An Application of ITS for Incident Management in Second-Tier Cities: A Fargo, ND Case Study

SHAWN BIRST AND AYMAN SMADI

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 using 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 13 percent (city arterials), 28 percent (freeways), and 18 percent (overall network); average trip times were reduced by 20 percent (overall network); and average speeds increased by 21 percent (overall network). Key words: incident management, second-tier cities, simulation models.

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 (*1*). 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 (*2*).

Advanced Traffic Analysis Center, Upper Great Plains Transportation Institute, North Dakota State University, Fargo, North Dakota 58105.

Background

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 (*3*). Incidents, such as traffic accidents, stalled vehicles, construction and maintenance, special events, and adverse weather conditions, account for nearly 60 percent of all traffic congestion in the United States (*4*). This congestion 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.

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 services, emergency medical services, hazardous material crews, and towing services, to facilitate nonrecurring congestion problems on freeway systems (*5*). Incident management systems attempt to reduce the detection, response, and clearance times of incidents, thereby reducing the delays experienced by motorists affected by the incident. Incident management also provides 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.

ITS in Incident Management Systems

ITS technologies were developed to increase the efficiency and safety of the transportation system. Incident management systems primarily incorporate two components: Advanced Traffic Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS). The ultimate goal of ATMS is to provide traffic control strategies that are capable of adjusting to the existing traffic demands through surveillance technologies, data processing, and communications (*5*). ATMS also can detect incidents using inductive loop detectors or video-image detectors. Based on the incidents' characteristics, ATMS can select a proper response, such as diverting upstream traffic away from the incident and adjusting traffic signal timing plans on alternative routes. In addition, the incident information can be provided to motorists using ATIS so they can adjust their travel routes.

ATIS collects and distributes traffic information for both "pre-trip" and "en-route" travelers (*5*). 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 motorists to change their plans or routes to minimize their travel times.

Traffic Simulation Models

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. Several freeway simulation studies have been performed to evaluate incident management protocols and strategies, including:

- Santa Monica, CA (I-10),
- Houston, TX (US-59),
- Arlington County, VA (I-66),
- Fort Worth, TX (I-35W), and
- Orlando, FL (I-4).

The freeway simulation studies varied in case study location, incident occurrence and duration, and optimization strategies. However, each study found that implementing various forms of ITS in incident management systems benefitted the transportation network. The studies evaluated several components of ATMS and ATIS, and estimated several quantitative system improvements, such as (*6*, *7*, *8*, *9*):

- Freeway and arterial speed increases of 15.3 and 10.1 percent, respectfully (Santa Monica, CA),
- Total network delay time ranging from 22.9 to 27.4 percent for the small network and 14 to 16 percent for the large network (Houston, TX),
- Diversion efficiencies as high as 298 percent for the small network and 79 percent for the large network (Houston, TX),
- Total system delay reduction of 63 percent (Arlington County, VA), and
- Total network delay savings of 1 to 11 percent, freeway delay savings of 300 to 500 percent (Fort Worth, TX).

IMPORTANCE OF RESEARCH

The case studies in the previous section analyzed freeway corridors in several large urban areas across the United States (note: no applications in smaller urban areas). Traffic levels, trip characteristics, and the availability of alternative routes are distinctly different in smaller urban areas; however, it is expected that similar benefits may be realized in small-to-medium size metropolitan areas. These benefits must be quantified and accurately examined to support ITS deployment decision in these areas.

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 (Figure 1).

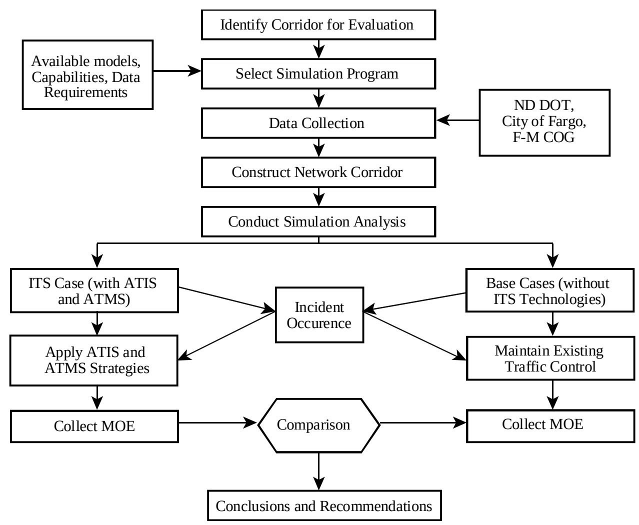

FIGURE 1 Proposed methodology flowchart

The evaluation is based on comparing key Measures of Effectiveness (MOE), such as travel time, trip time, and speed. The MOEs are estimated using traffic simulation models for several cases that represent the network under current conditions and with ITS deployment. 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.

The INTEGRATION simulation model (developed by Dr. M. Van Aerde) was selected for this case study for a number of reasons, including 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, and
- It provides graphical output, which allows the user to "fine-tune" or adjust the model to reflect actual traffic conditions and compare different scenarios.

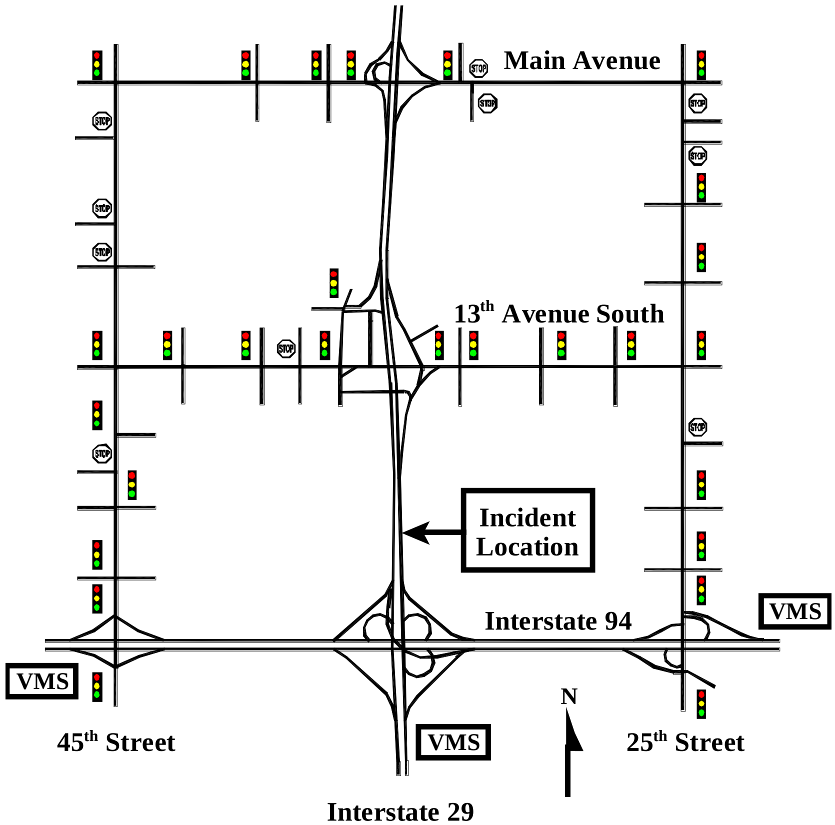

FIGURE 2 Case study corridor

CASE STUDY

Fargo is the largest city of the four-city Fargo-Moorhead (F-M) metropolitan area, which had a population of approximately 166,000 in 1996 (*10*). 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 occurred on the freeway system within the F-M metropolitan area between 1994 and 1996 (*11*). This information may be used for examining potential benefits of IMS.

The analysis was conducted on a portion of Interstate 29 (I-29) and Interstate 94 (I-94), which are predominantly used for local traffic. Four of the area's heaviest traveled arterials are included in the corridor, which will provide motorists with diversion routes during incident occurrence. An incident occurrence will be simulated on a northbound segment of I-29 (Figure 2).

Evaluation Scenarios

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:

- Scenario 1: Base Case (without incident occurrence, ATIS, or ATMS),
- Scenario 2: Incident Base Case (without ATIS or ATMS),
- Scenario 3: ATIS Case, and
- Scenario 4: ATIS and ATMS Case.

The simulation period for all cases has a duration of 1 hour and 40 minutes. The following list describes the simulation timeline:

- The network is "loaded" with off-peak traffic demands (5 min).
- Traffic demands increase to simulate AM peak hour traffic conditions (60 min). Traffic demands will return to off-peak conditions for the remainder of the simulation.
- A one-lane-blocking incident occurs on a northbound segment of I-29 at the beginning of AM peak hour traffic demands (20 min).
- Traffic returns to normal conditions (recovery period). The recovery period was determined by inspecting the on-screen graphics of the simulation model (63 min 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 min).

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

TABLE 1 Summary of Results.

		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total Travel Time (veh-hrs)					
	Fre	607	929	683	670
	Art	2095	2103	2114	1825
	Net	2702	3032	2797	2495
Average Trip Time (min)					
	Net	5.5	6.2	5.6	5.0
Average Speed (mph)					
	Net	21.4	19.1	20.7	23.2
Difference in Travel Time (%)					
	Fre	-35	0	-26	-28
	Art	0	0	1	-13
	Net	-11	0	-8	-18
Difference in Average Trip Time (%)					
	Net	-11	0	-10	-20
Difference in Average Speed (%)					
	Net	12	0	8	21

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

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 baseline 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 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. Freeway vehicles only will divert to alternative routes if it is more beneficial to do so.

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 similar to Split Cycle Offset Optimization Techniques (SCOOT). 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. 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 incident base case (Scenario 2) output served as a baseline for comparing the other scenarios to determine the effectiveness of the ITS cases (Table 1).

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.

Travel time generlly decreased as the amount of ITS deployment increased. When compared to the incident base case (Scenario 2), both Scenarios 3 and 4 provided freeway travel time reductions of 26 and 28 percent, respectfully. Since Scenario 4 also incorporated ATMS strategies, city arterial travel times were reduced by 13 percent. Scenario 4 provided greater network benefits regarding travel time than the base case without an incident (Scenario 1) since the existing traffic signal system is not operating at the optimal timing plans.

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 case that only provided traveler information (Scenario 3) reduced trip times by 10 percent. Providing traveler information along with adjusting the signal timing plans to reflect the current traffic demands (Scenario 4) enhanced the corridor's performance by reducing trip times by 20 percent. Similar to the travel time output, the ATIS/ATMS case out-performed the base case (Scenario 1).

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. The ATIS scenario (Scenarios 3) provided 8 percent higher average speeds, while the ATIS/ATMS strategies (Scenarios 4) provided an increase of 21 percent. The ATIS/ATMS case provided higher average speeds than those encountered by the base case. The higher speeds 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.

CONCLUSIONS

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 combination of ATIS and ATMS provided reductions in network travel time and network trip time of 18 and 20 percent, while increasing the average network speed by 21 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 4) only diverted eight percent of the traffic that would have used the incident location to the arterials.

An important benefit of incident management relates to safety improvements. A study determined that 20 percent of all crashes occur upstream from an incident (*12*). The traffic levels of the ATIS/ATMS case returned to normal conditions 13 minutes earlier than the incident base case, thus reducing the potential of secondary incidents.

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 to the late Dr. Michel Van Aerde, the developler of INTEGRATION, for assisting the authors during the simulation analysis.

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