway motorists entering the incident location and will be in the form of current link travel times for all possible routes. Link travel time information, via VMS devices, will provide the vehicles with a minimum path based on the current network traffic conditions for 180 seconds. Figure 5-3 shows potential locations of the VMS, the northbound incident location, and possible diversion routes. The update frequency of the link travel times for the freeway vehicles that will receive traveler information was 60 seconds. Therefore, these vehicles will receive updated minimum paths every 60 seconds for 180 seconds after the vehicle passes a VMS to determine if diversion is warranted. After the 180-second period, the minimum paths of the vehicles that receive traveler information will return to be calculated using the free-speed.

The percentage of motorists that comply with traveler information depends on the type of information that is provided. A study conducted as part of the INFORM project reported that 5 to 10 percent of the motorist would divert given general VMS messages. The diversion percentages doubled when specific diversion routes were provided to the motorists (Smith and Perez, 1992). Another study, which evaluated motorists' attitudes for ATIS at highway-railroad grade crossing in the F-M metropolitan area, indicated that approximately 50 percent of the personal drivers might use traveler information and change their route (Krahn, 1999). Therefore, two simulation cases regarding ATIS will be analyzed in this study. The first case (Scenario 3) assumes that 20 percent of the affected freeway motorists are willing to divert, if warranted, while the second ATIS case (Scenario 4) uses 50 percent. The diversion strategies will only be utilized until the transportation network returns to normal conditions. It is important to note that 20 percent and 50 percent of the freeway motorists will not necessarily divert, but they will receive real-time link travel time information to determine if it would be more beneficial to due so.

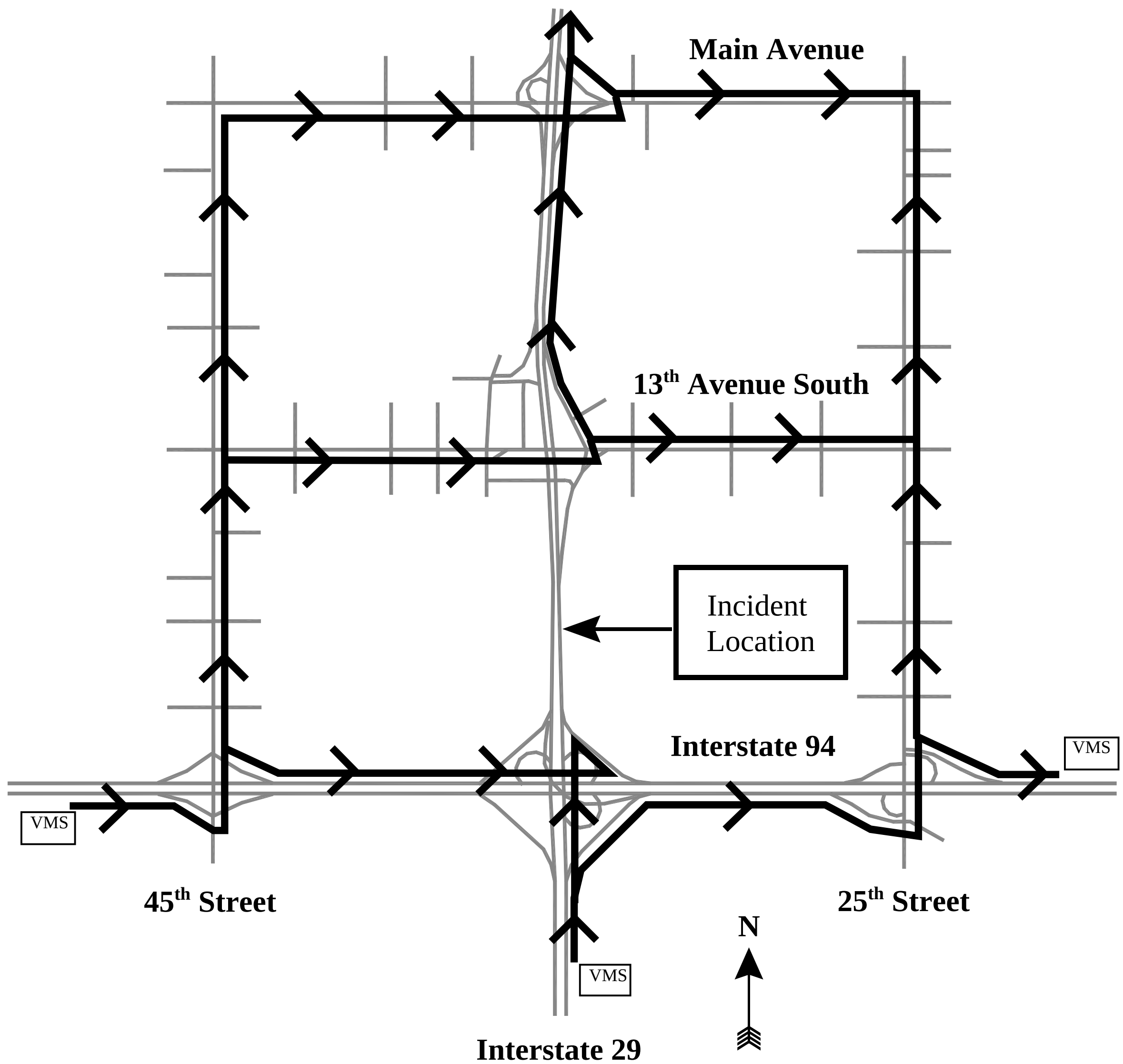


Figure 5-3. Location of VMS, incident, and possible diversion routes.

ATMS will be utilized to accommodate the diverted traffic from the freeway to the city arterials, and to reduce the impact of freeway incidents on both the freeway system and the city street system. Simply diverting traffic off the freeway will only benefit the freeway while creating a large burden to the city street network. Therefore, ATMS strategies will incorporate optimized signal timing plans for the city arterials. This process will include optimizing cycle lengths, phase splits, and offsets along diversion routes, which will eventually bring the diverted traffic back to the freeway.

Two scenarios that combine both ATIS and ATMS strategies will be simulated. Scenario 5 will combine Scenario 3 along with signal optimization, while Scenario 6 combines Scenario 4 with signal optimization. The cycle lengths, phase splits, and offsets will be optimized every 5 minutes with the cycle lengths ranging from 60 seconds to 120 seconds.

## Case Study Results

Three Measures of Effectiveness (MOE) values were compiled from the simulation model and included 1) total travel time for the freeways, city arterials, and total network; 2) average trip time for the O-D demands; and 3) average speed of the total network. The numerical output of the ITS cases was compared to the base cases to determine the benefits of implementing ITS technology for incident management in second-tier cities. The incident base case (Scenario 2) output served as a baseline for comparing the other scenarios to determine the effectiveness of the ITS cases (shown in Table 5-1).

Table 5-1. Summary of Results.

| | | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 | Scenario 6 |
|---|---|---|---|---|---|---|---|
| Total Travel Time (veh-hrs) | Fre<br>Art<br>Net | 607<br>2095<br>2702 | 929<br>2103<br>3032 | 813<br>2106<br>2919 | 702<br>2115<br>2817 | 776<br>1825<br>2601 | 692<br>1854<br>2545 |
| Average Trip Time (min/veh) | Net | 5.5 | 6.2 | 5.9 | 5.7 | 5.3 | 5.2 |
| Average Speed (mph) | Net | 21.4 | 19.1 | 19.8 | 20.6 | 22.2 | 22.7 |
| Difference in Travel Time (%) | Fre<br>Art<br>Net | -35<br>0<br>-11 | 0<br>0<br>0 | -12<br>0<br>-4 | -24<br>1<br>-7 | -16<br>-13<br>-14 | -26<br>-12<br>-16 |
| Difference in Average Trip Time (%) | Net | -11 | 0 | -5 | -8 | -15 | -16 |
| Difference in Average Speed (%) | Net | 12 | 0 | 4 | 7 | 16 | 19 |

Fre = Freeway links, Art = City Arterial links, and Net = Overall Network.

***Travel Time***

Travel time refers to the time it takes a vehicle to traverse a given link. The total network travel time refers to the summation of all link travel times throughout the corridor. The total network travel times were broken down into total freeway and city arterial travel times to determine how each facility type reacts to the given scenarios.

A general trend is evident in the travel time comparisons. The travel time decreases as the amount of ITS deployment increases. The ATIS/ATMS strategies (Scenarios 5 and

6) provided the greatest benefits to the freeway, city arterials, and overall network (shown in Figure 5-4). The reductions in network travel times for these two scenarios were 14 and 16 percent compared to the incident base case (Scenario 2). The ATIS/ATMS strategies provided greater network benefits regarding travel time than the base case without an incident since the existing traffic signal system is not operating at the optimal timing plans.

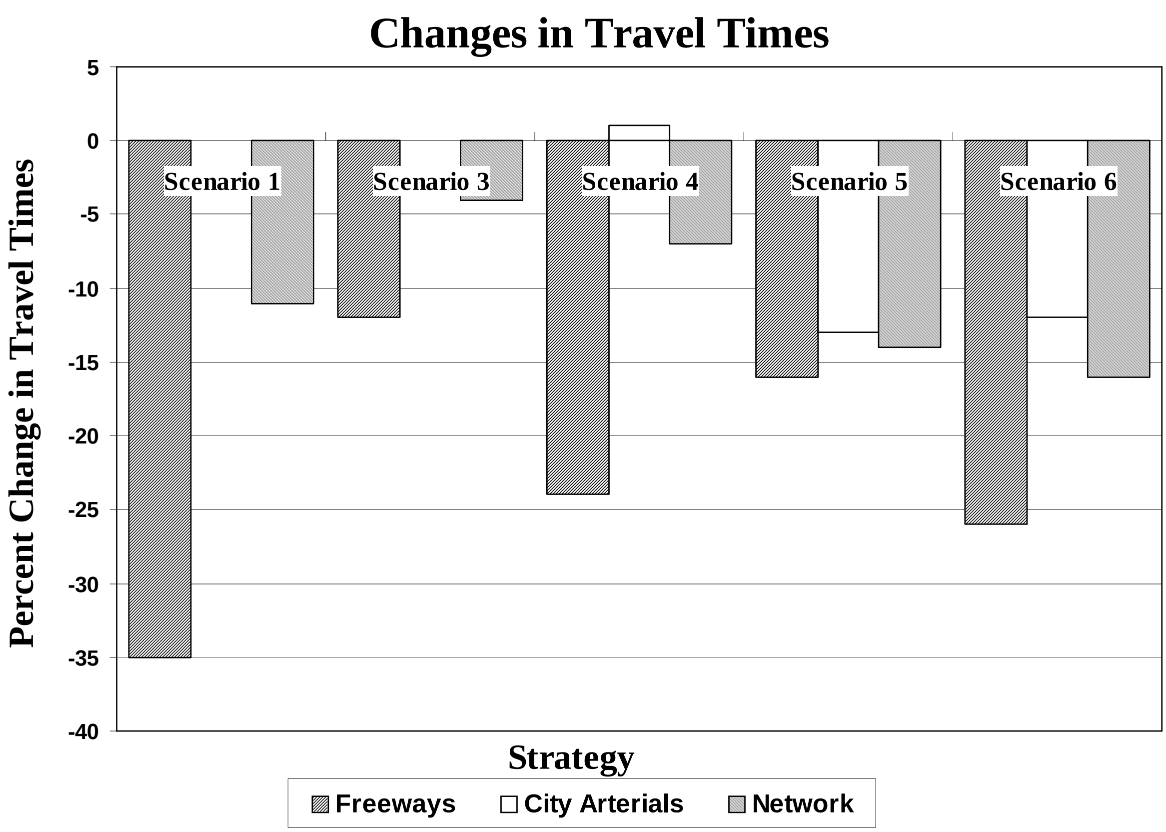


Figure 5-4. Changes in travel time compared to the Incident Base Case (Scenario 2).

***Trip Time***

Trip time is defined as the time it takes each vehicle to complete its trip. The average trip time values were obtained by summing the network O-D trip times by the total number of vehicles that were generated by the model. When compared to the incident base case (Scenario 2), the cases that provided traveler information (Scenario 3 and 4) reduced trip time by five and eight percent (Figure 5-5). Providing traveler information along with adjusting the signal timing plans to reflect the current traffic demands (Scenarios 5 and 6) enhanced the corridor's performance by reducing trip times by 15 and 16 percent. Similar to the travel time output, the ATIS/ATMS cases out-performed the base case (Scenario 1).

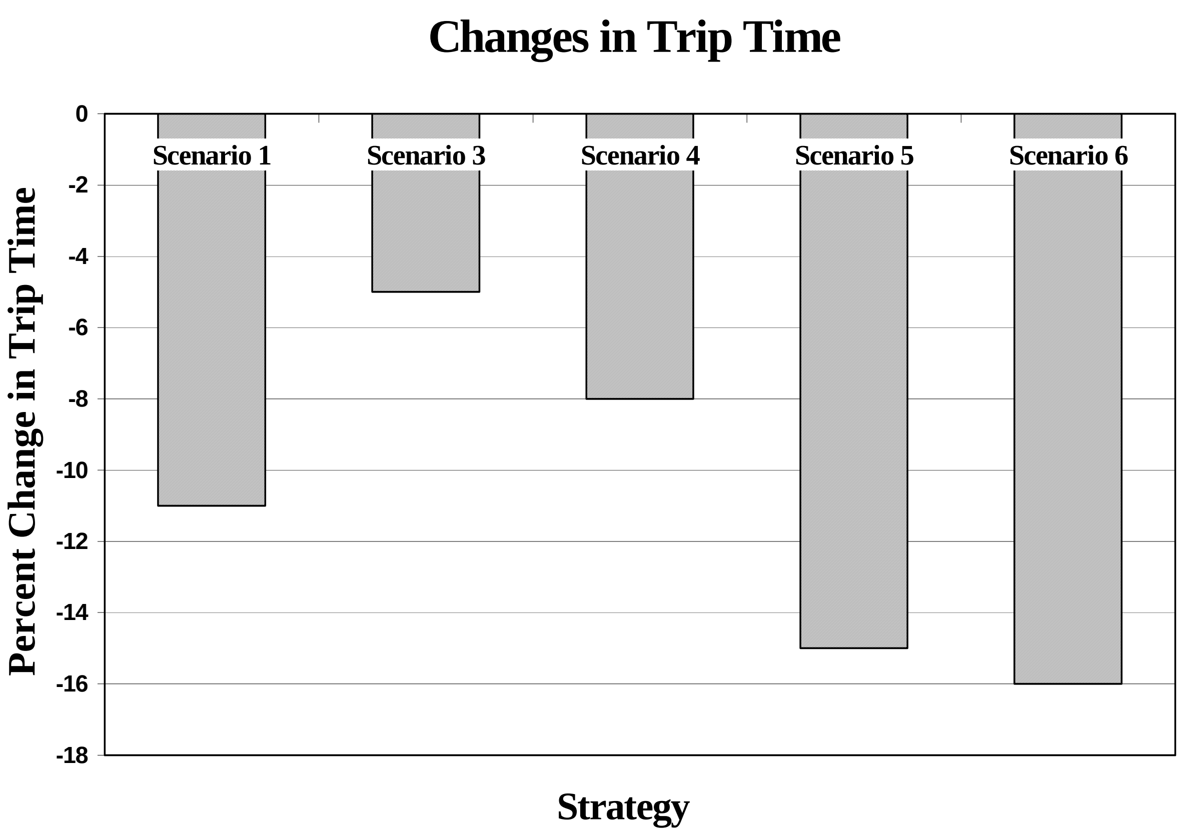


Figure 5-5. Changes in average trip time compared to the Incident Base Case (Scenario 2).

***Travel Speed***

Average travel speeds for every link were calculated by the simulation model. As experienced in the two previous MOE comparisons, the ITS cases provided higher average speeds, as shown in Figure 5-6. The ATIS scenarios (Scenarios 3 and 4) provided 4 and 7 percent higher average speeds, while the ATIS/ATMS strategies (Scenarios 5 and 6) provided increases of 16 and 19 percent. The ATIS/ATMS cases provided higher average speeds than those encountered by the base case (Scenario 1). The higher average speeds from the ATIS/ATMS strategies can be attributed to the reduction of traffic congestion, which was caused by stop-and-go traffic under incident conditions and by poor traffic signal coordination.

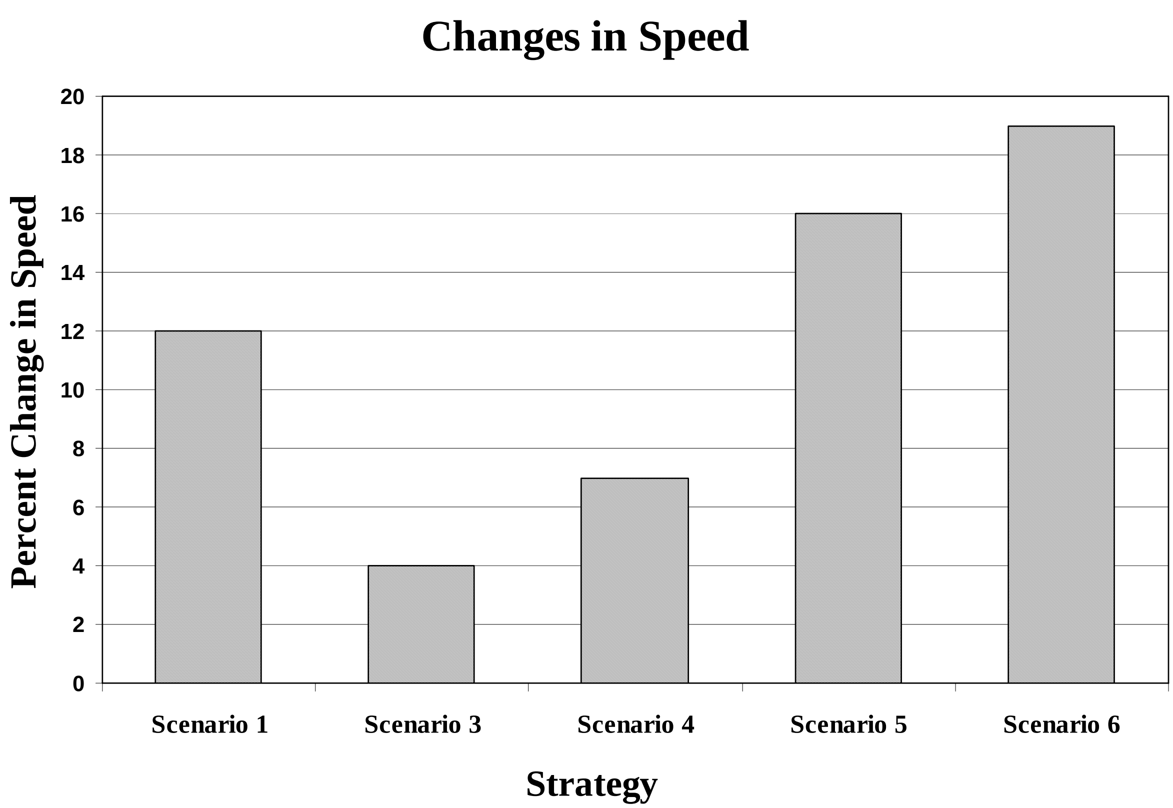


Figure 5-6. Changes in average speed compared to the Incident Base Case (Scenario 2).

## Validation of Results

Currently, there is no available information on traffic conditions during incidents in the F-M metropolitan area to validate incident cases. Therefore, only the base case (Scenario 1) was used to calibrate traffic volumes generated by the INTEGRATION simulation model. Calibration occurred by comparing the link volumes from a 1996 AADT map to the link volumes from INTEGRATION. Origin-destination demands were adjusted in INTEGRATION, if necessary, to accurately reflect the traffic volumes of the AADT map, as discussed in Section 5.1.2. of this study. Each time that the input O-D demands were adjusted, the model was simulated and compared to the AADT map. The adjustment and comparison process continued until all of the link volumes varied by 10 percent or less from the AADT map.

After the daily link volumes for the case study network were calibrated, the AM peak hour flow for the network was determined. Ten percent of the average daily traffic (ADT) is typically used to simulate peak hour periods, however, extensive queues occurred on some freeway ramps when this value was used. Therefore, the freeway O-D demands were adjusted based on personal observations. The fractional percentage that produced accurate observed conditions was determined to be nine percent of the AADT, while the city arterial O-D demands remained at 10 percent of the AADT.

The results obtained from this study seem reasonable and are similar to other simulation studies that have been performed in the past. According to personal observations while traveling on the freeway during an incident, the congestion encountered by on-screen graphics of INTEGRATION seemed reasonable. The incident management analysis provided similar speed output to the Santa Monica, CA, study and similar travel time reductions to the Houston, TX, study.

# CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

This chapter provides a summary of the findings and addresses some of the problems/limitations encountered in conducting the simulation analysis. It also suggests some recommendations on implementing incident management systems in second-tier cities.

## Summary of Findings

The operational effectiveness of using ITS in incident management was evaluated for several scenarios involving different levels of ITS implementation. The evaluation was based on comparisons of three MOEs (which included travel times, trip time, and speed) for each of the analysis cases. The ITS enhanced cases provided significant user benefits to both the freeways and city arterials, therefore, enhancing the overall operational efficiency of the transportation system. When compared to the incident base case, the most effective ITS case (50%-ATIS combined with ATMS) provided reductions in network travel time and network trip time of 16 percent, while increasing the average network speed by 19 percent. The analysis also revealed that implementing ATIS/ATMS strategies during incidents improved traffic conditions to such an extent that it was more effective than the base case without an incident. To achieve significant benefits for the case study corridor, the ITS cases did not need to divert a lot of the freeway traffic to the arterials. In fact, the best ITS case (Scenario 6) diverted only five percent of the traffic that would have used the incident location to the arterials.

The results encountered by the Fargo, ND, case study analysis were similar to those conducted in large metropolitan areas. The Santa Monica, CA, study provided similar speed output, while the Houston, TX, study provided similar travel time reductions as the Fargo, ND, study. Implementing ITS technologies for incident management benefits freeway and city arterial motorists, but they may negatively affect the motorists using side streets. Adjusting signal timing plans to accommodate the diverted traffic provides additional delays to motorists on the side streets, however, the overall system is improved since the arterials supply a majority of the vehicles. An important benefit of incident management relates to safety improvements. The traffic levels of the most efficient ITS case returned to normal conditions 13 minutes earlier than the incident base case, thus reducing the potential of secondary incidents.

## Problems/Limitations

Performing a simulation analysis of this nature poses numerous challenges and limitations. Evaluating incident management systems involves larger networks that consist of several types of transportation facilities, traffic signals, and diversion routes, which may cause several problems to the analysis process. Most of these complications can be grouped into model limitations, modeling effort, and data availability.

### *Model Limitations*

Although INTEGRATION provides many powerful and beneficial features and options, it does exhibit some limitations and negative aspects. The model does not allow for variations in driver behavior, such as different acceleration or deceleration rates for different driver types. Secondly, the model's input or output cannot be accessed by or exported to other traffic software programs, such as those that perform external signal optimization. It should be noted that most of the other simulation models also lack this feature.

Thirdly, the graphical display of INTEGRATION lacks realism in some respects. All of the links must be entered into the INTEGRATION model based on straight line representations. This method makes it difficult to view curves, such as loops, at an interchange. INTEGRATION does not provide microscopic characteristics of intersections. Therefore, the vehicle conflicts at signalized intersections cannot be accurately visualized.

Probably the biggest downfall of INTEGRATION is the lack of a graphical user interface module for building and editing the network. To prepare the network for INTEGRATION, several files had to be created for the nodes, links, O-D demands, traffic signals, incidents, lane striping, etc. These files were created in a tabular format where organization and proper referencing were essential to create an error-free transportation network. Efforts have been underway to create a graphical network editor which will greatly reduce the time/effort for building the model's transportation network.

***Modeling Effort***

Conducting a simulation analysis is major modeling effort, especially if the user is not familiar with the simulation model. The time to construct and code the transportation network depends primarily on the size of the study network, the level of detail that will be utilized, and the user's experience with the model. As previously mentioned, the lack of a graphical network editor in INTEGRATION significantly increased coding time requirements.

A significant amount of time was utilized during the calibration process. Every time that a refinement was made to the network, such as determining the proper simulation duration or traffic loading duration, the model had to be simulated and visually inspected to determine whether other changes had to be made. The simulation network required over 50 minutes to run on a high-end computer (450 MHz processor with 348 MB RAM); therefore, using a slower computer would dramatically increase the computing time. The simulation computing time primarily depends on the size of the network, level of detail, and O-D demands. A realistic estimation of the time to become familiar with the simulation model, as well as constructing and troubleshooting the case study corridor, is two person-months. The Houston, TX, study, which was discussed in Chapter 3, took approximately 3 person-months, while a large corridor study in Dallas, TX, took 12 person-months (Lee, Sibok, and Krammes, 1994).

***Data Availability Limitations***

The ability to acquire the necessary data to construct the simulation model is a challenging and time-consuming process. The required information must be obtained from a variety of agencies, including state, city, and other local agencies, and may take several weeks to obtain. Some of the data, such as geometric data, may be in an electronic format, however, information on some of the older roadways was only available in paper format.

The biggest challenge to a study of this nature is to acquire O-D data. Metropolitan planning organizations (MPO) in large urban areas may have the necessary personnel and resources to operate their planning model. However, smaller MPOs, such as the F-M COG, require a consultant to run their own planning model. Therefore, some additional expenses incurred to obtain the necessary O-D data. Conducting studies that require O-D demands in smaller urban areas, such as those less than 50,000 in population, are even harder to obtain since these cities are not required to perform traffic forecasts.

## Recommendations

Although the F-M metropolitan area has all of the incident management components to some degree, several improvements can be made to the incident management practices of metropolitan area, which include the following:

- Protocol for managing incidents,
- Implement ITS technologies,
- Uniform communication systems, and
- Centralized operations center.

Incident management systems encompass a large amount of information (i.e., incident location, severity, injuries, etc.) and require cooperation from multiple entities including state DOTs, law enforcement agencies (city, county, and state), fire departments, emergency medical services, and towing services. It is important to include all of the appropriate agencies and entities into the establishment of the incident management program. Furthermore, frequent communications among these parties is needed to ensure effective operations of the system.

The establishment of specific protocols or guidelines for all possible incident severities and locations would greatly improve the efficiency and effectiveness of the system. The protocol would provide criteria for involving certain agencies for various types of incidents, provide traffic control strategies (i.e., diversion routes), and establish jurisdiction among the agencies involved. The Metropolitan Incident Management Committee has developed protocols for long-term incidents, however, the committee has not developed any procedures for short-term incidents. The NDHP's current practice of incident traffic management is to have the on-site investigating officer determine the best traffic control strategies. An incident management system would incorporate optimum traffic management strategies, which could be developed by simulation models and committee input. Therefore, NDHP officers would have fewer issues to worry about during emergency situations.

Intelligent Transportation Systems (ITS) could be implemented into the transportation infrastructure to aid in incident management systems. Implementation of ITS would reduce or eliminate the need for law enforcement and NDDOT personnel to provide traveler information and traffic management during incidents, such as special events at the Fargodome. Providing traveler information about road closures, specifically when the interstates are closed or are about to be re-opened, would reduce the queues that occur near the freeway gates. The I-29 corridor will be reconstructed in a few years, providing an excellent opportunity to install some of the ITS infrastructure (i.e., communication technologies, vehicle detectors, and VMS).

Implementing a uniform communication system would allow all agencies to effectively communicate with other agencies and personnel. Since the F-M metropolitan area incorporates four cities, two counties, and two states, effective communication is a challenge for the agencies involved in an emergency situation. Currently, all local law enforcement agencies in the metropolitan area, which include the police departments of Dilworth, Fargo, West Fargo, and Moorhead along with Cass and Clay County Sheriffs

Departments, use different radio systems. Therefore, officers in each agency must go through dispatch centers to communicate with other officers. Direct officer-to-officer communication is available through the Fargo Dispatch Center, however, a time lag occurs in the transmission which makes it hard to communicate. The highway patrol is the only law enforcement agency that is effectively capable of directing communications with the dispatcher and other patrol officers. The F-M Ambulance, Fargo Fire Department, and Moorhead Fire Department also utilize different communication systems. Most of these entities communicate through the dispatch center, however, some agencies, such as the Fargo Fire Department, provide portable radio units to their personnel.

To take uniform communication to the next level, a centralized operation or dispatch center could be implemented. The agencies involved in such a merger could include highway patrols; state DOTs; local police, fire, and ambulance services; city traffic operations; and transit agencies. A good example of a centralized dispatching center is the Advanced Rural Transportation Information and Coordination (ARCTIC) center established in the Arrowhead Region of Minnesota. ARCTIC coordinates communication between state patrol cars, state DOT maintenance vehicles, snow plows, transit vehicles, and volunteer-driver vehicles located within the 18,000 square mile rural region. Due to the positive success of ARCTIC, the Minnesota Department of Transportation (MNDOT) plans to incorporate centralized communication centers in all MNDOT regions. These central control centers could also house traveler information and traffic management operations (Minnesota Department of Transportation, 1998).

The recommendations for the F-M metropolitan area could also be applied to other second-tier cities. Cities that have similar incident occurrences and frequencies, as well as possible diversion routes for freeway motorists, could experience similar benefits if ITS was implemented for incident management. The potential user benefits of an IMS include reductions in commute time and increased speeds. Increased safety, including reductions in secondary incidents, is also very important to an IMS and may occur with the implementation of ITS. Both the methodology and the simulation model (INTEGRATION) that were used for this study could be used in similar evaluations of ITS for incident management in other second-tier cities.

Incident management systems (IMS) are coordinated and planned programs that warn the motorist of traffic problems to optimize the efficiency and safety of the transportation system. Incident management incorporates ITS technologies, such as advanced telecommunications, computer sensing, and electronics. Existing IMS that utilize ITS technologies have exhibited reductions in travel time, fuel consumption, and secondary accidents. Future ITS implementation seems promising as traffic congestion increases and the cost to implement such technologies decreases. Simulation models are analytical tools that allow program users to evaluate different transportation strategies, such as ITS deployment. Therefore, continuous model refinements and improvements must be performed to provide more accurate and reliable results.

# REFERENCES

Al-Deek, Haitham M., A. Essam Radwan, Mohammed Abdallah, Sherif Ishak, Matthew P. D'Angelo, and Morgan C. Wang, *Volume I: Traffic Simulation along the I-4 Central Corridor*, Department of Civil and Environmental Engineering, University of Central Florida, Orlando, FL, October 1997.

Baker, M., and M. Van Aerde, *Microscopic Simulation of EPA Fuel and Emissions Rates for Conduction IVHS Assessments*, ITS America Conference Proceedings, Washington, DC, 1995.

Cambridge Systematics, Inc., *Incident Management. Final Report Prepared for Trucking Research Institute*, ATA Foundation Inc., Alexandria, VA, 1990.

Campana, Luis Raul, *Analysis of Freeway Diversion Routes for Incident Management Using Microscopic Computer Simulation*, M.S. thesis, University of Texas, Arlington, TX, August 1996.

Cragg, Catherine, and Michael Demetsky, *Simulation Analysis of Route Diversion Strategies for Freeway Incident Management*, VTRC 95-R11, prepared for Virginia Department of Transportation, Virginia Transportation Research Council, Charlottesville, VA, 1995.

Dudek, Conrad L., *Freeway Incidents and Special Events: Scope of the Problem, Management of Freeway Emergencies and Special Events*, *Transportation Research Circular*, Number 326, December 1987.

Fargo-Moorhead Metropolitan Council of Governments, *1996 Urban Area Traffic Count Map*, Fargo, ND, June 1996a.

Fargo-Moorhead Metropolitan Council of Governments, *Incident Management Standard Operation Procedures*, Fargo, ND, August 1996b.

Fargo-Moorhead Metropolitan Council of Governments, *Fargo-Moorhead Area Short and Long Range Metropolitan Transportation Plan*, Fargo, ND, October 1998.

Fenno, David W., and Michael A. Ogden, "Freeway Service Patrols: A State of The Practice," Texas Transportation Institute, Paper No. 980722, presented at the Transportation Research Board 77$^{th}$ Annual Meeting, Washington, DC, 1998.

Fink, Kenneth L., "An Analysis of Incident Management Programs in North America," *Graduate Student Papers on Advanced Surface Transportation Systems*, Texas Transportation Institute, Texas A&M University, Austin, TX, August 1993.

Gardes, Yonnel, and Adolf D. May, *Simulation of IVHS on the Santa Monica Freeway Corridor Using the INTEGRATION Model. Phase 2: Preliminary ATIS and ATMS Experiments*, California PATH, Institute of Transportation Studies, University of California, Berkeley, CA, August 1993.

Goolsby, M.E., *Influence of Incidents on Freeway Quality of Service*, Highway Research Record No. 349: Traffic Flow, Capacity, and Quality of Service: 5 Reports, Highway Research Board, Nation Research Council, Washington, DC, 1971, pp. 41-46.

Grenzeback, Lance R., and Clyde E. Woodle, "The True Costs of Highway Congestion," *ITE Journal*, Vol. 62, No. 3, pp. 16-20, March 1992.

Intelligent Transportation Systems, http://www.its.dot.gov/transi1.htm, 1998.

Judycki, Dennis C., and James R. Robinson, "Managing Traffic During Nonrecurring Congestion," *ITE Journal*, Vol. 62, No. 3, pp. 21-26, March 1992.

Krahn, Dawn C., *Motorists' Attitudes to Using ATIS at Highway-Rail Intersections*, M.S. thesis, North Dakota State University, Fargo, ND, May 1999.

Lee, Sibok, and Raymond A. Krammes, *Corridor Analysis Guidelines for Incident Management*, Texas Transportation Institute, Texas A&M University, Austin, TX, November 1994.

Lindley, J.A., "Urban Freeway Congestion: Quantification of the Problem and Effectiveness of Potential Solution," *ITE Journal*, Vol. 57, No. 1, pp. 27-32, 1987.

Lindley, J.A., "Transportation Research Circular 344: The Urban Freeway Congestion Problem," Transportation Research Board, Washington, DC, 1989.

Maas, Gerald C., Jr., "Estimating Benefits of ITS Technology in Incident Management: The Case of Northern Virginia," Paper No. 981341, presented at the Transportation Research Board 77th Annual Meeting, Washington, DC, 1998.

Mannering, Fred L., Mark Hallenbeck, and Jodi Koehne, *A Framework for Developing Incident Management Systems: A Summary*, Report WA-RD 224.2., Washington State Transportation Center, University of Washington, Seattle, WA, 1992.

McDade, Johathon D., "Personnel: The Critical Element in Successful Incident Management," *ITE Journal*, Vol. 62, No. 3, pp. 48-52, March 1992.

McShane, William R., Roger P. Roess, and Elena S. Prassas, *Traffic Engineering*, 2nd edition, Prentice-Hall, Inc., Upper Saddle River, NJ, 1998.

Meyer, M., *A Toolbox for Alleviating Congestion and Enhancing Mobility*, 2nd edition, Institute of Transportation Engineers, Washington, DC, 1989.

Minnesota Department of Transportation, 101 North Hoover Road, Virginia, MN, April 1998.

Mitretek Systems and PB Farradyne, Inc., *Developing Freeway and Incident Management Systems Using the National ITS Architecture*, FHWA-JPO-98-032, prepared for the U.S. Department of Transportation, Federal Highway Administration, Washington, DC, June 1998.

North Dakota Department of Transportation, 608 East Boulevard Avenue Bismarck, ND, May 1999.

Reiss, R.A., and W.M. Dunn, Jr., *Freeway Incident Management Handbook*, Report No. FHWA-SA-91-056, Federal Highway Administration, Washington, DC, 1991.

Skabardonis, Alexander, Ted Chavala, and Daniel Rydzewski, "The I-880 Field Experiment: Effectiveness of Incident Detection Using Cellular Phones," Paper No. 981273, presented at the Transportation Research Board 77th Annual Meeting, Washington, DC, 1998.

Smith, Steven, and Cesar Perez, "Evaluation of INFORM-Lessons Learned and Applications to Other Systems," Paper No. 920748, presented at the Transportation Research Board 71st Annual Meeting, Washington, DC, 1992.

United States Department of Transportation, *The National Architecture for ITS: A Framework for Integrated Transportation into the 21st Century*, Washington, DC, January 1997a.

United States Department of Transportation, *The National ITS Program: Where We've Been and Where We're Going*, Washington, DC, March 1997b.

United States Department of Transportation, *Intelligent Transportation Systems (ITS) Projects Book*, Washington, DC, January 1998.

Van Aerde, M., *Integration Release 2.10 for Windows: User's Guide-Volume I: Fundamental Model Features*, Blacksburg, VA, July 1998a.

Van Aerde, M., *Integration Release 2.10 for Windows: User's Guide-Volume 2: Advanced Modeling Features*, Blacksburg, VA, July 1998b.

Van Aerde, M., "A Single Regime Speed-Flow-Density Relationship for Congested and Uncongested Highway," Paper No. 950802, presented at the Transportation Research Board 74th Annual Meeting, Washington, DC, 1995.

Van Aerde, M., and M. Baker, "Modeling Fuel Consumption and Vehicle Emissions for the TravTek System," VNIS Conference Proceedings, Ottawa, Canada, 1993.

Walters, Carol H., "Setting an Ideal and Making it Real-Overcoming Institutional Barriers in Dallas," presented at the 1999 Institute of Transportation Engineers International Conference, Kissimmee, FL, March 1999.

Wie, C., P. Hsu, and S. Leung, "A Working Freeway Service Patrol Program Its Role in Traffic Management," ITS America Conference Proceedings, Washington, DC, March 1995, pp. 605-15.