Identifying Methods and Metrics for Evaluating Interagency Coordination in Traffic Incident Management

Final Report

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Executive Summary

Traffic incidents involve vehicle stalls and collisions, debris, stray animals and other impediments to the free flow of traffic on a public road. At an annual cost of $78 billion (TTI, 2007), traffic incidents are a pressing concern and attempting to manage these occurrences to avoid the costs discussed above is crucial in the current economic climate. Among transportation and traffic incident management (TIM) agencies in the United States, efforts are shifting from infrastructure creation and maintenance toward performance optimization through intelligent transportation systems (ITS) (Smith, 2007). As a result, considerable progress is being made in detecting and rapidly responding to unpredictable incidents as well as effectively managing planned incidents to reduce impact on road users.

Responding to traffic incidents, however, often requires resources from multiple agencies. Complicating this, each agency has different objectives from which they have derived specific response protocols. These different objectives often lead to conflicts between agencies during an incident, posing a significant challenge for those parties coordinating the overall incident management efforts between agencies.

Thus, the research objectives of this study were:

- Identify a common interagency goal;
- Use this goal to identify quantitative performance metrics that can be used to evaluate TIM performance; and,
- Identify a method for using these metrics as feedback to improve interagency coordination and overall TIM performance

With respect to the first objective, a literature review and competitive benchmarking effort using selected North American cities suggested the following common interagency goal:

> ***Without compromising safety, minimize the time spent dealing with a traffic-related incident.***

In turn, this goal suggested the following set of time-based metrics that could effectively evaluate TIM performance across all agencies involved – meeting the second objective of this study.

- Verification time: Detection to dispatch
- Agency dispatch time: Dispatch to arrival
- Lane clearance time: Arrival to lane clearance
- Queue dissipation: Lane clearance to all clear
- Removal time: Arrival to all clear
- Overall incident response time: Dispatch to all clear
- Overall incident time: Detection to all clear

Finally, these metrics suggested the use of a methodology for evaluating performance of a TIM system, the third objective of the study. Adopting a process-centered view for incident response, an internal benchmarking approach was demonstrated using process charting and a set of five statistical methods. Prediction model fitting, variability charts and process charting apply well to general performance evaluation and can be considered the primary benchmarking tools; one-way factor analyses, contingency analysis and descriptive statistics are secondary methods that, although valuable, may be more suited to answering specific questions about TIM performance.

As a result, this study recommends adopting a complementary approach to tackling the congestion and travel delays associated with incidents: make them as short as possible. In most cases, the less time that an incident has to impact traffic, the less congestion and delay it can cause. The following four recommendations were be drawn from the internal benchmarking demonstration to support a process-based approach to TIM performance improvement:

Recommendation 1

Modify data collection and archiving methods to support a process-centered approach to performance evaluation.

Recommendation 2

Using appropriate statistical tools, analyze archival incident response data to support internal benchmarking and subsequent process improvement efforts.

Recommendation 3

For each major incident type, compile process charts that illustrate the steps and completion sequences for each responding agency.

Recommendation 4

Develop simulation models of the incident response process.

Chapter 1
Introduction

A traffic incident is defined as a "…non-recurring event that causes a reduction in roadway capacity or an abnormal increase in demand" [1]. These incidents include anticipated and unanticipated events that are obstructions to the free flow of vehicular traffic. Traffic incident management (TIM) is "a planned, coordinated process to detect, respond to, and remove traffic incidents" in a manner that ensures motorist safety and the rapid restoration of traffic capacity [2]. The management of traffic congestion, vehicle crashes, and other such traffic incidents is highly important to most municipal authorities. To this end, steady but dramatic increases in urban populations have resulted in the development of new infrastructure and the modernization of existing road and railway facility to alleviate increasing demand on road networks.

Considering vehicle ownership trends and the limited benefits (and feasibility) of further road construction in finite and developed urban spaces, there has been a move toward intelligent traffic systems (ITS) aimed at optimizing existing traffic management methods, and demand control through improvements in the quality and availability of public transportation, flexible work hours, and high occupancy vehicle (HOV) and toll (HOT) lanes. However, with its rapid population and business growth, Minneapolis-St. Paul has the 17th highest level of traffic congestion in the U.S., according to the Texas Transportation Institute's 2007 Urban Mobility Report [3]. Traffic congestion is no small matter: in 2005 alone, the economic cost of traffic congestion in the United States was estimated at $78 billion. This is derived from the 4.2 billion labor-hours and 2.9 billion gallons of fuel (equivalent to 105 million weeks of vacation and 58 fully loaded supertankers) wasted due to traffic delays [4]. Effective and efficient TIM becomes even more critical in cities such as Minneapolis-St. Paul in which the population is large and growing. The Twin Cities is home to over 2.81 million people – a 6.4 percent increase from the 2000 census figures - and the number of households in the region rose to 1.1 million in the 5-year period following the census, according to Metropolitan Council estimates [6]. Since population growth can be correlated with increases in vehicle ownership and traffic density, one can extrapolate that traffic congestion will likely continue to worsen unless negated by effective traffic management practices, including TIM.

In Minneapolis-St. Paul, incident-induced delays account for about 50% of all traffic congestion [3] and at least one-half of these delays arise from unplanned and unanticipated incidents such as automobile crashes, debris, spilled cargo and stray wildlife. These conditions and increasing levels of congestion indicate the importance of effective TIM practices. Thus, could targeted modifications to the management of traffic incidents at Minnesota Department of Transportation (Mn/DOT) facilities reduce traffic congestion levels (and lower its national congestion ranking) by reducing delay times during traffic incidents and more quickly restoring free flow conditions (roughly defined as vehicle travel speeds of 60 miles per hour)?

One area to explore for targeted modifications is the resource coordination between multiple transportation and public safety agencies required for effective management of traffic incidents. In the Twin Cities, the Regional Transportation Management Center (RTMC) was opened by staff at the Minnesota Department of Transportation in the 1970's in response to a need for uniform traffic response systems in the Twin Cities. Tasked with monitoring and responding to traffic incidents across the region, the RTMC comprises multiple agencies, including the Minnesota State Police (MSP) dispatch, Mn/DOT Metro District Maintenance dispatch and the Mn/DOT Office of Traffic, Security and Operations [5].

Across the country, TIM personnel state that this type of interagency arrangement engenders coordination between law enforcement and transportation officials and allows for uniform incident response plans which, in turn, yields shorter incident response and clearance times as well as reductions in the risk of secondary accidents. But these claims are made anecdotally and rarely backed up with quantitative data or analysis. Yet, case studies of business and industry (e.g., manufacturing, retail, service) repeatedly show that, if performance measures are not consistently measured or evaluated, organizations frequently have difficulty identifying areas for improvement, hindering their ability to meet core objectives effectively and efficiently.

In addition, an absence of consensus between agencies on an overall TIM goal and related objectives often occurs and is manifested by overlap and gaps in response protocols. These are driven by agency-specific goals and performance measures and are thought to contribute to prolonged incident durations and degradation in public safety, greater probability of fatalities, longer traffic delays, and increased occurrence of secondary incidents (crashes or related events caused elsewhere in the transportation network by the subsequent delays and confusion of the original incident) [2]. To make matters even worse, the Statistical Abstract of the United States reports that, in 2005, three hundred and ninety-one (391) responders from various agencies were killed and numerous others injured or disabled while attending to an incident.

Research Objectives

This report considers TIM practices in selected cities across the United States in order to identify any quantifiable effects that coordinated TIM efforts have on traffic congestion measures and determine methods and metrics that could facilitate interagency coordination in the management of traffic incidents. This work, carried out with the support of the Northland Advanced Transportation Systems Research Laboratory (NATSRL) at the University of Minnesota Duluth, compares these findings to incident management practices at Mn/DOT's Regional Transportation Management Center (RTMC) in Minneapolis-St Paul and suggests modifications targeted to that facility. However, the suggestions made easily can be generalized and applied to other TIM facilities across the country.

This study attempts to identify and assess quantitative metrics through which interagency coordination of incident response could be evaluated and improved. Consideration will be given to how well a metric supports the goals outlined by the National Traffic Incident Management Coalition (NTIMC) and co-located agencies across the country: maximizing vehicle flow, minimizing congestion, providing traveler information, managing incidents, and aiding stranded motorists [5]. Keeping this in mind, the following three objectives are proposed:

1. Identify a goal common to all agencies involved in traffic incident management;
2. Use this goal to identify suitable quantitative performance metrics that can be used effectively to evaluate TIM performance; and

3. Identify a method for using these metrics as feedback to guide suggestions for improving interagency coordination and overall TIM performance.

Steps taken

To achieve these objectives, the following steps were taken. First, historical traffic data from 1982 to 2005 was analyzed for relationships between incident management programs in different North American cities. Possible performance metrics were assessed by comparing incident data to TIM practices (based on data and responses to surveys) in several North American cities. Time constraints necessitate the use of historical incident response data. Considerable ambiguity exists in definitions for TIM parameters; delay in one city might not be regarded as such in a comparable locale. In order to ensure standardization, data was obtained from the Texas Transportation Institute and not from individual agencies. While this had no apparent impact on the validity of results, the effects of city – specific variations were not as readily evident.

Second, as suggested above, TIM personnel in selected cities were surveyed to gather information on actual TIM practices utilized in each locale. Combining this information with the historical data provided some insight into likely cause-and-effect relationships. In this case, cities were selected based on levels of interagency coordination, population size, and other related factors. Because surveys, while an excellent source of information, are time consuming and have historically low response rates, city selection criteria were closely defined in an effort to (1) accomplish goals within the established time frame and (2) obtain relevant, representative information.

While this entailed using a smaller survey and sample size than considered optimal, comparing dissimilar cities would ultimately prove unhelpful.

Third, the results of these first two steps indicated that a process-based approach to evaluating TIM performance might be beneficial. However, none of the cities surveyed seemed to be using a process-based approach nor could an example be found in the TIM literature. To investigate how such an approach might benefit TIM practices, a proposed methodology was used to analyze a sample set of incident data obtained from the RTMC and suggest changes in data collection and analysis of appropriate TIM performance measures at the RTMC.

Report structure

To this end, this report is structured as follows. Chapter 2 reviews the literature on incident management with a focus on interagency coordination issues. This chapter looks to identify best practices, benefits and issues currently associated with TIM practices across the country. Chapter 3 outlines a competitive benchmarking approach taken in this study to build on the findings from the prior chapter. Chapter 4 presents results from an internal benchmarking exercise, keeping an eye on addressing the stated research objectives and Chapter 5 summarizes the findings, making suggestions to modify certain procedures in order to improve and guide TIM efforts. .

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Chapter 2
Literature Review

To investigate the effect of interagency coordination on Traffic Incident Management (TIM) and establish suitable performance metrics, a review of relevant literature on Traffic Incident Management has been conducted to determine variations in TIM approaches, documented effectiveness, and best practices across North America. This review looked to satisfy the research objectives by addressing questions concerning the effect of interagency coordination on the quality of response to traffic incidents, the effect of responder resources on their effectiveness and on the use of performance metrics that can be applied across agencies.

As TIM performance is commonly measured in terms of delay and congestion levels, definitions of these two measures should be standardized in some way. This report utilizes the standard definitions used by the Texas Transportation Institute (TTI); the TTI was also the primary source of historical data for the first step of this study. The TTI defines delay as "…travel occurring at less than free flow speed (60 mph [70 mph in Minnesota] on freeways and 35 mph on streets)" and congestion is defined as the accrual of delay [7].

Traffic Incident Management

A traffic incident is defined as an event that creates hazardous driving conditions and/or delays the normal flow of traffic. Traffic Incident Management (TIM) is an attempt to control these occurrences: "the systematic, planned and coordinated use of human, institutional, mechanical, and technical resources to reduce the duration and impact of [traffic] incidents [1]." To this end, Traffic Incident Management involves the timely detection of incidents and dispatch of necessary response personnel to execute predetermined plans that often entail the management of multi-agency, multi-jurisdictional responses to traffic disruptions [8]. Therefore, TIM increasingly requires cooperation between police, fire, medical, transportation, and other public and private agencies.

As was mentioned in Chapter 1, due to the nature of multi-agency operations, definitions for incidents and severity classifications are agency-specific and vary in accordance with organizational goals [9]. Incident severity depends on its effect on the following agency specific variables:

1. Public safety (Police departments)
2. Traffic flow (Departments of Transportation, DOTs)
3. Presence and extent of injuries (Emergency Medical Services)
4. Presence and extent of fires and/or entrapment (Fire departments)
5. Ease of retrieval and transportation (Towing companies)

Apart from delay and congestion (defined earlier), definitions in this report are intended to be consistent with Mn/DOT objectives and (where available) standardized, currently implemented interagency agreements. Although traffic delays often arise from planned or predictable incidents such as roadway construction and maintenance, athletic and entertainment events, parades and other highly attended public gatherings [10], the focus in this report is on unplanned or unpredictable incidents, such as those involving car crashes, stray animals, hazardous spills and other occurrences unexpectedly resulting in traffic delay and congestion.

Benefits of Traffic Incident Management

As suggested above, one can easily argue that society benefits from efficient and effective TIM programs [17]. The major benefits of TIM are expected to include reductions in incident induced delays and traffic congestion along with an increase in safety [15]. Shorter delays have benefits extending beyond the roadway network. The Environmental Protection Agency (EPA) reports the emissions from a single light-duty gasoline fueled vehicle (i.e., an automobile) contain an average of 21.2 grams/hour of Volatile Organic Compounds (VOCs), 371 grams/hour of Carbon Monoxide (CO) and 6.16 grams per hour of Nitrogen Oxide [16]. Factoring in emissions from trucks, busses and other large heavy-duty vehicles, reductions in a region's incident-induced traffic congestion should yield lower harmful emissions and improved air quality due to shorter vehicle operation and idling periods. In essence, TIM efforts have an added benefit of reduced fuel consumption and cleaner air. These claims were examined in a study of over 32,000 incidents by the Coordinated Highway Action Response Team (CHART) in Maryland in which researchers at the University of Maryland evaluated regional TIM system performance based on detection, response time, clearance and overall duration. They used this information to develop a regression model that illustrated an annual total delay reduction of 30 million hours due to regional TIM efforts, which they associate with a 5 million gallon reduction in fuel consumption [17].

Stages in Traffic Incident Management

Among transportation and Traffic Incident Management agencies in the United States, efforts are shifting from infrastructure creation and maintenance toward performance optimization through intelligent transportation systems (ITS) [11]. In doing so, TIM agencies are shifting their emphasis toward detecting and rapidly responding to unpredictable incidents as well as improving management of planned incidents so that any given incident will have a minimal impact on road users. As a result, incident management is becoming increasingly complex and utilizes a wide variety of strategies and standards.

Widely accepted as an authoritative voice on incident management practices [2, 8, 9, 12], the Traffic Incident Management Handbook details the following five stages of Traffic Incident Management [1], which is corroborated by other sources as well [8]:

1. Detection and verification
2. Dispatch and response
3. Site management
4. Traffic management
5. Traveler information

Detection refers to the means by which response agencies become aware of incidents. Examples include in-field discovery, 911 calls, closed circuit TV cameras, and loop detectors. Verification involves methods used to confirm an incident's occurrence and its location; these methods overlap with detection and include means such as closed circuit television cameras, loop detectors, and patrol teams. As shown in Figure 1.1, the duration of this stage is the time elapsed between an incident's occurrence and its confirmation by TIM parties.

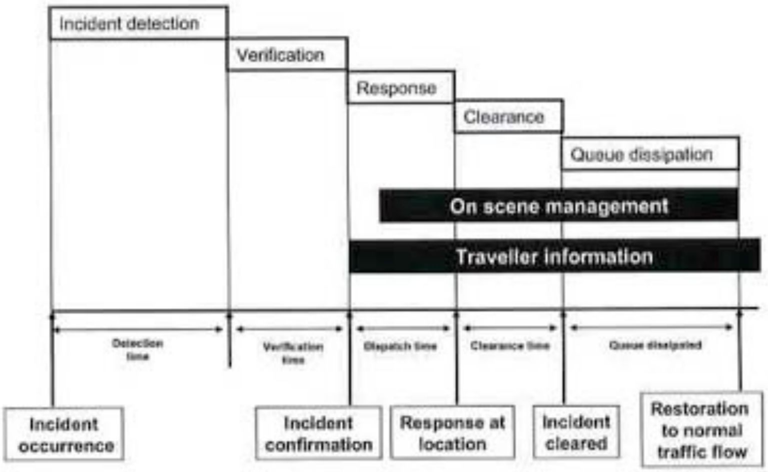


Figure 1.1: Incident management timeline [8]

Dispatch and response refer to activities after verification. Dispatch involves notifying appropriate responders and the length of this stage depends on how long it takes them to arrive at the incident scene after being notified (shown as "response at location" in Figure 1.1).

Site management is the process through which incident sites are secured. This entails taking steps to ensure the privacy of incident victims, containment of fires and other hazards and overall organization of responder – traffic flow within the incident site. This comprises one part of the "on-scene management" shown in Figure 1.1. The other part of on-scene management, traffic management, involves directing traffic flow around the scene of the incident while ensuring the safety of responders and the general public. This often involves either the use of personnel, signs, or roadway markers to divert traffic around an incident.

Finally, the “traveler information” phase involves disseminating incident information to road users, an element essential to traffic incident management. Variable Message Signs (VMS) and public radio systems help divert traffic to alternate routes, thus helping some drivers avoid the incident and reducing the chance for secondary incidents and prolonged delay.

Challenges to Effective Traffic Incident Management

Commonly in multi-agency initiatives, personnel intrinsically revert to the goals and practices of their specific agency. In TIM, Transportation, Police, Fire, and other Emergency agencies all respond to incidents, but each define an incident type and its severity in accordance with their own agency–specific objectives (Table 2.1). For example, transportation agencies classify incidents according to impact on traffic flow while emergency medical service agencies base incident ratings on injury severity and response resource requirements [2, 9]. If not resolved, these differences can create confusion and on-scene ambiguity concerning lines of authority and may also result in secondary incidents.

Table 2.1: TIM agency specific objectives

Agency	Primary goal
Department of Transportation	Minimize disruptions to normal traffic flow (frequency and duration)
Public Safety Personnel (Police, Highway patrol, etc.)	Protect and serve the public
Fire Services	Contain fires and related hazards as well as prevent further damage
Emergency Medical Services	Provide appropriate and timely medical interventions (triage, treatment and transport)
Towing and Recovery	Recover vehicles and clear roadways
Media	Alert and inform public regarding current incidents

On an interpersonal level, tasks performed by any one responder are dependent on his or her immediate individual goals and objectives, which may not be in accordance with the agency's overall goal. As noted by researchers at the Center for Advanced Transportation Technology (CATT) at the University of Maryland, schemes to standardize and measure TIM efforts are uncommon. Consequently, improvements to incident management are difficult to assess, particularly with respect to the effectiveness of proactive inter-agency cooperation. Complicating effective TIM efforts even further is the erosion of resources (equipment and personnel) in many publicly funded agencies, a factor identified by some researchers as an additional hindrance to "effectively contend[ing] with ever increasing congestion in the daily commuting traffic network" [17].

Approaches to Traffic Incident Management

Only in the past decade have proactive Traffic Incident Management practices been widely adopted. As a result, there is no single recommended method of implementation; instead, this rapid and sporadic development of TIM programs across the country over the past decade has created a hodgepodge of TIM procedures and guidelines that vary widely from a more "traditional" ad-hoc and unstructured use of response agencies on one extreme to interagency teams utilizing coordinated response protocols on the other [13]. Many locales seemingly have "reinvented the wheel" when implementing or modifying a TIM program, repeating efforts and – in some cases - mistakes already carried out elsewhere. While region-specific protocols appear essential to the success of TIM, some understanding is needed regarding which methods applied in successful TIM agencies across the country are regionally specific and which can be considered "best practices" that can be applied anywhere in the country.

The wide variation in TIM quality and standard operating procedures has prompted a movement to create a national approach to incident response. The National Traffic Incident Management Coalition (NTIMC) – an alliance of national organizations that represent TIM stakeholders from across the United States – has formulated a National Unified Goal (NUG) to promote a unified national agenda for TIM practices. Stakeholder groups include Transportation Departments, Public Safety Communications bodies, Emergency Medical Services, Law Enforcement agencies, Fire & Rescue services, and Towing & Recovery firms. The NTIMC argues that its NUG will facilitate performance measurement and improvement efforts as well as improve program and institutional cohesion in joint incident management exercises. In particular, the NUG has the dual aims of *reducing traffic congestion* and *increasing responder safety* by advocating the nationwide adoption of unified, multi-disciplinary policies, procedures and practices geared toward optimizing the following [14]:

1. Responder safety;
2. Safe, quick incident scene clearance; and
3. Prompt, reliable incident communication.

However, the NUG may be met with some resistance. The idea of a generalized national strategic approach may not sit well with many regional TIM centers, who have already adopted specific pragmatic approaches they believe work for their areas and which also account for regional factors. Further, in their 2002 report on *Incident Management Performance Measures* [2], Balke, Fenno and Ullman suggest that most regional agencies have converged independently on a common set of performance measures that help them manage incidents:

1. **Detection Time** – the time between the occurrence of an incident and notification of a response agency.
2. **Preparation (or verification) Time** – the elapsed time between when an incident is detected to when the response vehicles are dispatched.
3. **Response Time** – the elapsed time between when the response vehicle was dispatched and when response vehicles arrive at the incident scene.
4. **Clearance Time** – the elapsed time between when response vehicles arrive at the incident scene to when traffic completely recovers after the incident.
5. **Response Time** – the elapsed time between when an incident is

detected to when the response vehicles arrive at the scene.

6. **Incident Duration** -- the elapsed time between when an incident occurred to when the response vehicles depart at the scene.

Performance Measures

This common set of performance measures warrants further exploration. In general, performance measures are standards that express the degree to which tasks are accomplished efficiently and effectively. In many settings, performance measurement includes the use of statistical analysis to determine conformity to organizational goals [2]. These measures reflect the objectives governing the activities being performed and are used for [27]:

1. Identifying critical areas,
2. As-is situation analysis,
3. Planning and implementing changes,
4. Monitoring results, and
5. Developing control systems.

While the cost of operations provides some indication of business performance with regard to profitability, a focus on cost management/reduction in project and agency management is often achieved at the expense of true organizational goals [28]. Thus, a need exists for additional indicators that directly reflect and drive commitment toward accomplishing the goal of the agency in question, highlighted by the following quote from a Brown University report on performance measurement [29]:

> "The rationale for performance measurement is that [every]…organization requires objective feedback about its own performance [This is feedback with which] it can

> internally…support quality-improvement activities, and externally demonstrate its accountability to the public, payers, regulators and advocacy groups”.

Further, the Government Accounting Standards Board (GASB) defines performance measurement as the reporting of “…Service Efforts and Accomplishments (SEA)…” which indicate:

1. Productivity (expresses outputs as a quantitative fraction of inputs),
2. Effectiveness (provides relation of outputs to intended goals),
3. Quality (relates performance to accepted standard or state of practice), and
4. Timeliness (measures the time required to produce a desired output).

These measures are generally aimed at identifying areas in which to make improvements, whether by indicating successes to be duplicated or shortcomings to be addressed. In this case, performance measures provide a baseline for the evaluation of subsequent efforts that [30]:

1. Provide a basis upon which required improvements can be determined; and
2. Allow for predictions of future performance – invaluable in planning for future agency expansions should urban/road network growth occur.

Perhaps of greatest importance is the use of performance measures in progress reporting. In cases where the measures are representative of TIM goals (e.g., where they provide feedback on the impact of incidents on traffic flow), they facilitate detailed evaluation of TIM practices, allow for comparison between locations and inform the determination of aggressive but achievable goals.

Performance Measures in Traffic Incident Management

As previously stated, performance measures indicate the quality, effectiveness, and appropriateness of incident management practices. Said measures are often agency-specific and are closely related to the objectives of each TIM organization (Table 2.2). Notably, police and public safety agencies have goals and performance measures that are most closely related. This is not surprising, given that both agencies are committed to the safe and rapid clearance of incidents and the maintenance of orderly traffic flow – more so than other response agencies. This may explain the trend toward co-location of Transportation and Police agencies in several U.S. cities.

Table 2.2: Examples of agency specific goals and related performance measures

Agency	Goals	Performance Measures
Transportation	Minimize delay, Improve safety, Provide relevant traveler information	Response time, Clearance time
Police/ Public Safety	Maintain law and order, Improve safety of general public and responders	Response time, Clearance time
Emergency Medical Services	Prevent fatalities, Minimize and treat injuries, Provide safe transportation to secondary "level of care"	Number of fatalities, Number of injuries, Number of responders dispatched, Response (arrival) times

Barriers to Effective Performance Measurement

As discussed earlier, the use of agency-specific goals and definitions complicate incident management, data collection and consequently the ability to assess improvements in response, clearance, and other incident management goals. This fragmentation leads to a lack of understanding of metrics where present and a resultant lack of uniformity in the application of these metrics.

An example from a non-transportation related entity illustrates this issue. In their report on the Value and Impact Program (VAMP) at university libraries across the United Kingdom, Creaser, Conyers, and Lockyer discuss the perceived lack of effective performance measures at these institutions. Through surveys and other analysis, they portray a lack of either understanding or awareness of available tools, a lack of standardized tools and methods of application, an overall unawareness of the relationship between feedback from existing performance tools, and overly broad objectives [31]. Although not in the area of traffic management, lessons learned here readily apply to TIM.

As evidenced in recent attempts by the NTIMC at education and streamlining of national TIM activities, the conditions described by Creaser et al (2007) are common to large, decentralized systems. The Kansas City Scout (Kansas City's TIM body) details [32] similar challenges faced in disseminating incident management guidelines and increasing awareness of the existence and content of the manual among TIM personnel. This challenge is exacerbated in situations in which component agencies are increasingly dissimilar – achieving consensus between Department of Transportation and fire or emergency medical services, for instance.

Best Practices in TIM Performance Measurement

In their investigation of system operations performance measures for the Virginia Department of Transportation (VDOT), researchers from the Virginia Transportation Research Council (VTRC) attempted to "develop system operations performance measures for VDOT" [11]. They discussed the need and willingness at VDOT to determine and standardize definitions for incidents, incident duration, and other like parameters. By placing focus on agency goals aimed at improving safety and security, preserving infrastructure, and improving highway operational performance, VDOT was able to develop a set of clear measures for assessing various TIM related efforts in traffic operations, incident response, traveler information and ITS device reliability.

In general, the integration of performance measures into the budgetary process is also advocated by the Government Finance Officers Association (GFOA) since [33]:

1. Government agencies use strategic plans to identify broad goals, which are then translated into specific objectives;

2. Budgetary decisions are framed on the basis of results and outcomes that are directly linked to these specific goals and objectives; and

3. Performance measures are the sole means of monitoring results and outcomes, and thus, the achievement of outlined goals and objectives.

As a result, the GFOA calls for the use of non-generic performance measures. Their argument appears to oppose the propositions of organizations like the NTIMC who are looking to create common and perhaps generic measures and goals for TIM organizations across the country. However, while basic concepts of performance measurement apply across industries, the need for non-generic measures in the highly diverse and mature financial sector of government and private organizations may not be readily transferable to the largely generic transportation sector. Although true that locales may differ and adaptations might be necessary, the need in TIM is largely one of uniformity with an aim to create comparable performance data. And, arguably, the best method to identify and utilize these performance measures is benchmarking.

Benchmarking

An internationally recognized authority on benchmarking, knowledge and performance management, the American Productivity and Quality Center (APQC) defines benchmarking as the "process of **identifying**, **sharing**, and **using** knowledge and best practices [involving] the continuous process of measuring products, services and practices" [19]. The identification process involves establishing *what* is to be compared and *where* or *with whom* said comparisons are to be made. Sharing refers to the exchange of identified parameters or processes between benchmarking partners, who then apply or exploit shared knowledge to the advantage of their respective agencies.

A comprehensive understanding of the benchmarking process is gained through clearly defining the parameters being measured and leads to the determination of best practices; activities that give an organization a competitive advantage [20]. Within industry, Wireman indicates that best practices vary depending on industry conditions and product life cycle – for example, while best practices in a declining industry will reflect profitability and risk aversion capabilities, a manufacturer of products that are in the growth phase of the product life cycle will look for best practices that yield market penetration, customer satisfaction and an increasing return on investment.

In order to assess performance in TIM, the effects of interagency coordination on incident management must be better understood. In this case, the expected (normal) responses (or, baselines) must be identified before post interagency coordination comparisons can be made. Where interagency comparisons are being made, generally accepted response metrics – based on information from government or other nationally recognized transportation research bodies – should be used as performance measures. Benchmarks serve as excellent tools for performance evaluation and the determination of best practices. While they do not relieve managers of goal and direction setting responsibility, they serve as valid yardsticks for progress measurement and as indicators of methods to be adopted [21]. The establishment of these standards (benchmarks) in TIM is crucial as failure to do so will hinder identification of interagency coordination effects on the quality of incident response, discovery of areas in need of improvement, and evaluation of performance metrics required for continuous process enhancement.

By providing an objective assessment of internal changes in performance, the creation of relevant internal and/or external baseline standards against which future performance can be evaluated gives insight to organizational strengths and weaknesses [22]. This allows for innovation through proactive process improvement attempts by management and non-management staff [23]. When these measures are collected by a different organizations working toward a common goal, benchmarks can provide a useful tool for motivating individuals and creating “learning organizations” adept at knowledge acquisition, transfer and rapid adaptation into standard operating procedures [24]. McGonagle and Flemming [39] claim the benefits of effective benchmarking include:

1. An exposure of disparities between perceived and actual organizational performance,
2. The creation, and sustenance, of momentum for organizational change,
3. The establishment of criteria against which goals, and advancement toward said goals, can be determined, and
4. The discovery of improvements in “the state of practice” with respect to technological and other improvements.

These benefits are directly applicable to the operation of Traffic Incident Management programs and the interactions between agencies. The development of benchmarks could provide a means to identify cities with best practices with regards to incident clearance, traffic congestion, and other such criteria. Benchmarks also provide a basis against which local agencies can measure performance and, in turn, identify areas in which improvements are needed. Developing benchmarks in this sector would, therefore, facilitate interagency and perhaps even inter-city TIM coordination, as promoted by the NTIMC.

Approaches to Benchmarking

In the attempt to determine suitable performance metrics, it is essential to choose an appropriate benchmarking methodology. To this end, consideration will be given to various benchmarking methods. A brief review of these approaches and previous applications should provide an indication of any methods currently used in the transportation industry and of the method(s) to which this study is best suited.

The fact that benchmarking highlights potential targets for improvement makes it critical to the success of any improvement project. In accordance with project specific requirements and resource availability, the following approaches to benchmarking are discussed by Storhaug [26] as originally put forward by McGonagle and Flemming [39]:

1. **Internal Benchmarking:** In this approach, an organization looks within, often to other divisions for ideas for improvements. Typically, the focus is on low-level, repetitive operations lacking strategic focus.

2. **Competitive Benchmarking:** This method involves comparisons between competitors on specific products or operations, often using information readily available in trade journals and other public portals.

3. **Shadow Benchmarking:** In this scenario, benchmarking is aimed at dominance to the detriment of the organization being benchmarked as opposed to the improvement of the general “state of knowledge/practice.” Competitor-to-competitor comparisons are made without the knowledge of the “benchmarked” party.

4. **Industrial Benchmarking:** This approach appears to eschew the intuitive purpose of benchmarking activities. The comparison here is often with an organization not typically considered as exemplar. Industrial, or functional, benchmarking often is used by organizations in search of new and different ideas for process improvement.

5. **Transnational Benchmarking:** This involves comparisons of generic, non-industry-specific activities. Also aimed at the determination and application of best practices, this method involves comparisons with organizations considered "best in class" for the activity being performed.

APQC Blueprint for Benchmarking

Irrespective of approach, a generic benchmarking process outline (Figure 2.1) has been developed by the APQC. The concept of a "structured approach" to benchmarking has been widely upheld by organizations in which benchmarking activities have been successfully conducted [25, 26]. Among these approaches, the APQC is widely recognized as having the best methodology. Its four-step approach is divided into a planning, [data] collection, [data] analysis, and an adaptation phase.

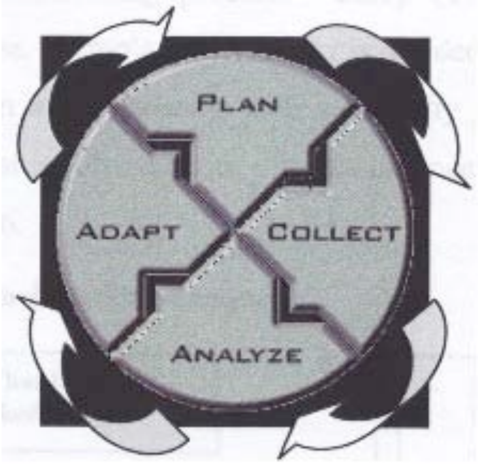


Figure 2.1: The APQC benchmarking cycle [25]

The first stage, planning, involves the determination of key measures and focus areas. It entails the identification of data collection tools and best practices through preliminary research. In the second stage, collection, the aim is to use tools like questionnaires and surveys to gather "qualitative data." Visits may then be organized to locations in which desired best practices (determined in stage 1) have been successfully implemented.

In the third (analysis) phase, critical evaluation of the data is conducted to identify trends, anomalies and specific cause-effect relationships. The aim in this phase is to identify factors that support or impede the achievement of desired goals. These findings then inform recommendations that are proposed to the client. In order to ensure success, the fourth stage of the benchmarking cycle looks to integrate (adapt) the proposed solutions to existent practices, or to the overall culture, at the client organization [26].

Finally, the APQC highlights three attributes common to historically excellent benchmarking activities:

1. The realization that knowledge transfer is a people-to-people process. Interpersonal relationships are central to the successful establishment of benchmarks and must be developed before meaningful information sharing can occur.

2. An ongoing commitment to the re-evaluation of benchmarks. The learning process is dynamic and employee knowledge acquisition leads to process improvements. Realization of this process and the creation of avenues through which acquired knowledge can be disseminated within an organization is essential to the benchmarking process.

3. A deep-seated desire to learn. The APQC informally defines benchmarking as being sufficiently humble to admit that others perform some tasks better and wise enough to learn to match and surpass them at said tasks.

Approaches to Benchmarking in Traffic Incident Management

Based on a review of TIM literature, the predominant approach to benchmarking among TIM agencies and municipal traffic authorities focuses on **internal** and **competitive** benchmarking. One example of pre-existent internal benchmarking occurs in Salt Lake City, where the Utah Department of Transportation (UDOT) uses postage paid response cards to solicit feedback from motorists involved in a traffic incident.

These responses provide raw data for evaluating the effectiveness of operational changes. Other sources of data that can be used in internal benchmarking include uniform computer aided dispatch (CAD) systems which, when properly implemented, can generate automatic records of incident response and clearance times, and shared radio systems (between police and transportation, and in some cities, fire personnel), which can provide transcripts from which interagency coordination can be analyzed to suggest updated training requirements, protocol adjustments, and required improvements to information dissemination systems. The records generated by these systems provide the historical basis for internal performance against which current and proposed activities can be measured.

Competitive benchmarking among TIM agencies is facilitated by published studies and research projects. Agencies and programs like the Federal Highway Administration (FHWA), the Transportation Research Board (TRB), the National Cooperative Highway Research Program (NCHRP), Texas Transportation Institute (TTI) and Austroads provide a wealth of information about traffic incident management in not only the United States, but in countries around the world.

Challenges to Effective Benchmarking Practices

Because TIM involving multiple agencies dispatched from a single location is a recent development, few uniform metrics for this scenario exist. Farradyne discusses the discrepancy between traditionally benchmarked data and incident performance measures. He states that there is no means for comparison between agencies due to the absence of quantitative measures [1].

A considerable challenge to effective internal benchmarking is the absence of good data. Due to the high workload and responsibility levels in TIM centers, the inconsistencies in training procedures for data entry personnel, or perhaps simply sheer fatigue, the information found in many TIM data collection systems is either incomplete or illogical. As discussed by Katmale and Wyrick [34], such data sets compromise efforts at process improvement and often require careful examination of incident radio transcripts – a time consuming process which TIM personnel cannot often indulge.

Networking at transportation conferences with professionals from other TIM centers can make for excellent industrial benchmarking opportunities based on proximity, personal preference, and other similarities. However, the NTIMC and similar organizations have yet to achieve consensus buy-in by TIM agencies across the country, thus denying prospective benchmarking partners the opportunity to utilize standardized "best in class" performance metrics. Further, reviewing and analyzing transportation-related literature detailing best practices and other such recommendations often requires considerable time commitment, which TIM agencies typically cannot afford their employees. Regrettably, crucial information contained in such reports often gain prominence only after major transportation disasters.

Perhaps of greatest concern, is the challenge posed to effective comparisons between TIM agencies (both intra- and inter-city) by the absence of clearly defined and standardized measures of performance. This absence can hinder effective benchmarking and, as noted earlier, the differences in agency goals, training procedures, and authority structures often impede incident clearance and increase the likelihood of a secondary incident. There remain, however, stellar examples of effective TIM practices which will be presented in later chapters of this report.

Chapter 3
Competitive Benchmarking

As noted in the prior chapter, benchmarking is a widely accepted and proven method for evaluating program effectiveness [22]. Recall that planning, the first stage in benchmarking, involves identifying areas of focus and associated metrics, then utilizing research to select appropriate data collection methods and best practices. From a benchmarking view, incident management can be considered as a service provided to motorists. This service is rendered by the TIM agencies through use of an incident response process intended to minimize the impact of incidents on other motorists. In this view, the motorists' perception of incident response quality is a critical metric and quality is compromised if a motorist perceives a discrepancy between their expectations for incident response and the actual response experienced. Personal comfort also plays a part, influenced by the degree of inconvenience the motorist associates with the incident response process. In this case, because delays experienced by road users (clients) due to an incident are typically unexpected and perceived as inconvenient, delay-related metrics will likely provide a reasonable indicator of how motorists will rate a region's incident response quality.

Competitive Benchmarking

From a competitive benchmarking standpoint, using delay-related measures to indicate the quality of TIM in a region would permit comparisons of incident-related delays between different cities. These comparisons could be used to estimate the impact of different levels of interagency coordination on incident-related delays and indicate TIM practices associated with high-quality incident responses.

To explore this further, uniform data sets for incident response in several North American cities were obtained from the Texas Transportation Institute (TTI). TTI compiles exhaustive data sets on traffic flow in regions across the United States and publishes an annual Urban Mobility Report. Because the Urban Mobility Report presents various transportation-related measures for cities throughout the United States, the TTI database has been standardized with regard to definitions of the data collected, methods of collecting that data and the calculations utilizing that data. Time constraints and limited access to personnel and comprehensive data sets also influenced the decision to use the TTI data sets.

In addition to comparisons based on the data obtained from the TTI, a second method of competitive benchmarking was also used: surveying TIM agencies from different regions across North America. As is widely discussed in literature, surveys can be conducted in three primary ways [36, 37]: face-to-face interviews, telephone interviews, and self-administered questionnaires (mailings, e-mail, web based, et cetera). Notably, the effectiveness of each survey type progressively declines, starting with the highly effective *face-to-face* interviews and ending with the *self-administered* alternative that is often biased by low response rates and nonchalant responses. Because survey respondents were spread across the country, face-to-face interviews were deemed prohibitively expensive and inefficient in view of time constraints. Telephone interviews remained an acceptable option, but the need for detailed information on TIM practices necessitated the design of short, self-administered surveys. The risk of low response rates typically associated with this latter approach was mitigated through the following techniques.

1. <u>Targeted selection of respondents</u>

   Applying the criteria in the following section, Traffic Management Center supervisors or other such professionals with a significant interest in TIM improvements were identified as potential respondents to this survey.

2. <u>Initial telephone contact</u>

   Once respondents were identified, they were contacted by phone and preliminary discussion held with each prospective respondent in order to detail the broad objectives of the study and its expected benefits as well as to make a personal request for participation in the survey.

3. <u>Reiteration of survey objectives</u>

   Once a potential respondent agreed to participate, the survey was sent by e-mail. The survey included a brief re-introduction the project, assured participants of response and personal detail confidentiality, and requested contact details for follow-up purposes (e.g., confirmation of the veracity of statements made in telephone and e-mail correspondence.)

The questionnaire (Appendix A) was designed to elicit specific information from which cause-effect relationships might be determined as well as provide broader details on operations in each locale. This latter information was solicited through open-ended questions and a request for "any additional information" deemed relevant to TIM interagency coordination.

Identify Similar Regions for Comparison

In order to utilize competitive benchmarking, regions similar to Minneapolis-St. Paul with respect to TIM had to be selected. In 2003, the Transportation Research Board published NCHRP 520 [15], a study on incident management practices in U.S. cities providing insight into levels of interagency coordination in each of the cities included in the report. Selection of regions was based on the following criteria indicating a region's similarity to Minneapolis-St. Paul; inclusion in the Federal Highway Authority's Intelligent Transportation Systems (ITS) early deployment plan (EDP) and the NCHRP 520 report was weighted heavily as these provided contact information for individuals who had participated in prior TIM studies. Table 3.1 shows the cities selected for consideration and the criteria which applied.

1. <u>Number of peak period travelers</u>

   Based on peak travel volume data from the Texas Transportation Institute, this criterion was chosen on the assumption that similar numbers of peak period travelers would yield comparable incident levels.

2. <u>Population size</u>

   A common measure used in comparing cities, this criterion was assumed to impact the number of peak period travelers.

3. <u>The number of freeway miles</u>

   The number of freeway miles covered by the TIM center in question is a measure of infrastructure availability. Comparing miles to population size and traffic density was thought to provide an indication of the effectiveness of certain TIM practices and facilitate comparisons between locales.

4. <u>Availability of quality data</u>

    As discussed by Katmale and Wyrick [34], the availability of quality data relevant to TIM in a given city is a major determinant. Inconsistent, inaccurate, or missing data is a major hindrance to effective benchmarking and improvement initiatives. The NCHRP report provided some indication of a region's data quality.

5. <u>Evidence of efforts toward implementation of interagency TIM plans</u>

    The extent to which TIM activities are coordinated in a given locale was another criterion selected. TIM activities across North America were divided into the following categories:

    > <u>Category A:</u> Indicates proactive Traffic Incident Management that may include co-location of several agencies in a single command center (like the RTMC).
    >
    > <u>Category B:</u> Although formal/procedural incident management plans exist, they are not proactively implemented.
    >
    > <u>Category C:</u> No Traffic Incident Management plans implemented or published.

    This criterion, coupled with explanations for the division between categories (in Chapter 4), was assumed to provide further insight into the effect of interagency interaction on Traffic Incident Management and have the potential to assess the effect of interagency coordination on the quality of incident response.

6. Infrastructure similarity

   Finally, a relationship may exist between freeway network characteristics (shape, number of intersections, and size) and the number of incidents and level of incident-induced delay experienced in U.S. cities. This relationship is thought to impact response time and, in some cities, interagency coordination efforts.

Table 3.1: City selection criteria

City	Selection Criteria
Minneapolis-St. Paul	
Albany, NY	Inclusion in NCHRP 520, TIM agency co-location
Austin, TX	Inclusion in NCHRP 520, nascent TIM co-location
Cincinnati, OH	Inclusion in NCHRP 520, significant coordination without co-location, geographical and freeway network similar to the Twin Cities
Kansas City MO-KS	Structural similarity (Twin Cities)
Seattle, WA	Population (3.0 million); implementation of interagency TIM plans
Salt Lake City, UT	Inclusion in NCHRP 520
San Diego, CA	Population (2.9 million), inclusion in NCHRP 520

At this point, some detail regarding the individual regions selected is warranted. Albany is a small city in which co-location and resource sharing between police and transportation officials occurs primarily as a result of proximity to the New York Thruway system. The inclusion of Austin gives some insight into conditions before co-location and the process of achieving coordination between agencies. TIM practices in Cincinnati involve a wide array of public and private agencies. Coordination between these agencies appears to rival that of most co-located areas. This case seems to challenge the need for co-location and provides an interesting perspective.

Kansas City, geographically split between Missouri and Kansas, was chosen primarily due to its structural (municipal) similarity to Minneapolis-St. Paul. Being a "twin city" in Missouri and Kansas, any effect of jurisdiction overlap or other administrative issues should - to some extent - be evident in both cities. If an effect is not evident in one of the cities the method of mitigating such problems might be included in best practice recommendations for implementation in the other city.

While having a strikingly different geographical layout from Minneapolis-St. Paul, Seattle is a larger city in which interagency coordination has also been implemented, although lacking a co-located center on the scale of the RTMC. Its inclusion was partly driven by the degree of cooperation by officials at the Washington Department of Transportation.

The effect of geographical layout can be discussed in light of data from San Francisco, which was included based on analysis by Brooke (2004) in the NCHRP 520 report. Also identified in the NCHRP 520 report, Salt Lake City is a growing, mediumsized city (population: 1.06 million) [35]. Though located in a single building, police and transportation personnel operate out of separate areas.

Results

The survey results are summarized in Table 3.2; see Appendix C for the unedited responses to the open-ended questions on the survey. With respect to the latter, while several respondents indicated improvements to TIM as a result of coordination between agencies, most responses reinforced the pattern evident in the literature of portraying qualitative benefits with little or no quantitative basis – apart from possible cost savings to the agencies involved.

While spending reductions are beneficial, the objective of most TIM agencies remains the maintenance of safe and "hassle-free" traffic flow. As defined earlier, incident-induced delay refers to both reductions in the free flow of traffic that are solely due to an incident and delays that are exacerbated (i.e., in addition to normal traffic delays) as a result of traffic incidents. Anecdotally, TIM-related improvements (i.e., improved interagency coordination plans, increased traffic capacity (e.g., additional lanes)) are believed to positively impact motorists as reflected in changes to incident-induced delay over the years. On the other hand, these impacts may be masked by increases in regional population and road construction projects.

Notably, cities in which co-location does not exist are relatively small compared to Minneapolis-St. Paul. Further, attempts at correlating delay data with population or size of the freeway network (in miles) proved unsuccessful. Although the number of miles in a regional freeway network tended to increase as the region's population climbed, the rate of increase varied widely between cities. Thus, an alternative method of evaluation was devised in which cities were divided into the following three categories reflecting the levels of interagency coordination:

<u>Category A:</u> Proactive interagency Traffic Incident Management.

<u>Category B:</u> Formal/procedural interagency incident management plans.

<u>Category C:</u> No interagency Traffic Incident Management plans.

Table 3.2 indicates the category assigned to each city selected for this study as well as the factors used in assigning these classifications.

Once assigned, TIM efforts in category A cities were compared with efforts in cities assigned to categories B and C in hopes of identifying any effect on incident-induced delays due to coordination level. However, this also was unsuccessful, as illustrated by Figure 3.1 which compares incident-induced delay in three cities. Minneapolis falls into category A as does Seattle, the latter providing one of the best examples of interagency collaboration in terms of protocol and goal setting for TIM practices. Yet between 1982 and 2005, delays in both cities increased at roughly 1.25 million hours/year while delays in Salt Lake City, placed in category B because TIM agencies are located in separate rooms and lack formal inter-agency agreements, increased only about 0.25 million hours/year.

Table 3.2: Survey-based Classification of Interagency Coordination Levels

	Information Sharing				**Formal Agreements**		
City	**During Incidents**	**After Incidents**	**Communication Systems**	**Shared Facilities**	**Consensus Metrics**	**Consensus Guidelines**	**Category**
Albany, NY	Sometimes	Sometimes	Phone, Teletype	**Yes** - NYSDOT & NYSP only	No	Incident Command System (Executive order)	B
Austin, TX	**Yes** - Voice, Electronic (to be implemented)	**Yes** - Face-to-face meetings (1 week after)	Radio, Phone *(primary)*, e-mail, CAD *(available but not used; staff do not dispatch for rest of DOT)*	**Yes** - Local Police, State and Local transportation, Fire and EMS	No	**No**	B
Cincinnati, OH	**Yes** - CAD (ARTIMIS monitors activity)		Local police have direct radio link to the ARTIMIS control center. All traffic related incidents are sent to ARTIMIS from the County's dispatch computer to a CAD terminal at ARTIMIS. The traffic camera video is available at the County dispatch center. A fiber connection permits these transfers.	**No**	Some	**Yes**	A/B

Kansas City, MO-KS	**Yes** – Radio or telephone (where radio is unavailable)	**Yes** - E-mail, Telephone, Letters, Monthly traffic safety meetings *(Timeliness increases with incident magnitude)*	Radio and Nextel. Developing CAD system to incorporate the use of AVL and mobile data terminals for the MoDOT Motorist Assist and Emergency Response operators. CAD in use by police and fire departments.	**Yes** - Highway patrol dispatchers in KC Scout (TIM agency) center	**Yes**	**Yes** - Manuals exist, but have not been effectively disseminated to all response personnel	B
Minneapolis, MN	**Yes** - Shared CAD and radio systems.	**Yes** - CAD, Face-to-face meetings	CAD, radio, mobile phones	**Yes** - MSP and MnDOT, MSP and FIRST	Some	**Yes** - Traffic Incident Management Recommended Operational Guidelines	A
San Diego, CA	**Yes** - CAD system	**Yes** - CAD system access	CAD, Shared radio frequencies, mobile telephones	**Yes** - California Higway Patrol and DOT	**No**	**Yes** - 90 minute clearance goal (though not adhered/agreed to by all agencies)	A
Salt Lake City, UT	**Yes** - CAD dispatch data from UHP, and local 911 PSAP's in Salt Lake and Utah Counties. UDOT monitors emergency radio channels in other counties.		CAD, 800 MHz radio and video in use by all agencies use: *UDOT Incident Management personnel are dispatched by UHP and share emergency radio channel. UHP and UDOT IM personnel communicate “car-to-car” on designated “event” radio channel. Shared traffic camera access with UHP and surrounding counties.*	**Yes** - UDOT and UHP (separate rooms in a single building)	**No**	**Informal (Yes)**	A/B

Seattle, WA	**Yes** - Shared dispatch systems	**Yes** - Dependent on need. Daily downloads of all incidents that exceed 90 minutes, weekly downloads of towing reports, and monthly downloads of all traffic incidents. Daily feeds for other traffic information needs.	Radio, Car-to-car frequencies, CAD - *WSDOT Traffic Management Centers have read-only access to WSP's CAD system; can view all pertinent information that the patrol has.*	**Yes** - WSDOT and WHP	**Yes**	**YES** - Joint Operations Agreement *(90 minute clearance goal)*. WSDOT utilizes WSP CAD data to analyze and report on incidents that last 90 minutes or more. This information is jointly reported by the directors of both agencies to the governor on a quarterly basis under her Government Management and Accountability Program (GMAP).	A

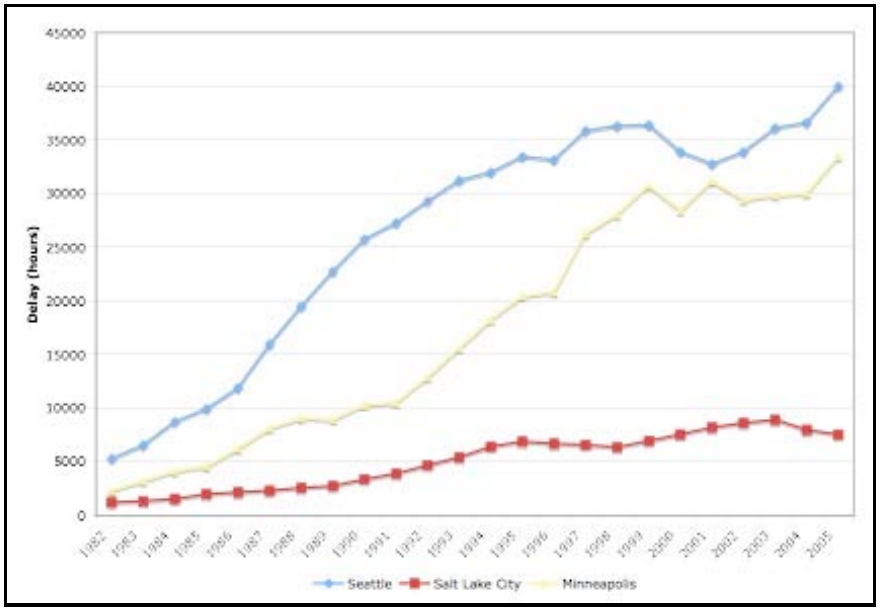


Figure 3.1: Annual incident-induced delays in Seattle, Salt Lake City and Minneapolis - St. Paul

Nor is this discrepancy attributable to regional population or miles of freeway. For example, over the 23-year period studied, the population and miles of freeway in Seattle remained about three times greater than that of Salt Lake City. Yet, counter-intuitive to the anecdotal statements found in the TIM literature and survey responses, the category B city is considerably more effective in slowing the rate of increase for incident-induced delays than the category A cities. If the anecdotal evidence is accurate, the rate of increase for incident-induced delay must be influenced by other unidentified factors. Upon reflection, police staffing levels in each region and miles of freeway construction were thought to be possible factors impacting delay; but when compared to incident-induced delays, no conclusive patterns were evident. The inability to identify a factor influencing this particular incident-induced delay measure begins to suggest that, although appropriate for the TTI urban mobility report, it may not be an appropriate metric for competitive benchmarking between cities.

However, this metric might still be useful for competitive benchmarking if one considers the rate of increase before and after implementing one or more TIM improvement strategies. Given that survey respondents had been asked to provide timeline information for TIM efforts, perhaps implementation of TIM practices could be correlated with changes in the rate of incident-induced delay. Yet once again, the evidence was inconclusive - although certain strategies seemed to have yielded improvements within a year of implementation.

- <u>Cincinnati:</u> after the Advanced Regional Traffic Interactive Management and Information System (ARTIMIS) became operational, the rate of increase in delay dropped from a 19% annual increase between 1982 and 1994 to a 4% annual increase between 1995 (the year of implementation) and 2005.

- <u>Salt Lake City</u>: After a co-located TIM center was built, a 15% rate of increase in annual delay between 1982 and 1994 gave way to a 2% annual reduction for the next five years.

- <u>Seattle:</u> On average, the rate of incident-induced delay dropped from a 14% annual increase prior to a 2% annual decrease over a five year period after TIM agencies were co-located.

Thus, one conclusion is that the TTI measure of incident-induced delay is not appropriate for benchmarking purposes – the measure cannot be clearly tied to any performance improvement activities and it's unclear what regional factors influence the measure. But, in order to measure performance changes brought about by interagency coordination and other efforts to improve TIM, measures clearly indicating this effect are required. Ideally, these measures should allow comparisons between cities (per the NTIMC and its National Unified Goal); at a minimum, these measures should provide information that can drive performance improvement within an agency. Going back to the literature review and reviewing the survey responses, a list of the most common metrics mentioned and their effect on TIM goals (as outlined by the NTIMC and RTMC) was compiled (Table 3.3).

Table 3.3: Some performance metrics and their effect on TIM goals

Robert Feyen 4/3/09 3:12 AM
Comment: Are there any metrics that can be added that are unique to an agency other than the EMS metric?

Metric (Agency)	Effect on TIM goals (per NTIMC and RTMC)	
Response time (All)	Positive	Where minimization of this metric is a top priority, a positive effect is had on overall incident duration: rapid restoration of traffic flow.
Clearance time (All)	Positive	Streamlining of activities to minimize total clearance time facilitates the rapid restoration of traffic flow.
Number of motorist fatalities (EMS)	Negative	The prevention of loss of life is, by no means, detrimental to TIM practices. A focus by one agency on evaluation based on this metric could, however, result in operational delays. The prescribed protocol for reducing this metric need to be explained to other responders on site.
Number of responders (All)	Positive/ Negative	Keeping the number of responders to a minimum reduces the probability of secondary incidents involving respondents. It could, however, prolong incident duration.

In outlining the effect of each metric on TIM goals (as stated by the NTIMC and RTMC), the assumption is made that each agency looks to achieve its goals by optimizing relevant metrics [9]. While multiple agencies might have similar metrics, varying levels of importance are placed on them, as noted in Chapter 1, the various agencies involved in TIM typically associate different goals with these metrics. In fact, the survey responses illustrated this effect to some degree. Respondents were asked how various agencies prioritized TIM activities (Figure 3.2). On a scale of 1 to 5 (where 1 = low and 5 = high), transportation and police agencies received the highest ratings (4.4 on average) while Fire and Towing/Recovery received the lowest ratings (2.7 on average). One could argue these ratings result from the close working relationships found between police and transportation departments in most locales (e.g., co-location projects usually start with police and transportation agencies). Further, respondents were almost exclusively transportation and police personnel. The lower ratings for EMS, Fire and Towing/Recovery could also reflect that (1) they are less frequently involved in TIM relative to the police and transportation agencies and (2) TIM activities do not comprise a significant portion of their day-to-day operations.

But, ultimately, one thing all of these Traffic Incident Management agencies have in common is that they strive to achieve their goals safely and as quickly as they can. Since the length of an incident-induced delay depends on how quickly and safely each agency achieves their goal for a given incident, metrics evaluating how much time an agency spends on an incident or some component of that time are likely to be useful to all agencies. Mentioned frequently in the surveys and subsequent discussions, outlined in

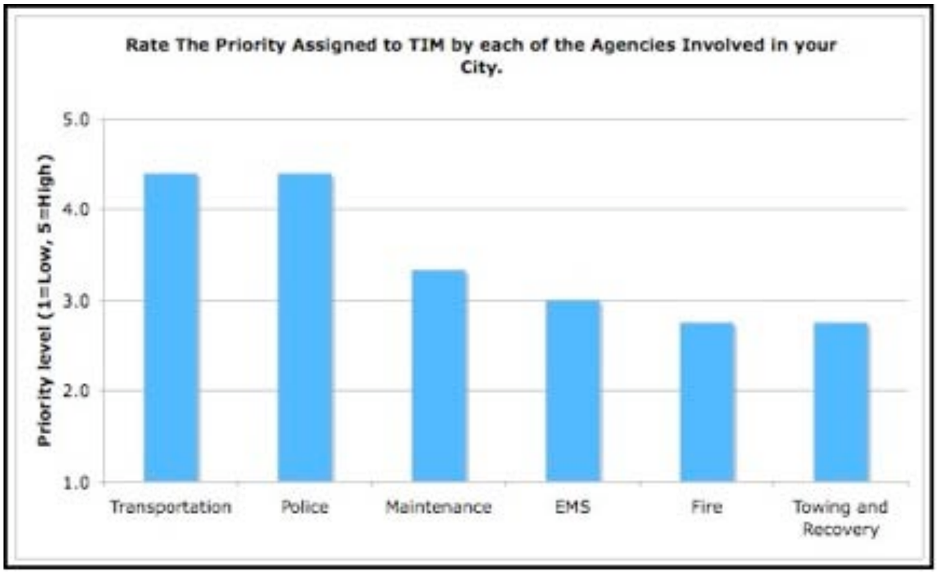


Figure 3.2: Agency-specific TIM priorities (average values)

the *Traffic Incident Management Handbook* [1] and widely used across the United States, three time-based metrics seem particularly appropriate. All agencies involved can easily collect and understand these measures; plus, they can be used for both competitive and internal benchmarking:

1. **Agency response time** – the elapsed time between when an incident is detected to when an agency's response vehicle arrives at the scene;
2. **Clearance time** – the elapsed time between the arrival of the first response vehicle and the restoration of traffic flow to normal levels; and

3. **Incident duration** – the elapsed time between detection and departure of the last response vehicle from the scene.

These measures can easily be defined differently between agencies: for example, response time may be broken down into two separate pieces: incident detection to vehicle dispatch and vehicle dispatch to arrival on the scene. On the one hand, a tow agency would likely treat response time as dispatch to arrival since they have little to do with incident detection; however, a police or transportation agency would likely use the formal definition above. For this reason, terms should be clearly defined and standardized between agencies. This is especially important if a national organization such as the NTIMC were to promote collection and dissemination of standardized performance metrics across the country for the purposes of competitive benchmarking and performance improvement. Until that occurs, competitive benchmarking of TIM efforts between cities will be a very difficult and perhaps meaningless endeavor. On the other hand, internal benchmarking deserves a closer look.

Chapter 4
Internal Benchmarking

In addressing this report's first objective, the close of the last chapter suggested the following may be the one goal easily shared by all agencies involved in traffic incident response:

> ***Without compromising safety, minimize the time spent dealing with a traffic-related incident.***

At first glance, this goal seems "common sense" and obvious. Perhaps it is. But therein lay the issue: for much the same reason, this goal appears to be the 800-lb pink elephant in the room that no one talks about. And so, very few TIM agencies devote much consistent effort or coordination with other agencies towards this specific goal.

This is not to say TIM agencies are unconcerned with incident response times. On the contrary, almost all TIM agencies surveyed or described in the literature collect some element of timing data. After all, some form of response, clearance, and overall incident duration times are recorded and archived by almost all TIM agencies and some use descriptive statistics to address specific questions about incident response. Others, like the RTMC, archive descriptive incident data as well. A select few TIM agencies go further and compare incident durations to a predetermined threshold value (e.g., 60 minutes) in order to consistently trigger a review of incidents that are not resolved quickly.

Beyond that, though, none of the agencies contacted or described in the literature appear to do much quantitative analysis beyond this. Is this surprising? Not really, when one considers that 72 metro area TIM agencies have already reported that the two areas in which they have the least success are in *interagency coordination* and *quantitative evaluation* [2, 13].

But the goal stated above may actually help TIM agencies achieve success in these areas: providing a common ground for coordinating incident response efforts across agencies, it utilizes an easily collected and understood variable: time. Now, assume that an interagency TIM team adopts this as their goal. How might they use this goal to guide how they coordinate incident response efforts? What incident data would be needed? How could this data be used by various agencies to measure how well they are meeting performance objectives?

Recalling the earlier discussion from Chapter 2, one could consider the incident response timeline (repeated in Figure 4.1) as a simple process flow diagram. The incident response process requires various responders (or, resources) to perform a number of tasks sequentially, either independently or cooperatively, so they can achieve the overall common goal while meeting their own specific objectives. Internal benchmarking strives to improve this process by using past performance as the starting point for comparisons with future performance. Recall that the steps in benchmarking a process are planning, collecting data, analyzing data and adapting the process. In this case, planning involves selecting appropriate metrics based on knowledge of the process and the goal to be achieved. The next step is collecting or obtaining the data necessary to evaluate these metrics. The data is then analyzed and results used to generate ideas for improving (adapting) the overall process.

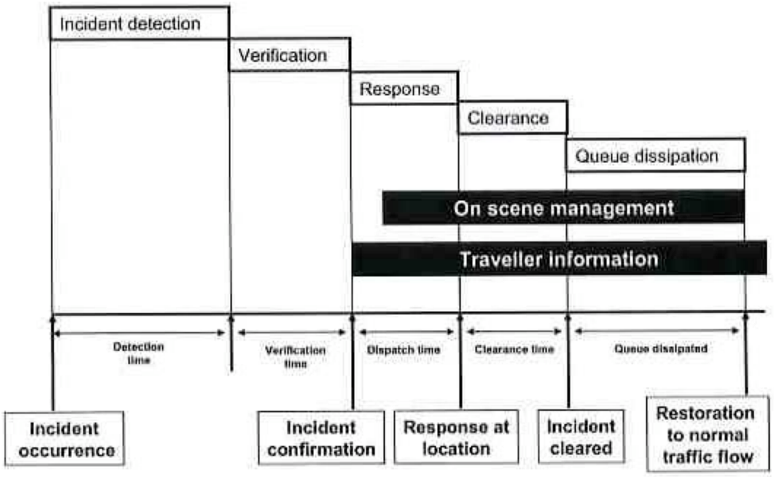


Figure 4.1: Incident response timeline – or simple process flow diagram?

This part of the study demonstrates how an internal benchmarking process might be applied to TIM. In terms of planning, the use of timing metrics has already been decided. Based on incident response procedures in the Twin Cities and the timeline shown in Figure 4.1, seven timing metrics are proposed as possibilities for assessing incident response performance both within and between agencies:

1. Verification time: Detection to dispatch
2. Agency dispatch time: Dispatch to arrival
3. Lane clearance time: Arrival to lane clearance
4. Queue dissipation: Lane clearance to all clear
5. Removal time: Arrival to all clear
6. Overall incident response time: Dispatch to all clear
7. Overall incident time: Detection to all clear

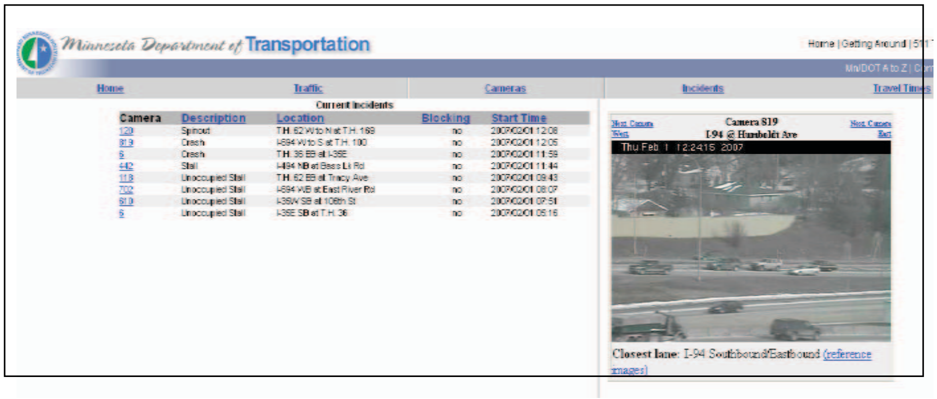
For the second step of the internal benchmarking procedure, historical incident response data will be obtained for a small segment of the Twin Cities freeway network and, in the third step, used to establish performance benchmarks for a select subset of metrics. These benchmarks set the standard against which future incident response performance should be compared and may help identify a core set of factors impacting the incident response duration. In terms of analysis, the various factors considered most likely to impact the duration of an incident response are:

- Location
- Time of day
- Direction of travel
- Incident type
- Weather conditions
- Number and type of vehicles involved
- Number and location of lanes involved
- Number and type of responders required on scene
- Traffic queues (delay)

As a result of one or more of these factors, the times associated with the incident response process are never the same – in other words, the timing metrics exhibit variability. However, one tenet of production and operations management is that, as variability increases, process performance decreases (i.e., on average, the process will also take more time). Further, variability occurring early in a process will often increase the overall process time more than variability occurring late in the process. Thus, determining where and how much variability occurs in the process will indicate the segment to be worked on first and what might be done to yield the most process improvement – the final step in the internal benchmarking process.

Data Collection and Analysis

At present, RTMC personnel collect incident response data differently than they did when this project started. Under a project through the Minnesota Guidestar initiative, the Conditions Acquisition and Reporting System (CARS) tool has been integrated with the Minnesota State Police's Computer Aided Dispatch (CAD) system. The CARS tool is linked directly to the 511 traveler information system to provide information on transportation-related events and conditions. Information input to CARS is reflected in the various messages, maps and displays generated by the 511 phone and web-based systems. Linking the two systems was done in hopes of providing more accurate and up-to-date traveler information, particularly with respect to crashes and other incidents available via the 511 phone and web systems (Figure 4.2) while eliminating the redundancy of data entry into both the CARS and CAD systems. This also allowed RTMC staff to stop entering incident response data into a separate incident log maintained by the on-duty Traffic Information Officers.



Current Incidents

Camera	Description	Location	Blocking	Start Time
120	Spinout	T.H. 62 W to N at T.H. 169	no	2007/02/01 12:08
819	Crash	I-694 W to S at T.H. 100	no	2007/02/01 12:05
6	Crash	T.H. 36 EB at I-35E	no	2007/02/01 11:59
442	Stall	I-494 NB at Bass Lk Rd	no	2007/02/01 11:44
118	Unoccupied Stall	T.H. 62 EB at Tracy Ave	no	2007/02/01 09:43
702	Unoccupied Stall	I-694 WB at East River Rd	no	2007/02/01 08:07
610	Unoccupied Stall	I-35W SB at 106th St	no	2007/02/01 07:51
6	Unoccupied Stall	I-35E SB at T.H. 36	no	2007/02/01 05:16

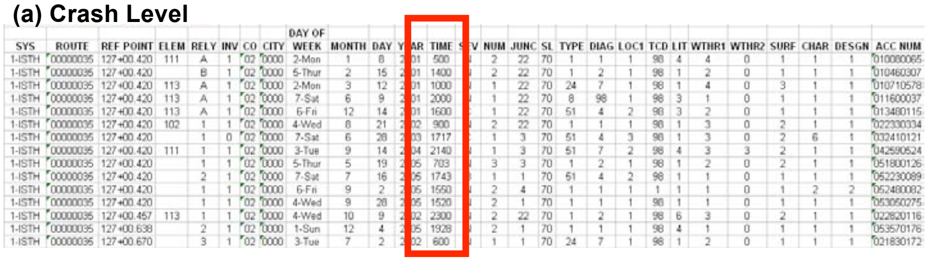
Camera 819
I-94 @ Humboldt Ave
Thu Feb 1 12:24:15 2007

Closest lane: I-94 Southbound/Eastbound (reference images)

Figure 4.2: Incident information webpage from Mn/DOT's 511 Traveler Service

The type of data currently available from the 511 system through CARS/CAD includes incident type, location, start time, and blocking information. This data, along with other incident and response data collected from the CARS/CAD system and police reports, is archived by incident in the Transportation Information System (TIS), a longstanding Mn/DOT database housing a vast store of transportation network data. Incident data in TIS includes two types of incident information: incident descriptors and vehicle/driver descriptors, the latter for all vehicles involved. A wide range of incident descriptors are stored for each incident including location, date, day, start time, number of vehicles involved, and weather conditions.

(a) Crash Level



SYS	ROUTE	REF POINT	ELEM	RELY	INV	CO	CITY	DAY OF WEEK	MONTH	DAY	Y AR	TIME	S EV	NUM	JUNC	SL	TYPE	DIAG	LOC1	TCD	LIT	WTHR1	WTHR2	SURF	CHAR	DESGN	ACC NUM
1-ISTH	00000035	127+00.420	111	A	1	02	0000	2-Mon	1	8	2 01	500		2	22	70	1	1	1	98	4	4	0	1	1	1	010080065
1-ISTH	00000035	127+00.420		B	1	02	0000	5-Thur	2	15	2 01	1400		2	22	70	1	2	1	98	1	2	0	1	1	1	010460307
1-ISTH	00000035	127+00.420	113	A	1	02	0000	2-Mon	3	12	2 01	1000		1	22	70	24	7	1	98	1	4	0	3	1	1	010710578
1-ISTH	00000035	127+00.420	113	A	1	02	0000	7-Sat	6	9	2 01	2000		1	22	70	8	98	1	98	3	1	0	1	1	1	011600037
1-ISTH	00000035	127+00.420	113	A	1	02	0000	6-Fri	12	14	2 01	1600		1	22	70	51	4	2	98	3	2	0	1	1	1	013480115
1-ISTH	00000035	127+00.420	102	1	1	02	0000	4-Wed	8	21	2 02	900		2	22	70	1	1	1	98	1	3	0	2	1	1	022330334
1-ISTH	00000035	127+00.420		1	0	02	0000	7-Sat	6	28	2 03	1717		1	3	70	51	4	3	98	1	3	0	2	6	1	032410121
1-ISTH	00000035	127+00.420	111	1	1	02	0000	3-Tue	9	14	2 04	2140		1	3	70	51	7	2	98	4	3	3	2	1	1	042590524
1-ISTH	00000035	127+00.420		1	1	02	0000	5-Thur	5	19	2 05	703		3	3	70	1	2	1	98	1	2	0	2	1	1	051800126
1-ISTH	00000035	127+00.420		2	1	02	0000	7-Sat	7	16	2 05	1743		1	1	70	51	4	2	98	1	1	0	1	1	1	052230089
1-ISTH	00000035	127+00.420		1	1	02	0000	6-Fri	9	2	2 05	1550		2	4	70	1	1	1	1	1	1	0	1	2	2	052480082
1-ISTH	00000035	127+00.420		1	1	02	0000	4-Wed	9	28	2 05	1520		2	1	70	1	1	1	98	1	1	0	1	1	1	053050275
1-ISTH	00000035	127+00.457	113	1	1	02	0000	4-Wed	10	9	2 02	2300		2	22	70	1	2	1	98	6	3	0	2	1	1	022820116
1-ISTH	00000035	127+00.638		2	1	02	0000	1-Sun	12	4	2 05	1928		2	1	70	1	1	1	98	4	1	0	1	1	1	053570176
1-ISTH	00000035	127+00.670		3	1	02	0000	3-Tue	7	2	2 02	600		1	1	70	24	7	1	98	1	2	0	1	1	1	021830172

(b) Vehicle/Person Level

VEHICLE 1								VEHICLE 2								VEHICLE 3								VEHICLE 4								GIS ATTRIBUTES	
VTYPE	DIR	ACT	FAC1	FAC2	PHYS	AGE	SEX	VTYPE	DIR	ACT	FAC1	FAC2	PHYS	AGE	SEX	VTYPE	DIR	ACT	FAC1	FAC2	PHYS	AGE	SEX	VTYPE	DIR	ACT	FAC1	FAC2	PHYS	AGE	SEX	TM	ROUTE
2	S	1	1	99	1	22	M	1	S	14	2	8	1	83	M																	127.497	0100000035
1	N	90	90	99	1	49	M	2	N	90	90	99	1	30	M																	127.497	0100000035
1	N	1	3	61	1	57	F																									127.497	0100000035
2	N	1	1	1	1	33	M																									127.497	0100000035
1	N	1	3	15	1	46	F																									127.497	0100000035
1	N	1	1	99	1	42	F	1	N	14	15	8	1	22	M																	127.497	0100000035
1	N	1	61	0	1	46	M																									127.497	0100000035
1	S	1	3	0	1	29	M																									127.497	0100000035
2	S	1	1	0	1	27	M	1	S	1	1	0	1	27	F	1	S	15	7	8	99	35	F									127.497	0100000035
1	N	99	8	18	3	26	M																									127.497	0100000035
1	N	11	1	0	1	22	F	1	N	1	15	0	1	17	F																	127.497	0100000035
1	N	10	1	0	1	32	F	1	N	1	15	0	1	31	F																	127.497	0100000035
1	N	1	99	99	1	47	M	2	N	15	3	7	3	31	M																	127.534	0100000035
1	S	1	15	0	1	16	F	3	S	13	8	0	1	48	F																	127.715	0100000035
2	S	1	15	21	1	55	M																									127.747	0100000035

Figure 4.3: Example of TIS incident data

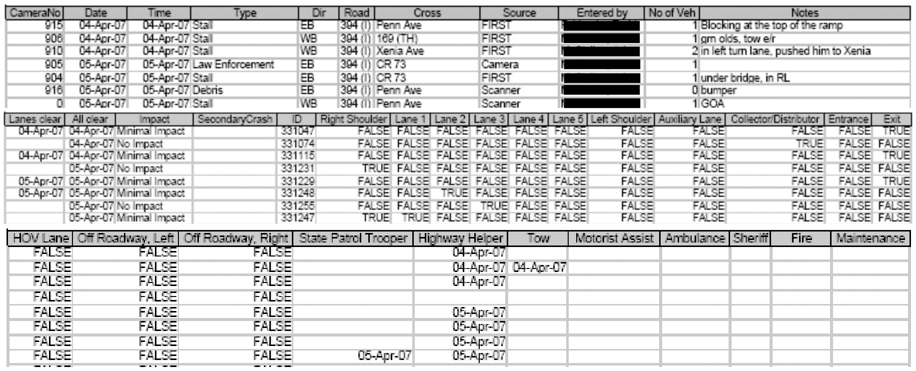
(Note: the red square denotes the only timing data stored: start time)

Analysis of the TIS incident data was greatly simplified in 2006 when Mn/DOT released a desktop software tool, the Minnesota Crash Mapping Analysis Tool (MnCMAT). This application enables authorized users simple access to the incident database and can be used to identify or filter incidents based on various field values. Utilizing a graphical approach to data presentation, the software produces a map with plotted crash locations and generates charts and reports based on the selected incident criteria. The software uses data filtering (such as location, city, date, or weather conditions) to allow users to specify incident characteristics and customize analysis.

Overall, the data collected and the analysis tool described above can provide valuable insights into the likelihood that an incident might occur and what factors may contribute to its occurrence. This approach makes an important contribution to TIM efforts because of its focus on reducing the total number of unplanned incidents in the network – and, thus, reducing congestion and frequency of delays. But, despite these efforts, incidents will still occur.

This is where the advantage of internal benchmarking is best utilized: by focusing on incident response as a process. In this approach, any incident that occurs has the potential to create congestion and traffic delays; the challenge is minimizing the detrimental impact of those incidents by proposing modifications that shorten the selected metrics associated with incident response. However, the incident logging method currently in place does not support internal benchmarking because it does not provide the means to collect the necessary metrics. But a reasonably simple option is already available: with some minor modifications, the separate incident log maintained by RTMC staff prior to implementation of the integrated CARS/CAD system is capable of collecting most, if not all, of the seven desired timing metrics described earlier.

To illustrate, a subset of incident response data was obtained from RTMC personnel for analysis. Initially recorded in the separate incident log, this data covered 644 incidents that had occurred on the north-south corridor of I-35W between Lake Drive to the north and SR 280 to the south (Figure 4.5) during the six-month period of May to October 2007. The original data set was provided in an Excel spreadsheet (fields and sample rows shown in Figure 4.4).



CameraNo	Date	Time	Type	Dir	Road	Cross	Source	Entered by	No of Veh	Notes
915	04-Apr-07	04-Apr-07	Stall	EB	394 (I)	Penn Ave	FIRST	[redacted]	1	Blocking at the top of the ramp
906	04-Apr-07	04-Apr-07	Stall	WB	394 (I)	169 (TH)	FIRST	[redacted]	1	gm olds, tow e/r
910	04-Apr-07	04-Apr-07	Stall	WB	394 (I)	Xenia Ave	FIRST	[redacted]	2	in left turn lane, pushed him to Xenia
905	05-Apr-07	05-Apr-07	Law Enforcement	EB	394 (I)	CR 73	Camera	[redacted]	1	
904	05-Apr-07	05-Apr-07	Stall	EB	394 (I)	CR 73	FIRST	[redacted]	1	under bridge, in RL
916	05-Apr-07	05-Apr-07	Debris	EB	394 (I)	Penn Ave	Scanner	[redacted]	0	bumper
0	05-Apr-07	05-Apr-07	Stall	WB	394 (I)	Penn Ave	Scanner	[redacted]	1	GOA

Lanes clear	All clear	Impact	SecondaryCrash	ID	Right Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Left Shoulder	Auxiliary Lane	Collector/Distributor	Entrance	Exit
04-Apr-07	04-Apr-07	Minimal Impact		331047	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE
	04-Apr-07	No Impact		331074	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
04-Apr-07	04-Apr-07	Minimal Impact		331115	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE
	05-Apr-07	No Impact		331231	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
05-Apr-07	05-Apr-07	Minimal Impact		331229	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE
05-Apr-07	05-Apr-07	Minimal Impact		331248	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
	05-Apr-07	No Impact		331255	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
	05-Apr-07	Minimal Impact		331247	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE

HOV Lane	Off Roadway, Left	Off Roadway, Right	State Patrol Trooper	Highway Helper	Tow	Motorist Assist	Ambulance	Sheriff	Fire	Maintenance
FALSE	FALSE	FALSE		04-Apr-07						
FALSE	FALSE	FALSE		04-Apr-07	04-Apr-07					
FALSE	FALSE	FALSE		04-Apr-07						
FALSE	FALSE	FALSE								
FALSE	FALSE	FALSE		05-Apr-07						
FALSE	FALSE	FALSE		05-Apr-07						
FALSE	FALSE	FALSE		05-Apr-07						
FALSE	FALSE	FALSE	05-Apr-07	05-Apr-07						

Figure 4.4: Excel spreadsheet format of incident response data

Upon closer examination of the data contained in the incident log, several issues impacted its suitability for the process-centered statistical analysis needed for internal benchmarking. First, although many of the time points of interest (arrivals, “all clear” notifications, etc.) were recorded, these are only the endpoints for the primary measures of interest such as response time, clearance time, and overall incident time. Second, many of these time points were missing, even when other time points associated with an agency were recorded (e.g., dispatch time recorded, but no arrival time). Third, many of the data points collected were not recorded in a form amenable to analysis. For example, date and time stamps must be converted to a numerical representation to support the mathematical operations (e.g., addition or subtraction of times) needed to determine process durations.

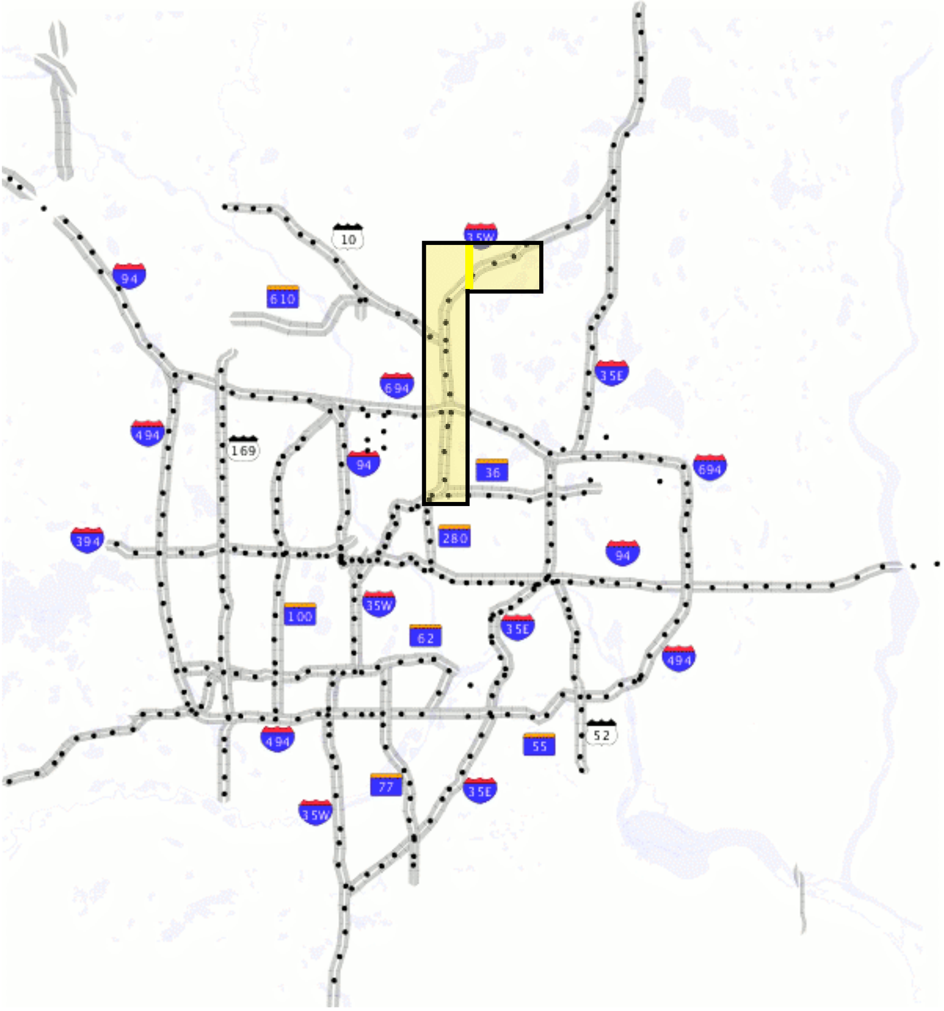
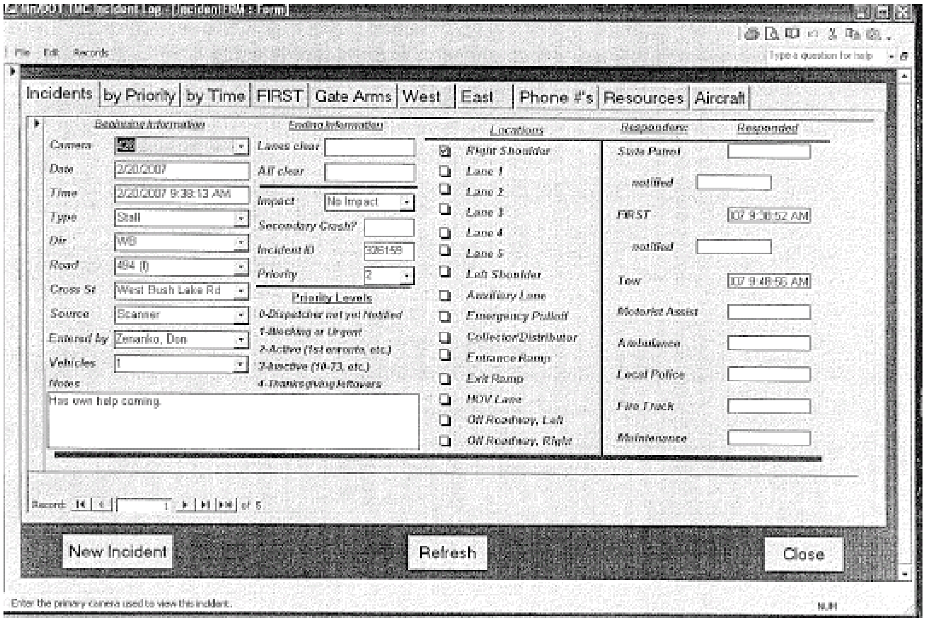


Figure 4.5: Twin Cities metro freeway system.

Note: Highlighted in yellow is the section of I-35W analyzed, bounded by Lake Dr. NE at the north end and SR 280 at the south end. Dots represent the location of cameras used for incident verification.



Beginning Information

Camera: [illegible]
Date: 2/20/2007
Time: 2/20/2007 9:38:13 AM
Type: Stall
Dir: WB
Road: 494 (I)
Cross St: West Bush Lake Rd
Source: Scanner
Entered by: Zeranko, Don
Vehicles: 1
Notes: Has own help coming.

Ending Information

Lanes clear:
All clear:
Impact: No Impact
Secondary Crash?:
Incident ID: 326159
Priority: 2

Priority Levels
0-Dispatcher not yet Notified
1-Blocking or Urgent
2-Active (1st enroute, etc.)
3-Inactive (10-73, etc.)
4-Thanksgiving leftovers

Locations

☑ Right Shoulder
☐ Lane 1
☐ Lane 2
☐ Lane 3
☐ Lane 4
☐ Lane 5
☐ Left Shoulder
☐ Auxiliary Lane
☐ Emergency Pulloff
☐ Collector/Distributor
☐ Entrance Ramp
☐ Exit Ramp
☐ HOV Lane
☐ Off Roadway, Left
☐ Off Roadway, Right

Responders:	Responded
State Patrol	
notified	
FIRST	07 9:38:52 AM
notified	
Tow	07 9:48:56 AM
Motorist Assist	
Ambulance	
Local Police	
Fire Truck	
Maintenance	

Enter the primary camera used to view this incident.

Figure 4.6: Incident log data entry screen

Preparatory work on the original data set to facilitate the process-centered statistical analysis included the following steps.

1. Data fields indicating process durations were created for each incident; the data entered into these new fields were derived from data in existing fields. The process durations derived covered the following five response stages:
    - Dispatch time: dispatch to arrival
    - Clearance time: arrival to lane clearance
    - Vehicle removal time: lane clearance to all clear
    - Overall response time: dispatch to all clear
    - On-scene time: arrival to all clear

2. Categorical data such as time of day, impact, vehicle position relative to roadway and agencies responding were recoded to support statistical comparisons using contingency tables. For example, time of day was recoded to the closest hour and recorded in 24 hour format (e.g., “2:15:05 pm” would be recoded as “14”).
3. The existing categorical data were screened for subtle coding differences that could impact analysis; for example, spelling errors or extra spaces in a code would result in that term being treated as a unique categorical level (e.g., “NW” and “N W” would be treated separately).
4. The overall data set was screened for errors and anomalies: for example, several incidents were logged with date stamps of 01/01/00 or had overall incident times exceeding 24 hours; these incidents were excluded from analysis.

Upon completion, the modified data set was imported into JMP, a statistical exploration tool developed by SAS, Inc. and analyzed using five different methods:

- Descriptive statistics
- One-way factor analysis
- Model fitting
- Variability charting.
- Contingency analysis

In addition to the five statistical analyses, one other important analysis method was carried out to assist in the benchmarking task: process charting. For all six methods, examples of possible benchmarks will be presented – but the examples are by no means exhaustive. Other benchmarks may also be relevant based on the needs or questions posed by the agency conducting the benchmarking task.

Results

The following results are presented solely for demonstration purposes. Because the dataset obtained did not contain sufficient data to make statistically valid conclusions for certain analyses, the following results should not be used as the basis for conclusions or statements pertaining to actual incident response performance.

Descriptive Statistics

To simplify analysis for purposes of this demonstration, only occupied stalls were examined further. All analyses conducted, however, can be extended to the other incident types. The rationale for this decision stems from the finding that, of the 644 total incidents in the dataset, occupied stalls were by far the most frequent incident type:

359 (56%)	Occupied stalls
125 (19%)	Crashes (including rollovers and spinouts)
56 (9%)	Unoccupied stalls
40 (6%)	Debris-related incidents
64 (10%)	Other (fire, law enforcement, maintenance, pedestrians, etc.)

Within the dataset, insufficient data was recorded to accurately generate many of the basic metrics pertaining to occupied vehicle stalls in which only state police (MSP) or tow services responded (i.e., average response times or overall duration times for responses not involving FIRST (highway helpers)). Once again, however, the dataset suggested that this did not occur very often.

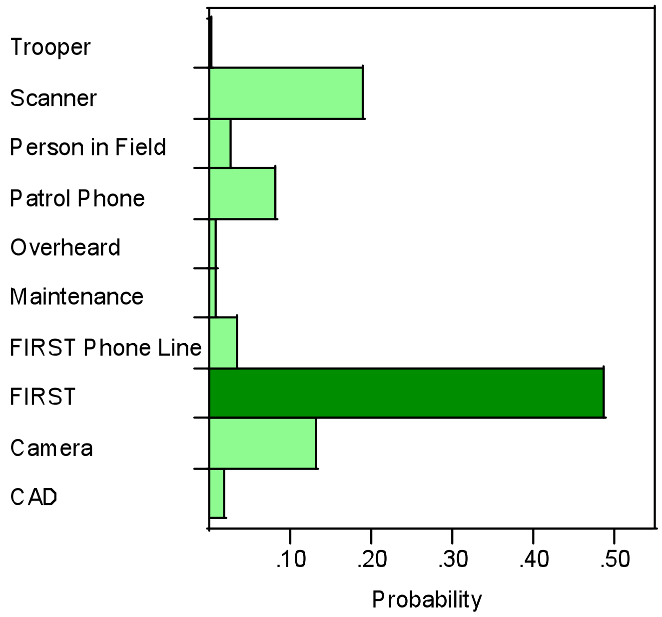


Figure 4.7: Probability of incident detection by detection mechanism

From a detection standpoint, roughly 80% of all occupied stalls were detected initially by MnDOT staff: almost half of all stalls were detected in the field by FIRST units and yet another third were detected by TIOs either by camera or scanner. In terms of response, FIRST was involved in 72% of all responses whereas tow services were utilized in only 25% of responses and MSP in only 15%. From an interagency coordination standpoint, occupied stalls provide little guidance for improvement efforts: only 25% of these incidents required coordination between 2 or more responders.

On average, the performance benchmarks for FIRST vehicles responding to an occupied vehicle stall were

- FIRST dispatch time: mean = 12 minutes SD = 8 minutes
- Lane clearance time: mean = 9 minutes SD = 14 minutes
- Vehicle removal time: mean = 19 minutes SD = 28 minutes
- Overall response time: mean = 36 minutes SD = 30 minutes

One-way analyses

One-way statistical analyses examine the effect of a single factor on a variable (e.g., performance metric). Quite often, these include an analysis of variance (ANOVA) and comparisons of means associated with different factor levels (i.e., conditions). From an incident response benchmarking standpoint, this may be useful for determining if one specific condition yields timing metrics significantly different (e.g., longer) than during other conditions and can guide TIM interventions to take advantage or downplay disadvantages posed by a specific condition.

In developing this benchmarking demonstration, 40 analysis of variance (ANOVA) tests were used to explore the statistical significance of factors (or, main effects) on incidence response metrics. A factor was considered significant if the p-value from the ANOVA test was greater than 0.05. Effects were graphed using quartile box plots (in which the bottom floating line represents the 10th percentile and the top floating line represents the 90th percentile; the bottom, middle, and top lines of the box represent the 25th, 50th, and 75th percentiles respectively), a line showing the overall mean, and means comparison circles (with a diameter representing the 95$^{\%}$ confidence interval - if two circles overlap, the factors associated with those two circles are not significantly different). Almost all of the tests did not indicate any significance differences between factor levels. In part, this stems from the high number of levels in many factors (e.g., hours per day, days per week, number of crossings); thus, grouping factors into fewer levels may be more appropriate for future one-way analyses.

As an example of a one-way analysis, consider the position of a stall relative to the roadway. Once dispatched, do FIRST responders arrive more quickly to a scene if a stall is detected on the roadway compared to a stall detected elsewhere (e.g., the road shoulder or a freeway access ramp)? Initially, no differences were detected. But once the position data was recoded into three groups: roadway, shoulder and access ramps, a different answer was obtained. With the recoded data, ANOVA indicates that roadway position does have a statistically significant effect on FIRST dispatch times (p-value = 0.015). The means comparison clarifies this finding: the statistical significance lies in the difference between response to stalls on the roadway and stalls on the access ramps. FIRST units arrived in just over 3 minutes to stalls detected on the roadway while taking almost 12 minutes when dispatched to a stall detected on a shoulder and over 18 minutes for stalls on an access (exit or entrance) ramp.

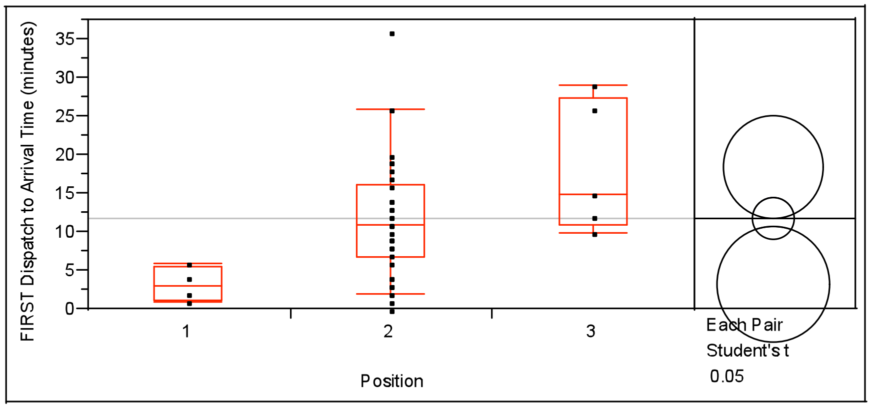


Figure 4.8: FIRST dispatch time for different positions of a stall relative to the roadway (where 1 = roadway, 2 = shoulder, 3 = access ramp)

Model fitting

To predict FIRST dispatch time, relevant dispatch timing data was modeled using a regression technique. To maintain relevance, the model does not include incidents in which a FIRST unit discovered the stalled vehicle (which is not consistent with the response time definition). Similar to the operation of the MnCMAT program, this model could be implemented easily into a spreadsheet or other software application and tied to a graphical display (e.g., map) for charting, reports and presentation purposes. The following describes the process for using the prediction model for FIRST dispatch time (minutes).

1. Select the value for the crossing road of interest:

10 (TH)	2.5
280 (TH)	7.7
36 (TH)	(-17.0)
694 (I)	3.3
88 (TH)	2.8
95th Ave	(-3.0)
CR B2	(-8.4)
CR C	0.5
CR D	5.5
CR E2	(-4.9)
CR I	(-0.3)
CR J	9.2
Lake Dr.	(-3.5)
Lexington Ave	5.7

2. Select the value for the direction of travel:

N	(-5.4)
N to W	7.8
S	(-3.0)
S to W	0.6

3. Select the value for the time of day (24 hour clock):

6	(-20.3)
7	12.8
8	(-3.9)
9	5.9
10	(-5.1)
11	(-8.1)
12	3.3
13	0.0
14	(-0.7)
15	14.8
16	2.5
17	(-6.9)
18	5.7

4. Select the value for the vehicle position relative to the roadway:

Exit	9.4
Lane 1	6.0
Lane 2	(-28.5)
Left Shoulder	9.6
N/A	(-1.0)
Right Shoulder	4.5

5. Add the four values together

6. Add a constant of 10.1 minutes to get the predicted dispatch time

To show how the model is used, assume a vehicle stall on the right shoulder of southbound I-35W near County Road D is verified at 3 pm. To estimate how long it will take a FIRST responder to arrive at the scene, simply sum the values for each parameter and add the constant to obtain the following prediction of FIRST dispatch time

5.5 + (-3.0) + 14.8 + 4.5 + 10.1 = **31.9 minutes**

So, based on this limited set of data and the conditions described, a FIRST responder will take an average of about one half hour to respond. Someone monitoring FIRST dispatch time for performance improvements might be intrigued: this particular response time is almost 3 times longer than the average FIRST dispatch time (11.8 minutes) for the segment of highway analyzed. A closer look reveals that FIRST responders in this segment take longer to respond during the 3 o'clock time slot than any other time of the day – an anomaly perhaps worth investigating further.

This predicted value can also serve as a benchmark (i.e., the baseline average) for assessing actual incident dispatch times. A complementary prediction equation from the model can be used to estimate the standard deviation (a.k.a. the standard error) of the predicted dispatch time under the given conditions (in this case, 15.7 minutes). Assuming that dispatch times are normally distributed and recognizing that 68% of all normally distributed data falls within one standard deviation of the mean, roughly 15% of the dispatch times will be longer than a dispatch time that is one standard deviation above the mean (~48 minutes). Thus, from a benchmarking standpoint, any dispatch time under these conditions exceeding 48 minutes could trigger a preliminary incident screening to see if some previously unidentified factor or event contributed to the longer than expected dispatch time.

This particular model predicts the FIRST dispatch times quite well, as suggested by Figure 4.9 and the r-square (r^2) value of 0.91. However, as noted before, this analysis is intended more as a demonstration than an in-depth statistical analysis. In this case, the dataset used to develop the model was rather limited in scope: several combinations of factors occurred only once or not at all. Further, all available data was used when developing the model, leaving none for validation purposes – this means that, although the model may be good at predicting the dispatch times found in the data set, it may not be nearly as good when predicting new scenarios. Nor was there sufficient data to conduct any interaction analysis – for example, one can reasonably surmise that, in many parts of the freeway network, dispatch times in a given direction will vary with changes in the time of day (i.e., rush hour traffic into or out of downtown). Using a similar approach, prediction models can be developed for other performance measures. For example, four additional performance measures were modeled using this data set:

- FIRST on-scene (arrival to all clear) time ($r^2 = 0.15$)
- FIRST overall response (dispatch to all clear) time ($r^2 = 0.69$)
- MSP on-scene time ($r^2 = 0.84$)
- Tow on-scene time ($r^2 = 0.51$)

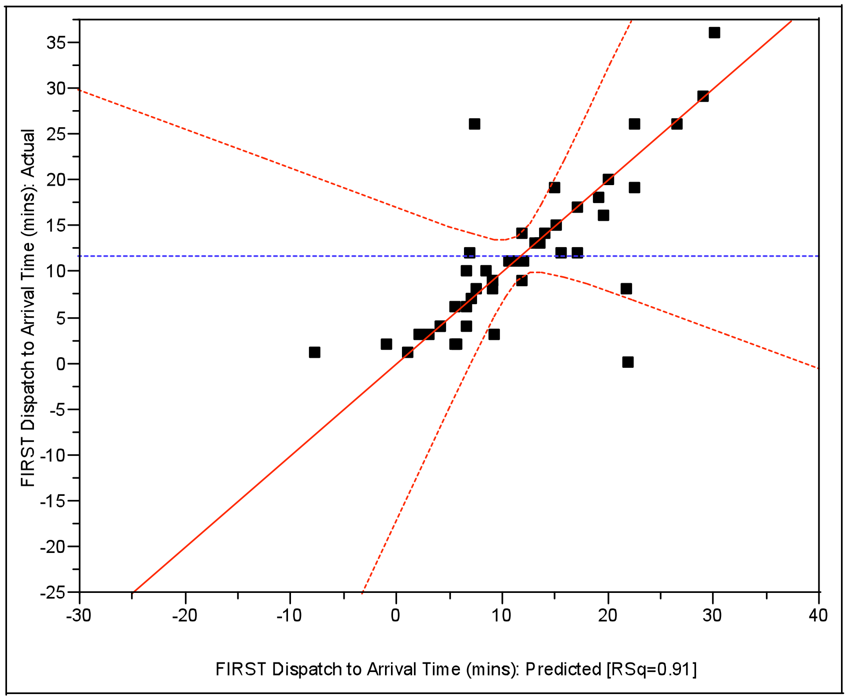


Figure 4.9: Actual vs. predicted values for the FIRST dispatch time model

Due to the insufficient number of available data points in the data set, the following performance measures – although potentially useful - could not be modeled:

- FIRST arrival to lane clear (clearance) time
- FIRST lane clear to all clear (vehicle removal) time
- MSP dispatch to arrival (dispatch) time
- MSP arrival to lane clear time
- MSP lane clear to all clear time
- MSP dispatch to all clear (overall response) time
- Tow dispatch to arrival time

- Tow arrival to lane clear time
- Tow lane clear to all clear time
- Tow dispatch to all clear time

A couple observations are worth noting. In determining the r-square value, prediction models are compared against the overall average from the data set. In general, the models predict the various timing measures quite well and much better than the overall average alone. However, in some cases, a model with a number of factors thought to impact performance may not predict performance any better than the overall mean and a low r-square value is obtained. Such is the case with the "FIRST arrival to all clear time" model, which also suggests another factor not yet identified is impacting performance.

Another curious observation resulting from exploring these other performance measures with prediction models was that a number of factors thought to influence performance actually did not contribute much to the best prediction models. Instead, four common factors influenced performance across the measures far more than any others: time of day, vehicle position relative to the roadway, nearest crossing, and direction. Other factors such as number of vehicles involved, day of the week, impact on traffic flow and responder type had little effect, even though the one-way analyses often suggested one of these other factors might have a greater impact. Of course, these findings apply only to occupied stalls only; these latter factors may be more relevant to crashes and other incident types.

Variability charts

Variability charting provides another way of looking at the historical incident response data. In this analysis method, a subset of factors is selected and its levels arranged hierarchically in a tree layout. The mean and standard deviation for each factor or combination of factors are then plotted separately. This allows a quick evaluation of which levels or combinations of level may warrant further investigation because of excessive response times or variability.

For example, in Figure 4.10, the FIRST dispatch time to an incident is presented by time of day for both northbound and southbound I-35W. Following up with the observations from the model fitting about FIRST dispatch times, this analysis shows that dispatch times during the peak traffic hours (7 am and 3 pm) exhibit significantly more variability than any other time and that this variability occurs primarily on the southbound segment. With a larger dataset, one might filter this analysis even further and add the crossing levels (e.g., CR D or 694) to determine which locations in the network contributed the most variability or if the variability was spread across the segment. However, with this dataset, most of the 3-way combinations either did not occur or only occurred once or twice - insufficient for calculating a meaningful standard deviation.

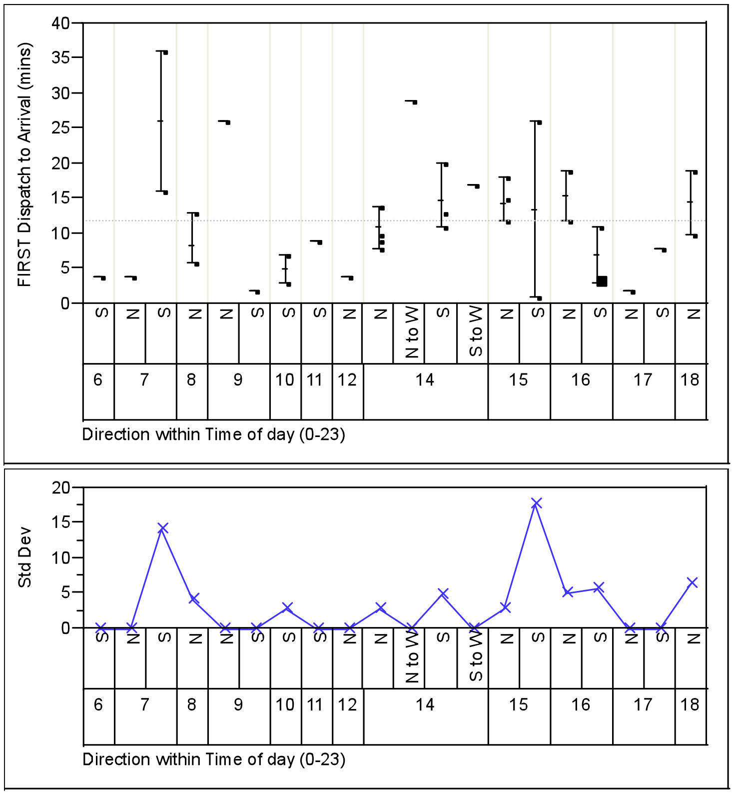


Figure 4.10: Variability charts breaking down response time (a) means and (b) standard deviation by time of day and direction of travel

Contingency analysis

Up to this point, each of the analysis methods examined the impact of one or more incident response conditions on incident response time metrics. Although not commonly considered, other questions could be asked about the factors themselves – are they related in some way? For example, is there one particular time and day of the week during which an incident is most likely to occur?

To answer these types of questions, a statistical method for exploring relationships between categorical data involves the use of contingency tables. These tables present how often a given condition is present when another condition is present. In addition to tables, mosaic plots are frequently used to illustrate the relationships between various conditions. Using contingency analysis, the most likely time and day for a stall to occur was found to be 2 – 3 pm on Thursdays and the second most likely occurred immediately afterwards: 3 – 4 pm on Thursdays.

To further illustrate, one might ask if any link could be identified between the agencies responding to a stall and its overall impact on traffic flow. Results, shown in Table 4.1 and Figure 4.11, indicate that only 7 of the 354 stalls caused traffic queues longer than a.0.5 miles. On the other hand, nobody responded in about 20% of all detected stalls. These likely include scenarios in which the motorist was able to rectify the stall before anyone was dispatched or arrived (e.g., repair a flat tire), but they might warrant further review since 40% of these stalls impact, albeit minimal, on traffic flow.

Table 4.1: Impact on traffic flow and agency response to an incident

Count Total % Col % Row %	0: No responders	1: MSP only	2: FIRST only	3: MSP and FIRST	4: Tow only	5: MSP and Tow	6: FIRST and Tow	7: MSP, Tow, and FIRST	
0: No impact	40 11.30 59.70 16.88	4 1.13 33.33 1.69	136 38.42 77.71 57.38	6 1.69 35.29 2.53	9 2.54 75.00 3.80	5 1.41 50.00 2.11	34 9.60 69.39 14.35	3 0.85 25.00 1.27	237 66.95
1: Less than ¼ mile queue	27 7.63 40.30 24.55	7 1.98 58.33 6.36	38 10.73 21.71 34.55	9 2.54 52.94 8.18	3 0.85 25.00 2.73	3 0.85 30.00 2.73	15 4.24 30.61 13.64	8 2.26 66.67 7.27	110 31.07
2: Less than ½ mile queue	0 0.00 0.00 0.00	1 0.28 8.33 20.00	0 0.00 0.00 0.00	1 0.28 5.88 20.00	0 0.00 0.00 0.00	2 0.56 20.00 40.00	0 0.00 0.00 0.00	1 0.28 8.33 20.00	5 1.41
4: More than ½ mile queue	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 0.28 0.57 50.00	1 0.28 5.88 50.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	2 0.56
	67 18.93	12 3.39	175 49.44	17 4.80	12 3.39	10 2.82	49 13.84	12 3.39	354

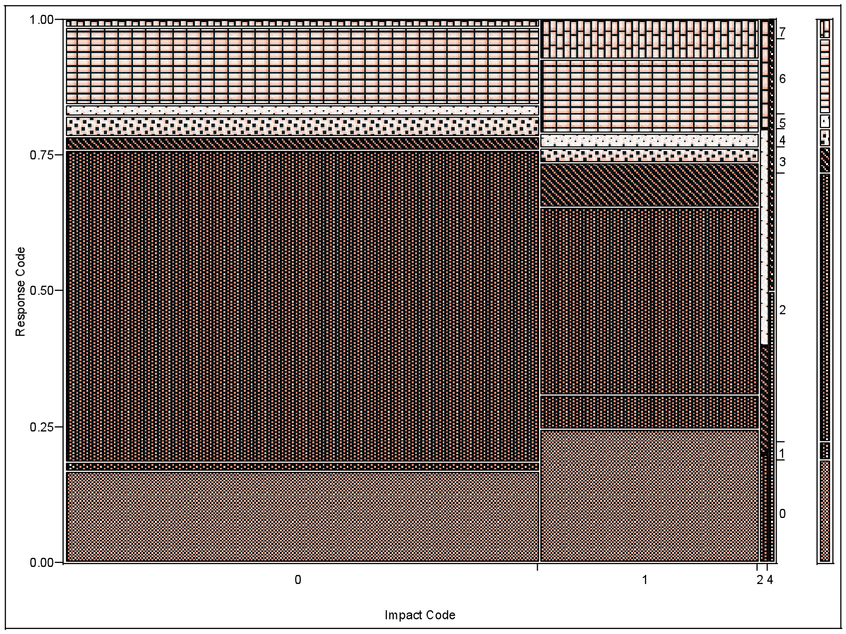


Figure 4.11: Mosaic plot of responding agencies against impact on traffic flow [see Table 4.1 for code descriptions]

Process charting

The last method used in this internal benchmarking demonstration is process charting. This is not a statistical method, but rather a method to explicitly describe a process to which performance measures are being applied. Following observation and review of any supporting documentation, the process is broken down into one or more sequences of task elements that must occur for the process to be completed successfully. The individual task elements are categorized and represented by specific shapes by type (Figure 4.12) then mapped to a diagram showing the flow of task sequences. In the case where multiple entities are involved (i.e., multiple responders), multiple flow diagrams may be developed that showing the allocation of tasks as well as any resource sharing or communications occurring between entities. The finished process chart is itself a benchmark, illustrating the currently expected sequence and allocation of tasks required for a given process (Figure 4.13).

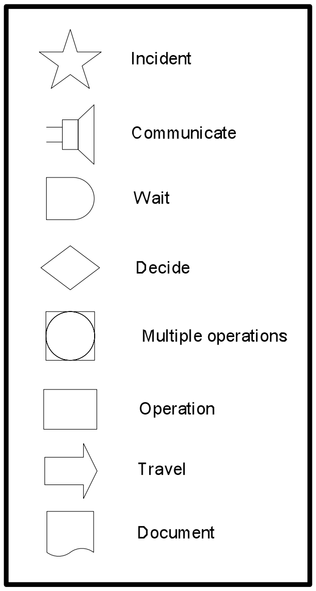


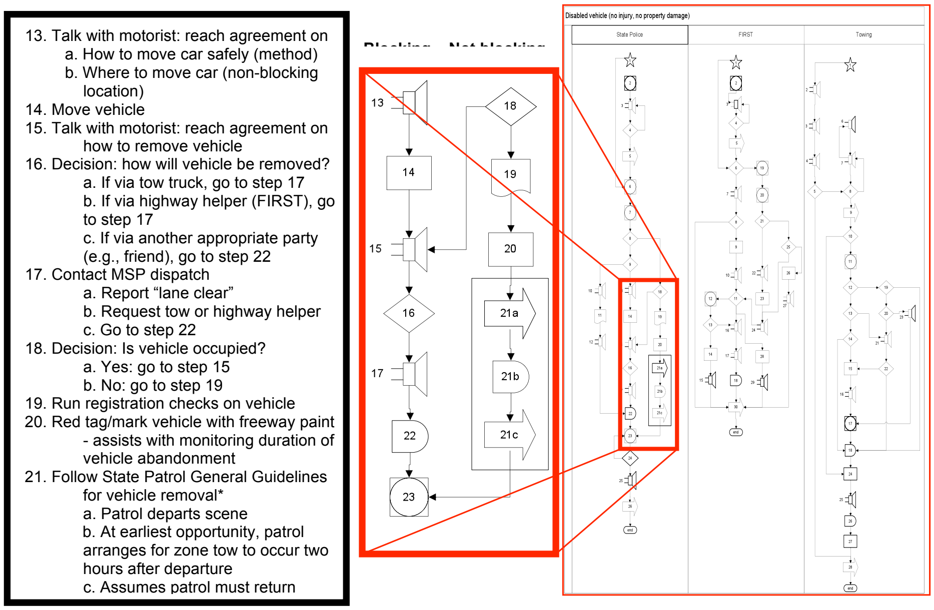
Figure 4.12: Process charting symbols

In the context of TIM, several benefits of process charting should be noted. In Minneapolis, incident response communications are recorded and archived for a year. Having process charts for different agencies and incident types would these audio records to be used in comparisons between how responders are expected to handle stalled vehicles (e.g., operational guidelines) and what is actually done in the field. Differences between the actual process and guidelines may indicate sources of variability in response times, reflect adaptations in the field to more effectively handle incidents, or highlight coordination conflicts and resource sharing needs between agencies in handling incidents.

Process charts are also useful when reviewing incidents with excessively long response times. In this case, the process chart becomes a template for identifying what task elements may have contributed and suggesting how the response delays may have occurred. These analyses may point out dependencies between agencies and other resources (e.g., personnel or equipment), inefficiencies in the overall process such as redundant communications or lack of guidance in certain infrequent scenarios. And, when evaluating proposed interventions to improve task performance, process charts can assist in assessing the impact of changes in task duties, task ordering, agency responsibilities, resource allocation, and communications.

In the latter case, process charts can also become the foundation for computational models of incident response. The statistical analyses described above provide timing information that can be integrated with the process charts to simulate incident response times under different task sequences, conditions, etc. Although not the intent of this study, the benefits of simulation-based incident response modeling will be discussed briefly in the next chapter.

In this study, incident response processes in the Minneapolis-St. Paul area were charted to illustrate the steps taken by the State Police, FIRST and tow services once a stalled (disabled) vehicle is detected. The process charts are based on incident response observations and guidelines published in 2002 by the region's Interagency Coordination Management Team. An excerpt is shown in Figure 4.13; the complete charts and task lists can be found in Appendix B. Worth noting is that the process charts can be split into segments corresponding to the incident response timeline and associated timing metrics described at the beginning of this chapter (Figure 4.14).



13. Talk with motorist: reach agreement on
    - a. How to move car safely (method)
    - b. Where to move car (non-blocking location)
14. Move vehicle
15. Talk with motorist: reach agreement on how to remove vehicle
16. Decision: how will vehicle be removed?
    - a. If via tow truck, go to step 17
    - b. If via highway helper (FIRST), go to step 17
    - c. If via another appropriate party (e.g., friend), go to step 22
17. Contact MSP dispatch
    - a. Report “lane clear”
    - b. Request tow or highway helper
    - c. Go to step 22
18. Decision: Is vehicle occupied?
    - a. Yes: go to step 15
    - b. No: go to step 19
19. Run registration checks on vehicle
20. Red tag/mark vehicle with freeway paint - assists with monitoring duration of vehicle abandonment
21. Follow State Patrol General Guidelines for vehicle removal*
    - a. Patrol departs scene
    - b. At earliest opportunity, patrol arranges for zone tow to occur two hours after departure
    - c. Assumes patrol must return

Figure 4.13: Excerpt from process chart for MSP response to a disabled vehicle

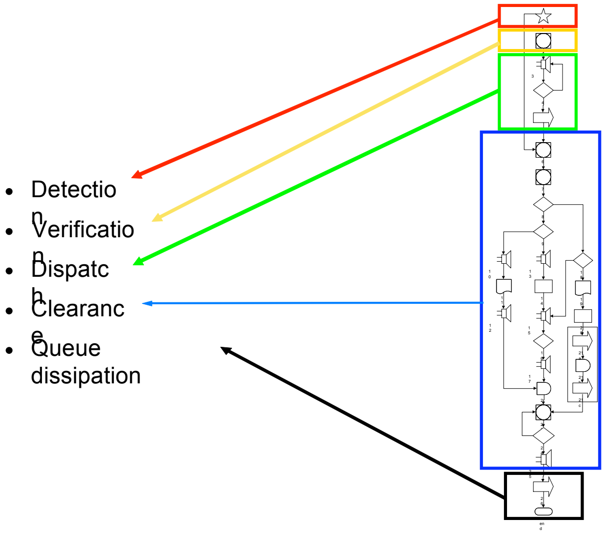


Figure 4.14: Relationship between process chart and incident response metrics

Chapter 5
Recommendations and Future Work

In summary, recall the initial research objectives of this study:

- Identify a common interagency goal;
- Use this goal to identify quantitative performance metrics that can be used to evaluate TIM performance; and,
- Identify a method for using these metrics as feedback to improve interagency coordination and overall TIM performance

With respect to the first objective, the literature review and external benchmarking efforts for selected North American cities suggested the following common interagency goal:

> ***Without compromising safety, minimize the time spent dealing with a traffic-related incident.***

In turn, this goal suggested the following set of time-based metrics that could effectively evaluate TIM performance across all agencies involved – meeting the second objective of this study.

- Verification time: Detection to dispatch
- Agency dispatch time: Dispatch to arrival
- Lane clearance time: Arrival to lane clearance
- Queue dissipation: Lane clearance to all clear

- Removal time: Arrival to all clear
- Overall incident response time: Dispatch to all clear
- Overall incident time: Detection to all clear

Finally, these metrics suggested the use of a methodology for evaluating performance of a TIM system, the third objective of the study. Adopting a process-centered view for incident response, internal benchmarking was used to demonstrate process charting and a set of five statistical methods. Prediction model fitting, variability charts and process charting apply well to general performance evaluation and can be considered the primary benchmarking tools; one-way factor analyses, contingency analysis and descriptive statistics are secondary methods that, although valuable, are more suited to answering specific questions about TIM performance.

Recommendations

As noted above, current incident response data collection and analysis supports an approach to reducing traffic congestion that emphasizes minimizing the number of incidents that occur. But incidents will still occur – and likely quite a few. This study recommends adopting a complementary approach to tackling the congestion and travel delays associated with incidents: make them as short as possible. In most cases, the less time that an incident has to impact traffic, the less congestion and delay it can cause. Should this latter approach appeal to a group of TIM agencies, four recommendations can be drawn from the internal benchmarking demonstration in Chapter 4; either by themselves or combined, each facilitates implementing a process-based approach to TIM performance improvement.

Recommendation 1

Modify data collection and archiving methods to support a process-centered approach to performance evaluation

Similar to the dataset preparation described in Chapter 4 (p. 59-62), this would entail reconfiguring current traffic incident data collection and archiving methods to track relevant timing data for one or more agencies involved in TIM. In some regional TIM centers, this would be in addition to the incident descriptors currently logged. In addition, the data should be stored using coding capable of supporting a variety of data filtering and analysis methods.

In some locales, a specialized means of entering, storing and retrieving the relevant incident timing data will have to be developed (e.g., a software application or front-end interface to an existing program like Excel). For the RTMC, the real-time incident logging application used prior to Fall 2008 would require few modifications. On the other hand, given the gaps in the dataset, training and other steps may have to be taken to improve the quality of the real-time data entry.

The primary outcome of this recommendation would be an updated system capable of obtaining large quantities of relevant quality data and stored in formats that can be readily used for relevant statistical analyses, as recommended next.

Recommendation 2

Using appropriate statistical tools, analyze archival incident response data to support internal benchmarking and subsequent process improvement efforts

As illustrated in pages 63-77, properly selected and archived traffic incident data can be used to establish baselines for various timing measures associated with incident response, taking into account the numerous factors that may influence each measure. In turn, these baselines can be used in several ways to suggest possible improvements or trigger reviews of specific incidents.

Examples of analyses that could be helpful include determining the 10 worst (or best) locations for each metric, identifying factor levels (i.e., conditions) that have a significant impact on each metric, and suggesting root causes of poor incident response performance (e.g., locations where another agency takes the lead). The prediction models could be used to suggest "waiting times" for traveler information (e.g., variable message signs) or provide an estimated time against which to compare actual response times and perhaps trigger incident reviews. Another area of interest is finding sources of variability and targeting them to minimize response variability. The benchmarking efforts ultimately aid decision making by providing insight into the impact of a process improvement intervention, knowledge that helps guide decisions regarding the selection and prioritization of various improvement options. The benchmarks also provide a quantitative baseline from which to assess the effectiveness of an improvement once implemented and justify expenditures for other improvement efforts.

Recommendation 3

For each major incident type, compile process charts that illustrate the steps and completion sequences for each responding agency

Each agency has a different role and procedures to carry out when responding to an incident. These may also vary by incident type, and may at times require coordination of efforts and resource sharing between agencies. Significant variation in a process results when a different method or sequence of tasks are used each time it is encountered. One way to assess this variation is to establish process charts for each incident type and agency (see pp. 77-80 and Appendix B). Preferably based on operational guidelines set by interagency consensus, each chart illustrates the recommended tasks, sequence of tasks and allocation of tasks and resources between responding agencies.

This allows comparison of actual response processes in the field to the recommended guidelines and aid identification of process variability. Elements which may differ from the recommended guidelines include not only different tasks or completion sequences, but also added or omitted tasks, task precedence (e.g., what tasks must finish before another can start), decision making, resources required, and communications with others. The latter can differ in terms of contact, reason for the contact, and the information shared (if any). Archived audio or transcripts of communications during an incident, particularly ones with excessive delay, can then be followed using the process charts to identify which steps contributed most to the delay and show where process differences between the actual incident and the operational guidelines may have occurred.

Recommendation 4

Develop a simulation model of the incident response process

This last recommendation builds on the prior two, utilizing the process charts and statistical prediction models to inform a simulation model of incident response. Conceptually, this model treats incidents as objects entering the freeway network at some random location in the network and requiring some type of processing by one or more network resources. These network resources, primarily the responders from various agencies, must then be notified and travel through the network to the incident. The responders follow the required steps to process the incident, possibly requiring additional resources to be brought through the network to the incident scene. Timing data is generated for the various stages, and the incident "exits" the network when processing is complete.

The benefits of a simulation model include the ability to quickly explore changes in the incident response process such as modifying initial responder locations (e.g., restructure FIRST or MSP zone boundaries), altering the number of available responders, or changing the task sequences. The model could also serve as a visual tool, potentially using animated graphics, to illustrate the impact of these various changes and provide quantitative data to support decision makers evaluating the effectiveness of various process improvement options.

Future work

Any continued work would require substantial RTMC support, not only in terms of advice and feedback, but also in terms of access to the archived incident data, both from the TIS and the incident logs maintained by the RTMC staff, and the audio archived for selected incidents with excessive response times. Assuming that the RTMC incident logs are reinstated, minor changes would be required with respect to data collection and entry and a mechanism established for gathering and storing relevant incident data from other agencies (i.e., MSP). This may also require permissions and access to observe on-site operations as well as raining on systems used to detect, track and manage incidents. In addition, as the process charts and simulation models are developed, contacts from the various agencies involved will be necessary so that each agency can provide feedback on the accuracy of a given chart or model.

Assuming these details could be worked out, this study leaves several avenues for continued work. The first is extending the internal benchmarking demonstration by incorporating data over a longer period of time and analyzing different incident types throughout the entire Twin Cities freeway network. Second, the TIS system contains data about incident response conditions such as weather and traffic levels not recorded in the RTMC incident logging system or the integrated CAD/CARS system. The influence of this data on incident response times may be significant, particularly for the prediction models, and is worth exploring further. Third, if a process-based performance improvement program were implemented at a TIM center, how should the program be administered and how would the data from the various agencies be gathered, compiled and stored (e.g., would this require a new graphical software tool, perhaps similar to MnCMAT)? Ultimately, work on each of these topics would help TIM staff reduce traffic congestion and delays and meet the overall goal stated earlier:

> ***Without compromising safety, minimize the time spent dealing with a traffic-related incident.***

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Acronyms

CHART	Coordinated Highway Action Response Team (Maryland)
DOT	Department of Transportation
FHWA	Federal Highway Administration
ITS	Intelligent Transportation Systems
HOT	High Occupancy Toll (lane)
HOV	High Occupancy Vehicle (lane)
MnDOT	Minnesota Department of Transportation
MoDOT	Missouri Department of Transportation
NATSRL	National Advanced Transportation Systems Research Laboratory
RTMC	Regional Transportation Management Center (Minneapolis-St.Paul)
TIM	Traffic Incident Management
VMS	Variable Message Signs
WSDOT	Washington State Department of Transportation

Appendix A

Traffic Incident Management Survey

Traffic Incident Management Survey

Northlands Advanced Transportation Systems Research Laboratory
University of Minnesota – Duluth

This survey is being conducted as part of a study on the management of traffic incidents in North American cities. Results will be used to determine best practices in Traffic Incident Management and will be shared with respondents upon request.

This survey should take about 5 minutes to complete.

Additional comments are welcome.
Thank you!

1. What local agencies (e.g.,, police, transportation department, etc,) are involved in Traffic Incident Management (TIM)? For each agency listed, rate the priority level given to Traffic Incident Management on a scale of 1 – 5 (1 = Low to 5 = High).

2. Is information on traffic incidents (car crashes, traffic congestion, etc.) shared between police and transportation personnel (dispatchers, traffic information officers, response personnel, etc.)…

…during incidents? YES NO

If YES, how is information transmitted?

…after incidents? YES NO

If YES, how is information transmitted? How long after (on average)?

3. Consensus incident management performance metrics have been developed and are used by all agencies for response evaluation and improvement.

   YES NO

4. What metrics are used by your agency (e.g., response time)?

5. (Select the **BEST** answer) Agencies involved in TIM share work facilities in the same:

   ___ Building

   ___ Floor

   ___ Room

   ___ No Shared Facilities

   What agencies share facilities?

6. For TIM in your region, have the agencies involved developed consensus guidelines for interagency coordination during incidents?

   YES NO

   If YES, use a scale of 1 – 5 (1 = Never to 5 = Always) to rate how well these guidelines are followed. If rated below 3, why do you feel that is the case?

7. What communication systems/methods do you use for dispatch and response (e.g., CAD, radio, et cetera)?

8. Are there changes to current practices and overall interagency coordination in your region that would improve TIM?

9. Would you like to receive a summary of the results when the survey has been completed?

   YES NO

10. Is there any additional information you would like to share?

Name (of contact person):____________________________________

Agency:____________________________________

Title:____________________________________

Phone:____________________________________

E-Mail:____________________________________

Address:

Please send completed survey by e-mail or fax by ***[Date]***

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Thank you for your time in completing this survey - Your help is greatly appreciated!

Appendix B

Process Charts

Note: The task descriptions and process charts assume all requests for assistance are routed through the various agency dispatchers. No linkages have been drawn illustrating on-scene dependencies between agencies. The following incident response sequences have been derived from incident response observations and the Interagency Coordination Management Team's recommended operational guidelines [40].

Recommended sequence of operational procedures for a disabled vehicle with no injuries or property damage

State Police

1. Incident occurs; time elapses until detected
   a. If incident detected by patrol car, go to step 6
   b. Else, go to step 2
2. Detection and verification of incident at RTMC
   a. Detection: 911 call, report from patrols, report from other sources (e.g., maintenance crews or highway helpers ("FIRST")), traffic flow patterns observed via cameras or road sensors
   b. Verification: Either via cameras or reports from other sources
3. MSP dispatch contacts patrol unit
4. Decide: Is unit able to respond?
   a. Yes: go to step 5
   b. No: MSP dispatch must call another unit (go to step 3)
5. Travel to scene
6. Protect scene
   a. Position vehicle
   b. Activate rear emergency flashers and/or chevron
7. Assess incident

8. Decide: Is vehicle blocking traffic?
    a. Yes: go to step 9
    b. No: go to step 18
9. Decide: Is vehicle occupied?
    a. Yes: go to step 13
    b. No: go to step 10
10. Contact MSP dispatch: request Zone Tow
11. Complete impound paperwork
12. Contact MSP dispatch
    a. Provide vehicle identification information
    b. Go to step 22
13. Talk with motorist: reach agreement on
    a. How to move vehicle safely (method)
    b. Where to move vehicle (non-blocking location)
14. Move vehicle
15. Talk with motorist: reach agreement on how to remove vehicle from highway
16. Decide: how will vehicle be removed?
    a. If via tow truck, go to step 17
    b. If via highway helper (FIRST), go to step 17
    c. If via another appropriate party (e.g., friend), go to step 22
17. Contact MSP dispatch
    a. Report “lane clear”
    b. Request tow and/or highway helper
    c. Go to step 22
18. Decide: Is vehicle occupied?

    a. Yes: go to step 15
    b. No: go to step 19

19. Run registration checks on vehicle

20. Red tag or mark vehicle with freeway paint

    - assists with monitoring duration of vehicle abandonment

21. Follow State Patrol General Guidelines for vehicle removal*

    a. Patrol departs scene

    b. At earliest opportunity, patrol arranges for zone tow to occur two hours after departure (Note: 2 hour delay is a grace period – e.g., the motorist may have left the scene to get help)

    c. Assumes patrol returns when tow occurs (go to step 23)

22. Wait for requested party or parties to arrive

23. Manage scene

    a. Secure scene as necessary

    b. Direct traffic as needed while vehicle is prepared for move

    c. Assist with removal or repair as needed

    d. Assist with re-entry of vehicle and tow/FIRST/other into traffic flow

    e. Other scene management or clearance tasks as necessary

24. Decide: Is scene cleared?

    a. Yes: go to step 25

    b. No: go to step 23

25. Contact MSP dispatch: report “all clear”

26. Depart scene

** Sequence inferred from ICMT guidelines, but not verified against the actual State Patrol guidelines*

Highway helper (FIRST)

1. Incident occurs; time elapses until detected
    - a. If incident detected by highway helper, go to step 6
    - b. Else, go to step 2
2. Detection and verification of incident at RTMC
    - a. Detection: CAD, scanner, report from FIRST patrols, report from other sources (e.g., maintenance crews), traffic flow patterns observed via cameras or road sensors
    - b. Verification: Either via cameras or reports from other sources
3. RTMC contacts FIRST unit
4. Decide: Is unit able to respond?
    - a. Yes: go to step 5
    - b. No (e.g., unit unable to respond (occupied, etc.)): RTMC must call another unit (go to step 3)
5. Travel to scene
6. Decide: First responder to arrive at scene?
    - a. Yes: go to step 19
    - b. No: go to step 7
7. FIRST notifies RTMC of arrival at scene
8. Decide: Is FIRST needed at scene in addition to other responder(s)?
    - a. Yes: go to step 9
    - b. No: go to step 31
9. Stage vehicle in an appropriate location per ICMT guidelines
10. Coordinate activities (e.g., clearance, scene protection) with MSP on-scene
    - Note: guidelines infer that MSP would be an on-scene responder, but what if Tow discovers incident and FIRST arrives next?

11. Decide: What task is assigned to FIRST?

    a. Repair or assist to get vehicle operational and back on the road

        - go to Step 12

    b. Assist with tow arrangements (owner and vehicle together)

        - go to Step 16

    c. Transport owner (separate from vehicle) to an off-highway location

        - go to Step 29

    (Note: at this point, guidelines infer the vehicle has already been moved into a non-blocking location by the initial responder, but what if the vehicle is still blocking traffic?)

12. Perform repairs and/or assist as necessary

13. Decide: Is vehicle operational?

    a. Yes: go to step 14

    b. No: go to step 16

14. Assist with re-entry of vehicle into traffic flow

15. Notify RTMC: “all clear” and go to step 31

16. Contact RTMC regarding need for tow

    - Note: assumes no prior Tow request (e.g., MSP step 17)

17. RTMC contacts Tow

18. Wait for Tow to arrive; go to Step 31

    - Note: Assumes FIRST does not assist Tow with recovery operations

19. Protect scene

    a. Position vehicle

    b. Activate rear emergency flashers and/or chevron

20. Assess incident

21. Decision: Is vehicle blocking traffic?
    a. Yes: go to step 22
    b. No: go to step 26
22. Decision: Is vehicle occupied?
    a. Yes: go to step 23
    b. No: go to step 24
23. Talk with motorist and reach agreement on
    a. How to move car safely (method)
    b. Where to move car (non-blocking location)
24. Move vehicle
25. Coordinate vehicle removal plan with others present, if any; go to step 11
26. Decide: Is vehicle occupied?
    a. Yes: go to step 25
    b. No: go to step 27
27. Red tag or mark vehicle with freeway paint
    - assists with monitoring duration of vehicle abandonment
28. Notify RTMC of vehicle status; go to 30
29. Assist as necessary with securing scene
30. Contact TIO to inform of transport plan
31. Depart scene

Tow service

1. Incident occurs; time elapses until detected
    a. If incident detected by tow unit, go to step 2
    b. Else, go to step 6
2. Tow unit notifies tow dispatch of incident
3. Tow dispatch notifies MSP of stalled vehicle and receives instructions
4. Tow dispatch contacts tow unit
5. Decide: unit needed on scene?
    a. Yes: go to step 8
    b. No: go to step 28
6. After detection and verification of incident at RTMC and determination of need, MSP or RTMC dispatch contacts appropriate tow service dispatch
7. Tow dispatch contacts appropriate tow unit(s) until an available one found; if no units available to respond, inform MSP/RTMC and go to step 6
8. Decide: tow unit(s) able to respond?
    a. Yes: go to step 9
    b. No: go to step 7
9. Travel to scene
10. Decide: First responder to arrive at scene?
    a. Yes: go to step 11
    b. No: go to step 25
11. Protect scene, stage vehicle in an appropriate location per ICMT guidelines

12. Decide: Is vehicle blocking traffic?
    a. Yes: go to step 13
    b. No: go to step 20
13. Decide: Is vehicle occupied?
    a. Yes: go to step 18
    b. No: go to step 14
14. Decide: Do traffic conditions permit a move of the vehicle to a nearby non-blocking location?
    a. Yes: go to step 15
    b. No: go to step 17
15. Move vehicle to safe non-blocking location
16. Tow notifies MSP and/or RTMC dispatch about new vehicle location
17. Wait for MSP and/or FIRST to arrive; upon arrival, go to step 24
18. Talk with motorist
    a. Inform motorist that MSP and/or FIRST is on its way
    b. If necessary,
        1) Decide where to move vehicle (non-blocking location)
        2) Decide how to move vehicle safely (method)
19. Decide: Does owner give tow consent to move vehicle?
    a. Yes: go to step 14
    b. No: go to step 17
20. Decide: Is vehicle occupied?
    a. Yes: go to step 21
    b. No: go to step 17

21. Talk with motorist
    a. Inform motorist that MSP and/or FIRST is on its way
    b. Decide how to move vehicle safely (method)
22. Decide: Does owner give tow consent to remove vehicle?
    a. Yes: go to step 23
    b. No: go to step 17
23. Prepare vehicle for removal; go to step 17
24. Coordinate vehicle removal activities with MSP and/or FIRST
25. If necessary, position truck for vehicle removal
26. Wait for go-ahead or further instructions (e.g., destination of tow) from MSP and/or FIRST
27. If necessary, prepare vehicle for removal
28. Depart scene as instructed

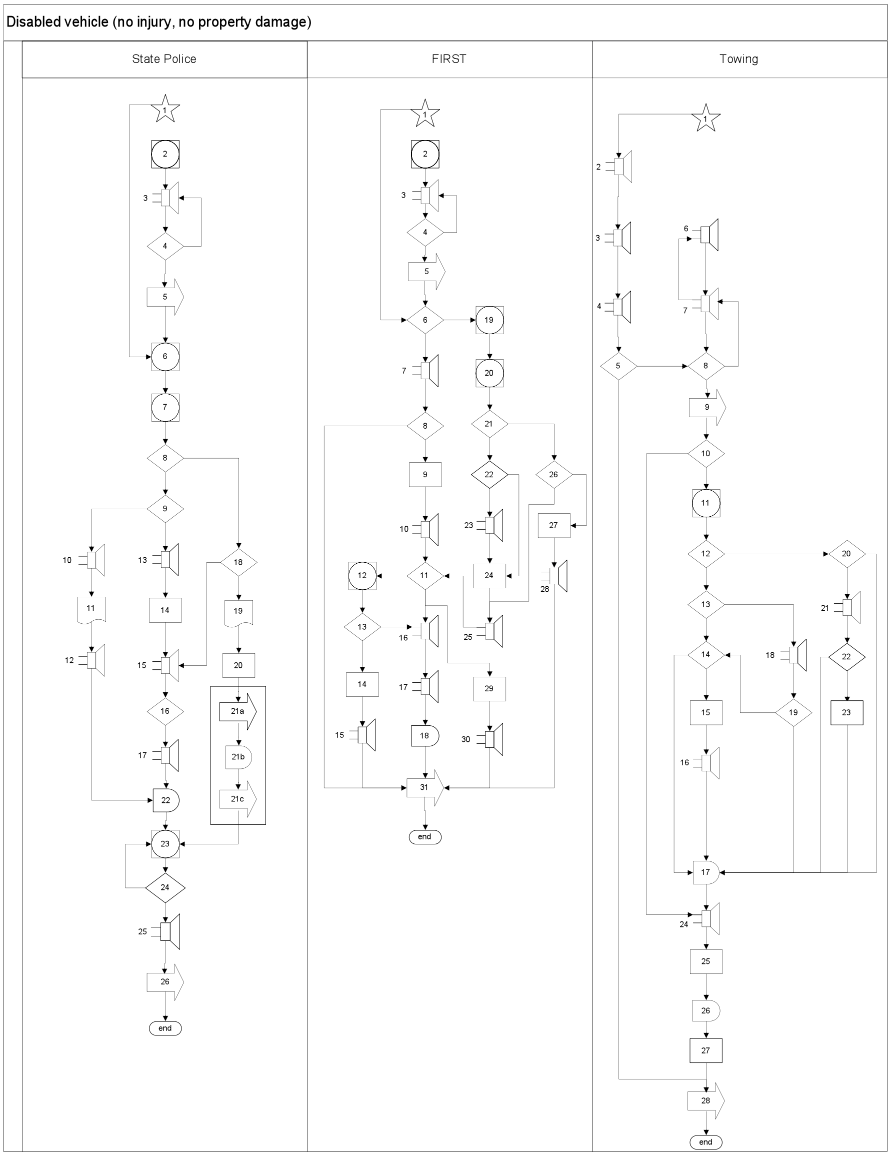

Figure B-3: Process chart for response to a disabled (stalled) vehicle

Appendix C

Survey Responses

Question 1	What local agencies (e.g., police, transportation department, etc,) are involved in Traffic Incident Management (TIM)? For each agency listed, rate the priority level given to Traffic Incident Management on a scale of 1 – 5 (1 = Low to 5 = High).
Albany	Traffic Supervisors, Highway Maintenance units, Thruway Statewide Operation Center (TSOC), State Police Troop “T”, Authorized Garages and local emergency services (Fire & EMS)
Austin	Enforcement (3), Fire(2), Public works/ Highway (2), Towing and recovery (3), Medical Examiner (1), Media (1), Commuter (1)
Cincinnati	All Hamilton County Agencies
Kansas City	**Police:** Belton Police Department (3); Blue Springs Police Department (4); Grain Valley Police Department(3); Grandview Police Department (3); Independence Police Department(2); Jackson County Sheriff Department (3); Kansas City Missouri Police Department (4); Lee’s Summit Police Department (4); Missouri State Highway Patrol (4); North Kansas City Police Department (2); Raytown Police Department (3); Riverside Department of Public Safety (3); Johnson County Sheriff Department (4); Kansas City Kansas Police Department (3); Kansas Highway Patrol (3); Leawood Police Department (4); Lenexa Police Department (4); Merriam Police Department(3); Mission Police Department (3); Olathe Police Department (3); Overland Park Police Department (3) **Fire:** Central Jackson County Fire Protection District (4); Kansas City Missouri Fire Department (3); Kansas City Kansas Fire Department (3); Johnson County Fire Departments (3); Lee’s Summit Fire (3); NKC Fire Department (3) **Transportation:** Kansas Department of Transportation (4); Missouri Department of Transportation(5); Towing Operators (2)
Salt Lake City	Utah Department of Transportation – 5; Utah Highway Patrol - 5; Fire Departments (various local departments) – 3 (varies); Contracted towing services – 3; Contracted medical response - 3
San Diego	California Highway Patrol (5); California Dept. of Transportation (5); Fire Department (5)
	Washington State Patrol – 5; Department of Transportation – 5; Local fire and EMS agencies – 3; Local law enforcement agencies – 3; Towing Industry – 3; Coroners/Medical Examiners – 3; Hazmat contractors – 3; Department of Ecology – 3 **Note:** It is important to note that all of the above responding agencies would have a high priority (5) when fulfilling their respective public safety missions. The lower numbers are more reflective on the different priorities when it comes to

Question 2	Is information on traffic incidents (car crashes, traffic congestion, etc.) shared between police and transportation personnel (dispatchers, traffic information officers, response personnel, etc.)…			
	Category A	Category B	Category C	
…during incidents	3 of 3	5 of 5		-
…after incidents	3 of 3	3 of 5		
Question 3	Consensus incident management performance metrics have been developed and are used by all agencies for response evaluation and improvement.			
	Category A	Category B	Category C	
	2 of 3	3 of 5		
Question 4	What metrics are used by your agency (e.g., response time)?			
	Response time	Clearance time	Incident duration	Delay
	5 of 8	7 of 8	2 of 8	1 of 8

Question 5	(Select the BEST answer) Agencies involved in TIM share work facilities in the same:			
	Building	Floor	Room	No Shared Facilities
	2		4	2
Question 6	For TIM in your region, have the agencies involved developed consensus guidelines for interagency coordination during incidents?			
	Category A	Category B	Category C	
	3 of 3	4 of 5*		
	*Often, guidelines exist, but are neither disseminated nor followed (personnel are unaware of guidelines). In some cases, these were mandated by state governments. In others, the guidelines appear irrelevant (possible lack of consultation during creation).			

Question 7	What communication systems/methods do you use for dispatch and response (e.g., CAD, radio, et cetera)?			
	Category A	Category B	Category C	
Radio	3 of 3	4 of 5		
Phone	2 of 3	1 of 5		
CAD	3 of 3	4 of 5		

e-mail/Intranet		2 of 5		

Question 8	Are there changes to current practices and overall interagency coordination in your region that would improve TIM?
	"More training of rural or smaller city fire departments. The larger departments work well with Highway Patrol and UDOT. "
	"Yes – if our TMC was made aware of incidents on a more regular basis from all of our operational partners."
	"All agencies committing to incident clearance goal of 90 minutes or less."
	"We are working to publicize the National Unified Goal for Traffic Incident Management and use it as a tool to bring more responders to the table. We just created a statewide Traffic Incident Management Coalition to oversee implementation of the NUG in Washington State. We tapped the president of the state firefighter's association and the executive director of the Towing and Recovery Assn to serve as chair and vice chair of the coalition. We have recruited representatives from the Department of Ecology and the Office of the Insurance Commissioner to serve on the coalition in addition to members representing AAA, the Washington Trucking Assn, etc. Our second annual statewide Traffic Incident Management Conference is scheduled for September 2008. We are using this as another tool to reach out to fire, EMS, towing, and other responders. "

	"We are in the process of updating and making adjustments to the incident management manual. KC Scout will be providing training to departments / agencies on the manual. The information will be provided in a format that will be easy for the responders to use, and it will be kept updated. The biggest problem is that the responders don't even know that the manual exists, much less what is in it."
	"It could always be better, but I feel we do a pretty good job. We have a consolidated communications center for the majority of the police and fire agencies in the county and work well with each other for major incidents..."