



INTEGRATION OF THE INCIDENT COMMAND SYSTEM (ICS) PROTOCOL FOR EFFECTIVE COORDINATION OF MULTI-AGENCY RESPONSE TO TRAFFIC INCIDENTS

FINAL REPORT

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In recent years, there has been an increased focus on Traffic Incident Management (TIM) and incorporation of the Incident Command System (ICS) to reduce traffic congestion on the nation's Interstates. In fact, studies show that for every minute a freeway lane is blocked due to an incident, there is a corresponding time of four minutes of travel delay, and the likelihood of a secondary crash increases by 2.8% for every minute that the primary incident remains a hazard. Efficiencies resulting from adoption of coordinated multi-agency response through ICS can reduce the impact of non-recurrent traffic congestion caused by traffic incidents on major roadways. This project investigated the effectiveness of multi-stakeholder agency coordinated ICS strategies for managing traffic incidents by considering their potential impacts in reducing incident duration. Between 2012 and 2013, there were 129 fatal incidents recorded on SC Interstates. Roughly half of the fatal incident recovery times (dispatch of response to incident cleared) were in excess of six hours, with maximum recovery times well over 12 hours. These clearance and recovery times are significantly higher than those in other states. States which have implemented enhanced ICS and TIM procedures are consistently achieving major incident clearance times of one and a half hours or less. After analyzing the current state-of-practice in South Carolina, and national best practices, the potential areas for improvement in incident response were identified. The TIM areas most in need of improvement were response and clearance strategies, with major gaps noted in towing, coroner, HAZMAT, and crash investigation procedures.

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EXECUTIVE SUMMARY

In 2014, there were 13,528 crashes on the Interstates in South Carolina. Of these, 90 were fatal, 2,489 involved injuries, and 10,949 were property damage only. The State Highway Emergency Program (SHEP) responds to roughly 60,000 incidents per year on Interstates near major urban areas in South Carolina. These incidents involve vehicles that are on fire, have medical emergencies, have crashed, or have mobility issues (e.g., engine failure or tire problems). Daily incidents on South Carolina roadways cause delay and threaten our quality of life, safety, and mobility.

In recent years, there has been an increased focus on Traffic Incident Management (TIM) and incorporation of the Incident Command System (ICS) to reduce traffic congestion on the nation's Interstates. In fact, studies show that for every minute a freeway lane is blocked due to an incident, there is a corresponding time of four minutes of travel delay (NTIMC, 2006). According to a study published in the ITS Journal, it was estimated that the likelihood of a secondary crash increases by 2.8% for every minute that the primary incident remains a hazard (FHWA, 2009). Further, severe congestion also leads to: increased response time by police, fire, and emergency medical services; lost time and a reduction in productivity; increased cost of goods and services; increased fuel consumption and vehicle maintenance costs; reduced air quality and other adverse environmental impacts; and, a negative public image for agencies involved in incident management activities.

Between 2012 and 2013, there were 129 fatal incidents recorded on SC Interstates. Roughly half of the fatal incident recovery times (dispatch of response to incident cleared) were in excess of six hours, with maximum recovery times well over 12 hours. The median recovery time for injury incidents is under two hours, with maximum recovery times approaching five hours. These clearance and recovery times are significantly higher than those in other states. States which have implemented enhanced ICS and TIM procedures are consistently achieving major incident clearance times of one and a half hours or less.

Resolving highway incidents, and responding to emergencies with clear and unified objectives, involves multi-stakeholder agency emergency response and may include personnel from the state department of transportation, highway patrol and/or other law enforcement agencies, fire services, emergency medical services, towing, coroner, and hazardous-spill cleanup services. Efficiencies resulting from adoption of coordinated multi-agency response through ICS can reduce the impact of non-recurrent traffic congestion caused by traffic incidents on major roadways. This project investigated the effectiveness of multi-stakeholder agency coordinated ICS strategies for managing traffic incidents by considering their potential impacts in reducing incident duration.

After analyzing the current state-of-practice in South Carolina, and national best practices, the potential areas for improvement in incident response were identified. The TIM areas most in need of improvement were response and clearance strategies, with major gaps noted in towing, coroner, HAZMAT, and crash investigation procedures. The summary of these recommendations for these four areas are as follows:

- Towing - In South Carolina, towing operations are conducted on a rotation dispatch system. The dispatched company has 45 minutes to arrive at the scene of the accident and is paid by the hour to clear incident vehicles. Under the current system, there is no motivation for the towing companies to get the job done quickly, because the longer they work the crash scene the more money they earn. In 2008, Georgia implemented the Towing and Recovery Incentive Program (TRIP) which compensates certified, inspected, heavy-duty recovery companies to expedite clearance at major incident scenes. Over the seven years that the program has been in operation, there have been 515 TRIP activations and clearance times have dropped from 216 minutes to under 40 minutes (38 min in 2014). An independent evaluation of the program in 2011 indicated a cost savings per incident of $456,396 (or 71% savings). Based on a median fatal incident recovery time of 355 minutes in South Carolina, and a 66% improvement in incident duration from implementation of a TRIP program, an estimated 234 minutes could be saved for a single fatal incident.

- Hazmat – Delays in HAZMAT response and clean-up may occur when DHEC resources are requested unnecessarily to incident sites which are notification-only events. The cause of this may most often be attributed to an overestimation of the amount of fuel spilled by on-scene response personnel. Accurately identifying when a HAZMAT team response is needed will result in faster clearance times for incidents. A statewide policy would provide consistency and formal protocols for evaluating fuel spills, as well as hazardous material cargo spills. By explicitly defining and developing standard statewide operating procedures and interactive spill training, hazardous material spills could be handled more quickly and efficiently by the resource personnel closest to the incident. Though HAZMAT response is not frequently needed, cargo spills containing hazardous materials entail some of the lengthiest incident responses.
- Coroner – Under South Carolina legislation, incident responders are not allowed to disturb a victim's body in any way (i.e., moving the body or the vehicle containing the body) until a formal investigation and authorization has been completed by a coroner, deputy coroner, medical examiner, or deputy medical examiner. Significant delays and increased congestion are likely outcomes due to the response time of the coroner. Additionally, there are typically a limited number of qualified individuals that may investigate and authorize the removal of deceased individual from a traffic incident scene. Texas, Tennessee, and Louisiana have implemented traffic fatality certification laws to address the removal of the deceased from incident scenes where the location obstructs or presents a hazard to adjacent traffic flow. These laws are a combination of quick clearance (i.e., allowing temporary removal of the deceased from the highway and/or certification of the incident fatality by someone other than the coroner, such as EMS and qualified Fire personnel) and hold harmless acts.
- Crash Investigation – In South Carolina, the Multidisciplinary Accident Investigation Team (MAIT) conducts in-depth investigations of traffic incidents involving complex circumstances (e.g., fatalities and felony cases). MAIT investigations are associated with having the longest incident time duration as much of the investigation is likely conducted in the field at the time of the incident. With the implementation of new technologies (e.g., 3D laser scanning and drone cameras), crash scene measurements may be completed in a fraction of the current time and have an added benefit of collecting a significant amount of additional data. Reductions in data collection time noted in the literature range from 50% to 90% when these technologies are used. Further, these technologies don't require personnel to enter hazardous areas of the scene, nor do they require traffic operations to be suspended during use.

Based on the analysis of implementing these strategies in other states, South Carolina should expect shorter incident duration times, reduced costs and increased efficiency for each stakeholder agency, and more effective cooperation with local responders. The motoring public should experience fewer secondary collisions, reduced congestion times, and lower vehicular operating costs. Additionally, there will be less fuel wasted and fewer emissions from idling vehicles due to reduced incident times. An intangible result should be of a more favorable opinion by the public of the agencies involved in incident management activities. A benefit-cost analysis was conducted to evaluate the effectiveness of ICS strategies; benefits were determined by comparing the simulation outputs between existing and enhanced TIM scenarios. The results show that implementing TIM strategies should provide a range of returns from $15 to $168 for every dollar invested. The return on investment accrues from savings in terms of travel time, fuel, and emissions

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1 INTRODUCTION

With the increasing number of severe natural disasters in the last decade and added concerns over homeland security issues, emergency preparedness with regard to our transportation system has received a great deal of attention. The transportation system plays an integral role in any emergency response plan whether to evacuate individuals from high hazard locations, or to move emergency response personnel and equipment into incident sites – particularly by way of upper level components such as Interstates. The transportation system, however, is not only taxed during major emergency or disaster situations; daily incidents on our roadways can cause tremendous delay threatening quality of life, safety, and mobility. Resolving highway incidents and responding to emergencies with clear and unified objectives among all related agencies (e.g., fire, law enforcement/highway patrol, EMS, and transportation agencies) facilitates the response and recovery functions necessary to handle incidents of all shapes and sizes.

While it is important to be prepared for the worst possible incidents (i.e., tsunamis, hurricanes, major hazardous material spills, ice storms, etc.), these events are relatively rare when compared to crashes and other incidents that occur daily on our transportation system. In 2014, there were 13,528 crashes on Interstate facilities in South Carolina. Of these, 90 were fatal, 2,489 involved injuries, and 10,949 were property damage only. This represents approximately 10.51% of the total 128,763 crashes that occurred on all South Carolina roadway facilities in 2014[1]. However, crashes represent a small part of incidents on interstates. Based on statistics from the State Highway Emergency Program (SHEP)[2] vehicles, approximately 60,000+ incidents were recorded in 2009 on less than 10% (roughly 300 of 3,742[3]) of the interstate lane-miles in South Carolina. These incidents involve vehicles that are on fire, have medical emergencies, have crashed or have mobility issues such as engine failure or tire problems. In almost every incident involving a vehicle crash, SHEP provides traffic control through lane closures and other means to protect the responders and other motorists on the roadway.

In recent years, there has been an increased focus on Traffic Incident Management (TIM) and incorporation of the Incident Command System (ICS) to reduce traffic congestion on our nation's interstates. Although DOTs are building and renewing major highway routes at rates commensurate with their funding levels, traffic volumes continually approach capacity. This phenomenon alone virtually assures that when any type of incident occurs on a high volume interstate facility, the result will be formation of undesirable congestion. In fact, studies show that for every minute a freeway lane is blocked due to an incident, this results in four minutes of travel delay time (NTIMC, 2006). Delay is not the only thing caused by incidents, the severe congestion also leads to:

- Secondary incidents that are often more severe than the initial congestion-causing incident,
- Increased response time by police, fire, and emergency medical services,
- Lost time and a reduction in productivity,
- Increased cost of goods and services,
- Increased fuel consumption and vehicle maintenance costs,
- Reduced air quality and other adverse environmental impacts,
- Reduced quality of pavement surface (shoving/rutting) due to hard braking by heavy vehicles, and

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[1] SCDOT Crash Data files
[2] http://www.dot.state.sc.us/getting/incident_stats.shtml
[3] http://www.fhwa.dot.gov/policyinformation/statistics/abstracts/2009/sc.cfm

- Negative public image for agencies involved in incident management activities.

Incident management and clearance involves multi-stakeholder agency emergency response including personnel from the state department of transportation, highway patrol and other law enforcement, fire services, emergency medical services, towing, and hazardous-spill cleanup services. The traditional step-by-step approach for incident management is largely performed independently with limited coordination among involved agencies (DHS, 2008). Efficiencies resulting from adoption of coordinated multi-agency response through ICS can reduce the impact of non-recurrent traffic congestion caused by traffic incidents on major roadways. To minimize the incident response time, it is essential that every stakeholder agency involved in incident management work in collaboration with each other. This project investigated the effectiveness of multi-stakeholder agency coordinated ICS strategies for managing traffic incidents by considering their potential impacts in reducing incident duration.

Figure 1.1 shows the complex network of decisions and paths of communication that are critical to successful resolution of highway incidents. Incident management requires completion of many distinct activities, each of which is the responsibility of a specific agency or response crew. It is essential that all of these partners work effectively and efficiently together to achieve the goal of roadway clearance in the shortest period of time. Interagency coordination, communication, and collaboration are critical, such that responders cultivate a working trust with one another, transfer command and control when necessary, and ensure sufficient on-scene resources exist at all times.

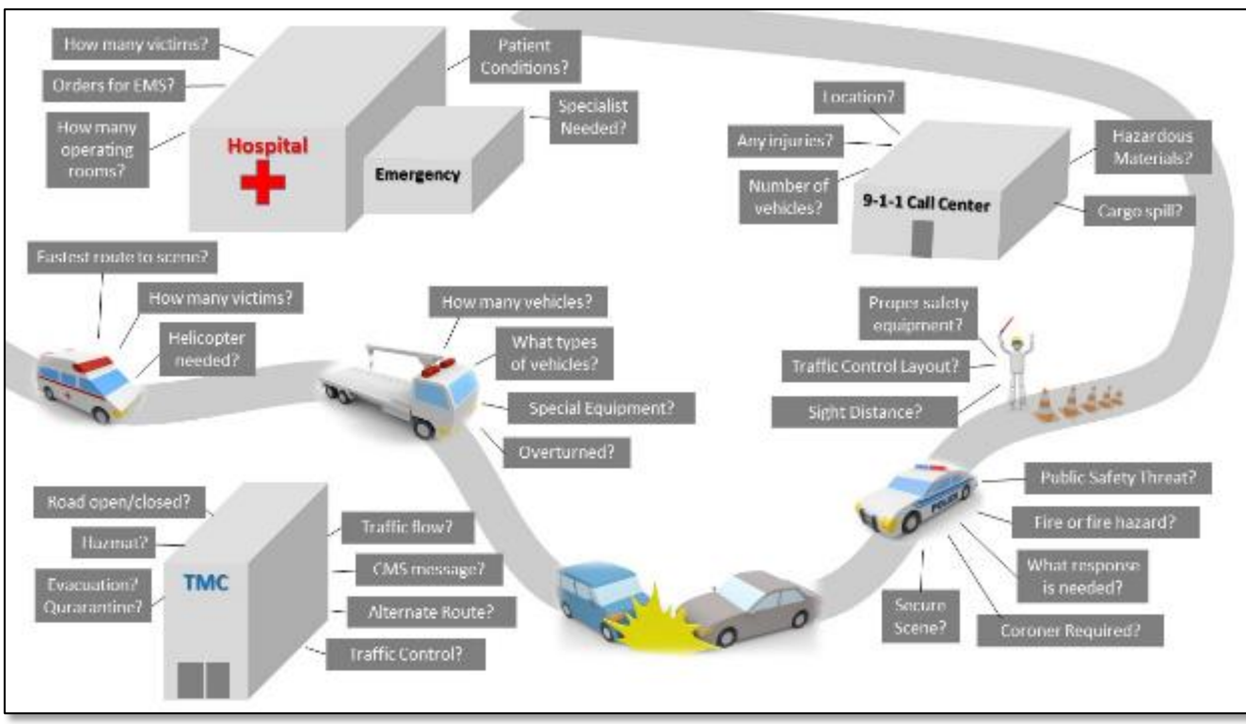


Figure 1.1 Complex Communication Paths and Management Requirements for Successful Resolution of Incidents

Many states and jurisdictions across the country have incorporated ICS into the continuum of traffic incident response and clearance activities. A Federal Highway Administration survey of agencies in the 75 most populated metro areas indicates that nearly two-thirds of the surveyed agencies use ICS to manage traffic incidents. More than half reported the presence of State law or formal policies that designate the Incident Commander (person in charge) at the scene of a traffic incident. Several examples of successful traffic incident management programs include the I-95 Corridor Coalition as well as Incident Management programs in the states of Washington, Florida, Georgia, and Maryland. The Georgia Traffic Incident Management Enhancement (TIME) team strategic vision included a towing and recovery incentive program (TRIP) that would compensate towing companies to expedite clearance at major incident scenes. The program requires minimum equipment levels, prompt response and 24/7 equipment availability, highly trained operators, and fluid spill mitigation capabilities. In the first year, the clearance time dropped from 216 minutes to 49 minutes (see Figure 1.2) with the transition from pay by the hour to incentive pay to clear within 90 minutes (disincentives are also used for clearance times over three hours). Similarly, impressive results were reported in an evaluation of the Coordinated Highways Action Response Team (CHART) program in Maryland. CHART found a 24% reduction in average incident duration, as compared other agencies, and this reduction in incident duration resulted in 290 fewer secondary incidents in 2005 (FHWA, 2011c). A study published in the ITS Journal estimated that the likelihood of a secondary crash increases by 2.8% for every minute that the primary incident remains a hazard (FHWA, 2009). Numerous programs, in conjunction with resources from the Federal Highway Administration, were studied to recommend programmatic changes to further enhance existing SCDOT practices and capitalize on much needed reductions in response and clearance times.

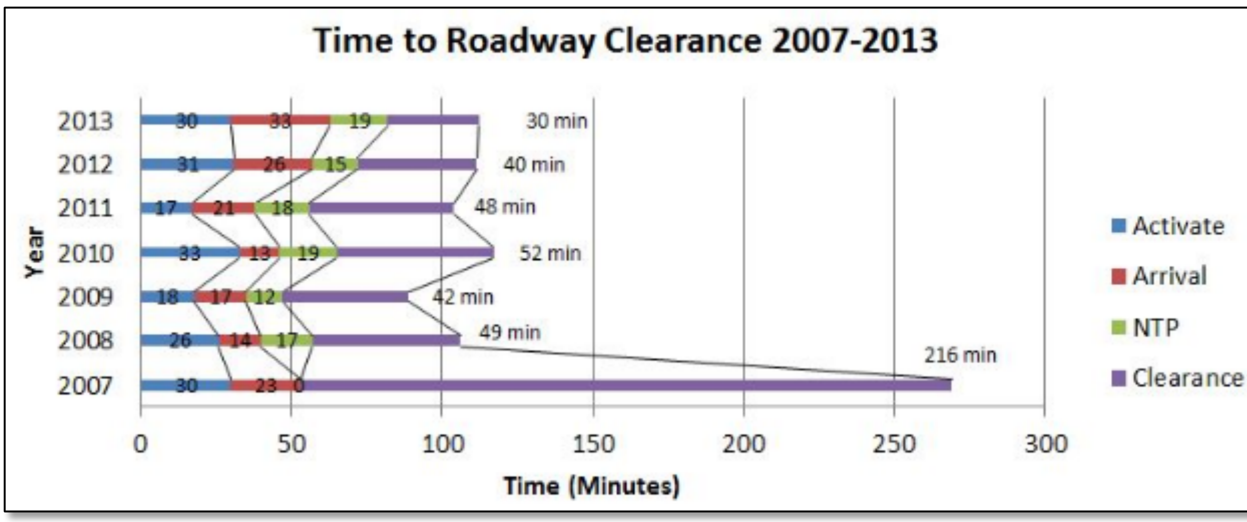


Figure 1.2 Georgia Towing and Recovery Incentive Program (TRIP) Reduced Clearance Time by 60%

1.1 STUDY GOAL AND OBJECTIVES

The major goal of this research project was to enhance the integration of ICS protocols and traffic incident management best practices to more effectively manage day-to-day incidents on South Carolina Interstates.

The research team conducted a number of tasks to successfully meet the overarching goal of the study. These tasks were generally divided into six focus areas including: review of ICS plans and practices, analysis of South Carolina incident data sources, review of national TIM best practices, gap analysis, best practice recommendations, incident simulation, and benefit/cost analysis. Following are specific tasks that were performed in each of these focus areas:

- Review of ICS Plans and Practices:
    - Conduct a fact-finding, document gathering, process documentation meeting to identify what ICS processes and documentation were in place for traffic incident management
    - Examine the processes to assure compliance with national ICS requirements and TIM best practices
    - Develop traffic incident action planning (TIAP) documents to supplement SHRP 2 TIM Training and encourage use of ICS
- Incident Data Analysis:
    - Retrieve incident data from multiple sources including: SC crash report database, SCDOT Traffic Management Center Logs, and SC Highway Patrol CAD files
    - Assess the data in each of the three sources to determine completion, accuracy, and usability
    - Use advanced searching formulas to attempt matching the disparate data sources to define a more complete picture of incidents
    - Analyze data sources to determine the magnitude and duration of incidents along I-26 between Columbia and Charleston
- Review of Best Practices:
    - Conduct a literature review of ICS and TIM best practices
    - Review best practices for reducing time required to complete lengthy response tasks including clearance of wrecked vehicles, cleanup of hazardous material spills, conducting crash scene investigations, and recommend policies, procedures, and technologies that may reduce time required for these tasks
- Gap Analysis:
    - Interview a stakeholder group to define SOP for current traffic incident management practices and gather any existing documentation
    - Compare the information gathered in interview with the review of best practices and identify gaps between SC SOP and TIM best practices with recommendations for policy or procedural changes
- Best Practice Recommendations:
    - For specific areas of need identified in the gap analysis, locate successfully implemented programs in other states and undertake more detailed research on factors to program success and outcomes of evaluations
    - Recommend specific programmatic, policy, or procedural changes for SC stakeholders to capitalize on successes from other states in adoption of state-of-the-practice in ICS/TIM
- Incident Simulation and Benefit Cost Analysis:
    - Perform benefit cost analysis to demonstrate the effectiveness of reduced incident clearance time as it pertains to efficiencies gained by implementation of a TIM incorporating ICS protocols and best-practices for responding to incidents on Interstate highways in South Carolina

Based on evaluations of other ICS/TIM enhancements, it is expected that implementing the results of this research will produce better communication, cooperation, and control between SCDOT, SCHP, and its partners when handling incidents on our highways. Based on results in other states, SC can expect shorter incident duration times, less cost, and better efficiency for each stakeholder agency and better cooperation with local responders. The motoring public will be better served by experiencing fewer secondary collisions, reduced time in congestion, and lower vehicular operating costs. There will be fewer emissions from idling vehicles since incident times are reduced and less fuel wasted. From a roadway maintenance perspective, reducing hard braking by heavy trucks may also reduce wear and tear on pavements. During severe braking maneuvers, the fatigue damage caused by front axle loading increase by a factor of 500 to 1000 percent (Gillespie, 1993). A more favorable opinion by the public of our agencies will result from this implementation. Additionally, highway capacities will be enhanced under any conditions as congestion is reduced.

1.2 STRUCTURE OF THE REPORT

The remainder of this report will present a brief background on ICS followed by detailed write-ups of the six major task areas and conclusions. Chapter two will establish the background and need of ICS integration, discuss ongoing training in South Carolina, and development of incident action plan documents to enhance ICS for traffic incident management. Chapter three will present available data sources for incidents along interstates in South Carolina. The magnitude of the incident problem will be analyzed along with response times and other metrics that can be used as baseline measures of effectiveness for future programmatic enhancements. Chapter four will cover best practices identified in other states across most major components of incident response. Chapter five will present findings from multiple stakeholder meetings held to ascertain the current standard operating procedures related to use of ICS and procedures for traffic incident management. The identified gaps between state-of-practice and SC standard operating procedures are identified and also reported in this section. Chapter six will address programmatic detail for four major areas of need identified in the gap analysis including: towing, hazardous materials, fatality certification, and major accident investigation. Chapters seven and eight cover the simulations and benefit/cost analyses conducted to provide the range of benefit across multiple sites within the state. Chapter nine will provide a summary of conclusions and recommendations.

2 INTEGRATION OF ICS IN SOUTH CAROLINA

2.1 BACKGROUND ON ICS

In 2005, Homeland Security Presidential Directive 5– *Management of Domestic Incidents* created the National Incident Management System (NIMS) to provide a "consistent nationwide approach for Federal, State, local, and tribal governments to work effectively and efficiently together to prepare for, prevent, respond to, and recover from domestic incidents, regardless of cause, size, or complexity."(DHS, 2008) An integral part of the success of NIMS is the effective communication outlined by Incident Command System (ICS) protocol. The ICS protocol is a "fundamental form of management established in a standard format, with the purpose of enabling incident managers to identify the key concerns associated with the incident—often under urgent conditions—without sacrificing attention to any component of the command system." (DHS, 2008) This protocol provides an organizational structure of command with the flexibility to expand and contract the size of the team to accomplish the remediation of a single or multiple incidents regardless of boundaries for the life cycle of the incident.

The ICS was developed in the 1970s as a response to the inadequate management of a series of wildfires in California. Studies following the catastrophic fires indicated that weaknesses of the response were often due to:

- Lack of accountability, including unclear chain of command and supervision,
- Poor communication due to both inefficient use of available communications systems and conflicting code words and terminology,
- Lack of an orderly, systematic planning process,
- Lack of common, flexible, predesigned management structure that enables commanders to delegate responsibilities and manage workloads efficiently, and
- Lack of predefined methods to effectively integrate interagency requirements into the management structure and planning process. (FHWA, 2011b)

Today, ICS protocol is used by numerous agencies on all levels of government and in the private sector. ICS has proven so effective in managing incidents that it is required for use under NIMS during responses to any/all incidents. According to FHWA's 2008 Traffic Incident Management (TIM) System Self-Assessment, 78% of TIM stakeholders report utilizing ICS Protocol which continues the steady increase from 2006 and 2007.

Use of the ICS has increased steadily over the last few years not only because it is mandated, but also it provides numerous benefits to day-to-day highway incident management and large scale responses. Benefits of its use include:

- Facilitation of a more consistent response to any highway incident by employing a common organizational structure that can be expanded or contracted in a logical manner based on the level of required response,
- Definition of responder roles and responsibilities,
- Establishment of a clear decision-making process,
- Accommodation of any responding agency regardless of jurisdiction or discipline,
- Minimization of redundancy in roles, thereby optimizing resource deployment, and
- Provision of effective two-way communication between response personnel, facilitating improved interagency coordination while reducing overall communications load associated with highway incident response. (FHWA, 2011a)

To maximize these benefits, ICS states that the size of an incident's management team is directly proportional to its complexity. Traditionally, a full ICS deployment is only reserved for the most severe of natural disasters and large scale terrorist attacks. In all incidents, there is an Incident Commander who maintains authority over all incident activities depending on the priority of the mission at hand. For instance, Fire is typically in charge until the injured are extricated, treated, and moved, and then command is transferred to law enforcement to complete the investigation. As the incident moves to clean-up/recovery, the Department of Transportation may assume command. Seamless transfer of command is only successful with an established unified command (UC) structure.

A predefined UC structure is derived from an Incident Action Plan (IAP) and allows "agencies with incident responsibilities to work within an established set of common objectives and strategies that can include:

- Agency assignments,
- Incident priorities,
- Assignment of agency objectives,
- Communications protocols,
- Knowledge of duties within agency responsibilities, and
- Acquisition and allocation of materials and resources." (FHWA, 2009)

The Incident Commander, a single person, or the UC, leaders of multiple agencies must fulfill the five major functions of an ICS organization: Command, Operations, Planning, Logistics, and Finance and Administration. Intelligence is gradually being adopted as a sixth function in response to the NIMS guidelines for gathering, sharing, and managing incident related information. Figure 2.1 depicts the priority of each function along with its responsibilities. These tasks can be self-performed or delegated to others within a reasonable span of control. NIMS ICS guidelines specify that the span of control should range from three to seven people with five being the normal level (DHS, 2008). If a task can be accomplished with less than three people, the commander should assume those responsibilities and the incident team contracted accordingly.

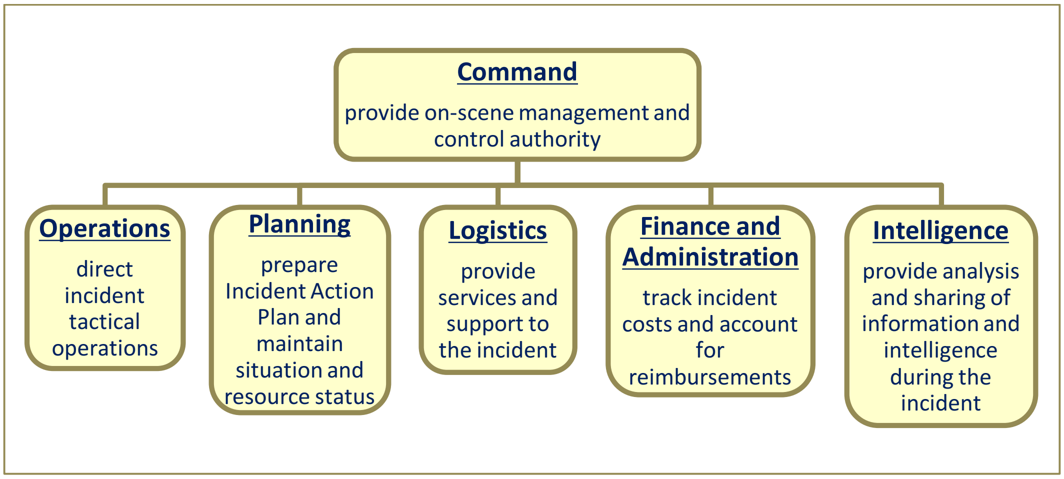


Figure 2.1 ICS Organization Functions and Responsibilities

In addition to a clear command chain, ICS emphasizes the necessity for common terminology to facility clear communication regardless of location. NIMS outlines three areas in which common terminology is used:

- Organizational Functions: Major functions and functional units are named and defined, and the organizational elements are standard and consistent
- Resource Descriptions: Major resources (i.e., personnel, facilities, and, major equipment and supply items) that support incident management activities are given common names and "typed" with respect to their capabilities to avoid confusion and enhance interoperability
- Incident Facilities: Designate the facilities in the vicinity of the incident area that will be used during the course of the incident

In addition to an integrated communication plan, interoperable communication processes and architecture must also be in place (see Figure 2.2). Similar to the planning necessary for unified command, integrated communication must be established prior to an incident and incorporated into the incident action plan. An effective communication plan aids in the deployment of personnel and available resources only when they are needed at the scene. This further emphasizes the ICS principle of using only what and who is needed when they are needed.

To eliminate confusion on what resources are available when an incident occurs, a comprehensive resource management system is needed to support the ICS organization during any incident. An accurate and up-to-date picture of personnel, teams, equipment, supplies, and facilities and their readiness status must be maintained. A key principle that supports resource management and the ICS organization is accountability. Effective accountability must be maintained at all jurisdictional levels and within individual functional areas. When accountability is achieved with resources and chain of command, information and intelligence management is possible. This is a process which must be established for gathering, analyzing, assessing, sharing, and managing incident-related information across agencies during and after the incident to allow for benchmarking and process improvement.

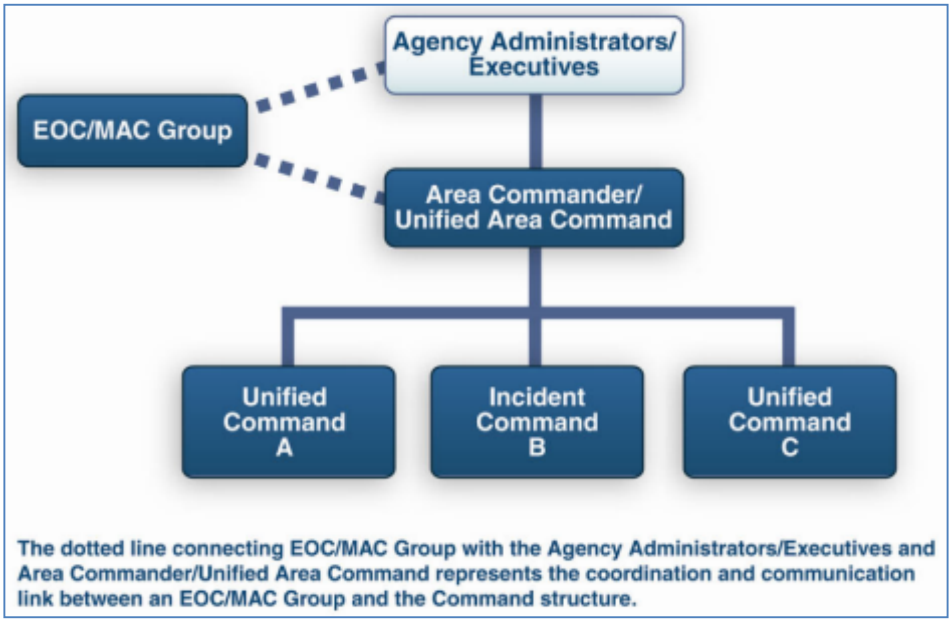


Figure 2.2 Chain of Command and Reporting Relationships (DHS, 2008)

ICS is an effective tactical structure for single incidents or multiple incidents located in the same manageable geographical area. An Area Command may be needed when incidents affect a large geographical area, are not immediately identifiable, and/or evolve over longer periods of time (e.g. hurricanes, public health emergencies, or any area where several incident management teams (IMTs) are requesting similar resources). The primary objective of an Area Command is to oversee the management coordination of multiple incidents while simultaneously working in tandem with groups providing support (e.g., Emergency Operations Center (EOC) or Multiagency Coordination Group (MAC Group)). (DHS, 2008) Incidents requiring an Area Command necessitate coordinated inter-governmental, non-governmental, and private sector coordination. Similar to the Unified Command for a single ICS, a Unified Area Command can be established when coordinated efforts across multiple jurisdictions are needed. The primary objective of Area Commands is to oversee the management coordination of multiple incidents and is designed to work in tandem with an Emergency Operations Center (EOC) or Multiagency Coordination Group (MAC Group) which coordinates support.

Incident Command System protocol, developed out of necessity for fire and rescue services in the 1970s and nationally mandated in 2005 with establishment of the National Incident Management System, has become a model for tactical incident response from a minor crash to a national security threat. This system relies on predefined objectives, explicit and flexible chain of command, and clear communication. "The two rules of thumb for managing an ICS structure are to: (a) ensure the organization develops at a pace that never constrains the level of required tactical operations and incident support activities at any time during the operational period, and (b) maintain an organization size that does not exceed the size required to meet the incident objectives and get the job done." (FHWA, 2011a)

2.2 ICS INTEGRATION AND TRAINING IN SC

In many instances, the implementation of standardized ICS procedures among state agencies can be based on historically accepted roles and operating procedures. In South Carolina, the adoption of ICS was initiated by the South Carolina Highway Patrol (SCHP) for the hurricane incident management planning process involving significant evacuation requirements and coordination of partners along the I-26 corridor from Charleston to Columbia. Given the familiarity of these agencies with ICS and incident management strategies, this corridor was chosen as the focus for this research program. I-26 extends from Spartanburg to Columbia to Charleston is the primary Interstate route connecting the piedmont region with the midlands, and coastal zone of South Carolina. The Columbia to Charleston corridor of I-26 extends from milepoint 116 at the I-77 Interchange to milepoint 221 in Charleston, with a length of 105 miles of Interstate highway. The route stretches across portions of six counties including: Lexington, Calhoun, Orangeburg, Dorchester, Berkeley, and Charleston. Additionally, the route extends through numerous municipalities, SC DOT Districts (1, 6, and 7), SC Highway Patrol Troops (1, 6 and 7), and countless other jurisdictional boundaries. As such, the 2012 SCDPS Hurricane Evacuation Operation Plan encompasses over 500 pages of pertinent information. However thorough, the document was not intended for general traffic incident management and therefore does not include some of the items needed for day-to-day traffic incidents. For instance, coroner and hazardous materials response are not typical for hurricane evacuation, but are often necessary responses for major traffic incidents. The research team spent a significant amount of time combing through the existing hurricane incident action plan (IAP) and used this as a basis for formulating the traffic incident action (TIAP) documents for multiple levels of incidents.

At the onset of the project, the research team was initially tasked with defining standard operating procedures and developing ICS training to ensure consistency across all incident response teams around the state. However shortly after the contract award, the Second Strategic Highway Research Program (SHRP 2) released a multi-disciplinary training course designed to establish the foundation for and promote certification of responders to achieve the three objectives of the TIM national unified goal: responder safety; safe, quick clearance; and prompt, reliable, and interoperable communications. The intent is to establish a common set of core competencies in order to promote a shared understanding of TIM goals among responders from different stakeholder groups—law enforcement, fire and rescue, emergency medical services, the U.S. Department of Transportation, towing and recovery, and notification and dispatch. The multiagency and multidisciplinary course uses a variety of adult-learning techniques including interactive seminar, case study analysis, tabletop role-play and scenario, and field practicum. Members of the steering committee and research team completed a thorough review and update of SCDOT's training materials incorporating SHRP 2's goals with SC-specific information related to transportation management functions and traffic information systems. As of the publication of this report, training has been offered to all counties and districts within the state, and will be ongoing due to the large number of responders needing it.

While the SHRP 2 training does a good job of training on ICS and TIM core competencies, it does not set forth the resource plans, contact info, etc., needed for day-to-day traffic incident management. To supplement the training, the research team developed traffic incident action planning documents (Appendix A) for the four levels of incident management in South Carolina shown in Table 2.1. The plans incorporate roles and responsibilities for typical responding agencies at each level (Table 2.2). An example of a traffic incident action plan document for a non-blocking incident with a single responder and tow truck is included as Table 2.3.

Table 2.1 Incident Response Level Assessment Criteria

Incident Response Level	Assessment Criteria					Agency Responsible for Establishing Unified Command
	# of Lanes Blocked?	Injuries?	HAZMAT Spill?	Fire?	Multiple Agency Reponse Needed?	
Level 1	None	None (O)	No	No	No	Law Enforcement
Level 2	1	Minor (C)	Vehicle Fluid Spill Only	No	No	Law Enforcement
Level 3	2 (or more)	Severe (A,B)	Vehicle Fluid Spill Only	Threat	No	Fire Rescue
Level 4	ALL	Fatality (K)	Yes	Yes	Yes	Fire Rescue

Table 2.1 provides a matrix for quick assessment of the incident response level necessary to clear the incident and restore traffic operations. The levels range from Level-1, a minor incident that only requires a single responder and possibly towing, to Level-4, a major incident that requires multiple response agencies and may include fatalities/fire/hazmat. The five assessment criteria include: number of lanes blocked, presence of injuries or fatalities, presence of hazardous material spills, fire or threat of fire, or need for multiple agency response. For each question in the assessment criteria, a single response level should be chosen. The highest level chosen for any of the criterion becomes the level of the incident for planning purposes. Additional information related to the incident should also be collected to aid in response dispatch. The following list provides a fairly comprehensive series of questions that should be answered in the field:

- How many lanes blocked?
- How many persons injured? What is the severity of injuries? Is extrication necessary?
- Fatalities involved? Is a coroner needed? Is MAIT needed?
- Are hazardous materials involved? What type? Magnitude? Is there a potential water contamination? Evacuation?
- Is there a threat of fire? Is fire involved? Is there potential for an explosion?
- How many passenger vehicles involved? How many need to be towed from the scene?
- Any heavy vehicles? What classification? Are special tow trucks required? Is there an overturned truck? Is there a cargo spill? Is special equipment necessary for cleanup?
- Will the traffic lanes be blocked for an extended period? Is additional traffic control needed? Are there hazardous traffic conditions (limited sight distance, darkness, etc.)? Will a detour be necessary?
- Is there debris in road? Downed utility lines? Trees or utility poles, etc.?
- Is there damage to road surface, safety hardware, or other infrastructure damage?
- Is a crime suspected?

Table 2.2 Traffic Incident Response Matrix for South Carolina

LEVEL	LAW ENFORCEMENT	FIRE & RESCUE	EMS	EPD/HAZMAT	TOWING & RECOVERY	SHEP/Incident Responder	SCDOT
Level-1	▪ Notify dispatch ▪ Establish *ICP ▪ Identify nearest shoulder or safe area for relocating vehicle (s) ▪ Relocate vehicles(s) to the shoulder or safe area, to await recovery	No Responsibility	No Responsibility	No Responsibility	▪ When directed, respond and remove vehicle(s) from the roadway shoulder, as quickly & safely as possible	▪ Notify TMC ▪ Relocate vehicle(s) to shoulder/safe area, to await recovery	▪ Notify TMC ▪ Assist relocating vehicle(s)
Level-2	Notify Dispatch Establish *ICP	May be dispatched to care for injured	▪ Provide medical care to the injured	No Responsibility	▪ When directed, respond and remove vehicle(s) from the roadway shoulder as quickly & safely as possible ▪ Remove crash debris from roadway in accordance with SCHP Regulations	▪ Notify TMC ▪ Assist the injured Establish & maintain traffic controls ▪ Assist in relocating vehicle(s) from the roadway	▪ Assist in removal of vehicles ▪ Assist with clean-up ▪ Check for state property Damage ▪ SHEP deployment
Level-3	▪ Secure traffic Incident scene ▪ Assist the injured until Fire and EMS arrives ▪ Assist with traffic control ▪ Conduct crash investigation	▪ Secure scene ▪ Protect life and property ▪ Establish *ICP	▪ Provide medical care to the injured	▪ Secure area ▪ Clean-up of debris	▪ When directed, remove vehicles from roadway after injuries are treated. ▪ Remove crash debris from roadway in accordance with SCHP Regulations	▪ Notify TMC ▪ Assist the injured ▪ Establish & maintain traffic controls ▪ Assist in relocating vehicle(s) from the roadway	▪ Establish Detours as needed ▪ Check for State property damage ▪ Provide support equipment & materials ▪ SHEP deployment
Level-4	▪ Secure traffic incident scene ▪ Assist the injured until Fire and EMS arrives ▪ Assist with traffic control	▪ Secure scene ▪ Protect life and property ▪ Establish *ICP ▪ Request clean-up and/or containment of hazardous materials	▪ Provide medical care to the injured	▪ Secure area ▪ Clean-up of Hazardous materials and debris	▪ When directed, by the Investigating Officer, remove vehicles from roadway, after injuries and/or HAZMAT dangers have been addressed ▪ Remove crash debris from roadway in accordance with SCHP Regulations	▪ Notify TMC ▪ Assist the injured ▪ Establish & maintain traffic controls ▪ Assist in relocating vehicle(s) from the roadway	▪ Establish detours as needed ▪ Assist with clean-up ▪ Check for State property damage ▪ Provide support equipment & materials

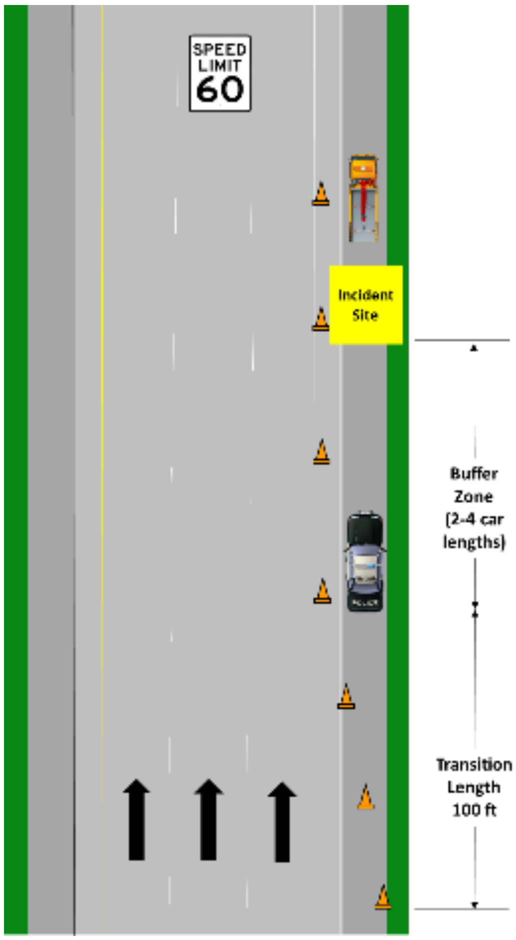
NOTE: Shaded areas [ ] Denote Key Agencies for each Level of Traffic Incident, during initial response.

REMEMBER: "The responding agency arriving first at the traffic incident scene, by default, is the *traffic incident manager*, at least until the nature of the incident changes and/or additional response agencies arrive on the scene and assume command."

Table 2.3 Incident Briefing (ICS 201) for Level 1 Response

1. Incident Name: Level 1 Response	**2. Incident Number:**	**3. Date/Time Initiated:** Date: Time:

4. Map/Sketch



5. Situation Summary and Health and Safety Briefing (for briefings or transfer of command): Recognize potential incident Health and Safety Hazards and develop necessary measures (remove hazard, provide personal protective equipment, warm people of the hazard) to protect responders form those hazards.

- ☐ Examples of this type of response may include a law enforcement traffic stops and motorist assistance provided by towing companies
- ☐ This minor traffic incident should affect travel for less than 30 minutes
- ☐ The incident can be handled with one or perhaps two single resources
- ☐ Law enforcement personnel may be dispatched to document the incident
- ☐ Towing companies may be necessary to remove the vehicle and restore traffic
- ☐ Command and general staff positions (other than the IC) are not activated
- ☐ No written IAP is required

6. Prepared by: Name: ________________Position/Title:________________Signature:___________________

1. Incident Name:	2. Incident Number:	3. Date/Time Initiated:
Level 1 Response		Date: Time:

ICS 201, Page 1 Date/Time: ____

7. Current and Planned Objectives:

- Ensure responder and motorist safety during incident operations
- Reduce traffic congestion caused by the incident
- Clear incident of all disabled vehicles, cargo, and debris
- Conduct motor vehicle collision investigation (if applicable)
- Restore traffic lanes to full operational status

8. Current and Planned Actions, Strategies, and Tactics:

Agency:	Actions:
South Carolina Highway Patrol	• Upon arrival, protect the scene by placing patrol car with emergency lights activated to rear • Establish traffic incident management area and place traffic control device, cones, or flares • Determine if vehicles can be removed from the traveled lanes • Call for tow services as necessary, advise dispatch of any special tow needs • Obtain necessary information from involved parties • Review physical evidence at scene and take photos as required • Complete TR-310 Crash Report (if applicable) • Contact SCDOT if there is any roadway or structural damage to highway infrastructure • Clear scene quickly, consider finishing paperwork off the highway
Towing	IF LAW ENFORCEMENT IS NOT ON SCENE • Towing will not operate unless law enforcement is present IF LAW ENFORCEMENT IS ON SCENE • Position tow truck so the towing process can begin • Coordinate with law enforcement for vehicle removal and communicate how to best reenter traffic flow

ICS 201, Page 2 Date/Time: ____

Prior to the development of the TIAP documents, the research team generated a functional decomposition of the communication flows between major stakeholder agencies, and other incident responders and intelligence agents (media, telecommunications) predominantly derived from the hurricane evacuation plan. The development of the traffic incident action plans will support the implementation of ICS by providing specific information on roles, responsibilities, communication protocols, traffic operation plans, contingency plans, and resource contacts; however, ICS is a tactical protocol. The improvement strategies must be embraced and adopted by the field agents responsible for execution, support staff responsible for maintenance and effective use of available technologies, leadership on all levels of managements, and as an institution as a whole. Without coordinated efforts on all levels of the organization and amongst organizations, incident response efforts will effectively fail within the organization and/or with other responding agencies. Strategies to help ensure successful improvement and progress towards the utilization of ICS include the development of joint interagency strategy plans and coordinated resourcing, develop functional flexibility into TMC equipment and operations, provide combined trainings for interagency communications, negotiate clearance time targets amongst all responders for clear expectations/objectives, and develop a regular reporting mechanism to gauge performance improvement and interagency cooperation. As these strategies improve the likeliness of implementation, full ICS deployment can only be achieved with dedicated interagency cooperation during an incident.

3 INCIDENT DATA AND ANALYSIS

To begin the discussion on incident data, it is imperative to define time measurement with respect to incident management. There is a linear incident timeline (See Figure 3.1) that begins at incident occurrence; however, the first recorded time is the time the incident is reported. The time from incident occurrence to incident report is called the detection phase. Following detection is a verification phase, which occurs before the identification of response needs and response dispatch. The response time starts at incident verification and continues until the response arrives on scene. While roadway clearance officially starts once response arrives on scene, if vehicles can be moved by the motorist, roadway clearance may begin when the incident is reported. There are basically two clearance phases. The first occurs when all lanes are open to traffic (i.e., roadway cleared), and the second occurs when the last response agency leaves the scene (i.e., incident cleared). The time to return to normal flow is referred to as the recovery period. In total, there are eight time records necessary to record the complete timeline.

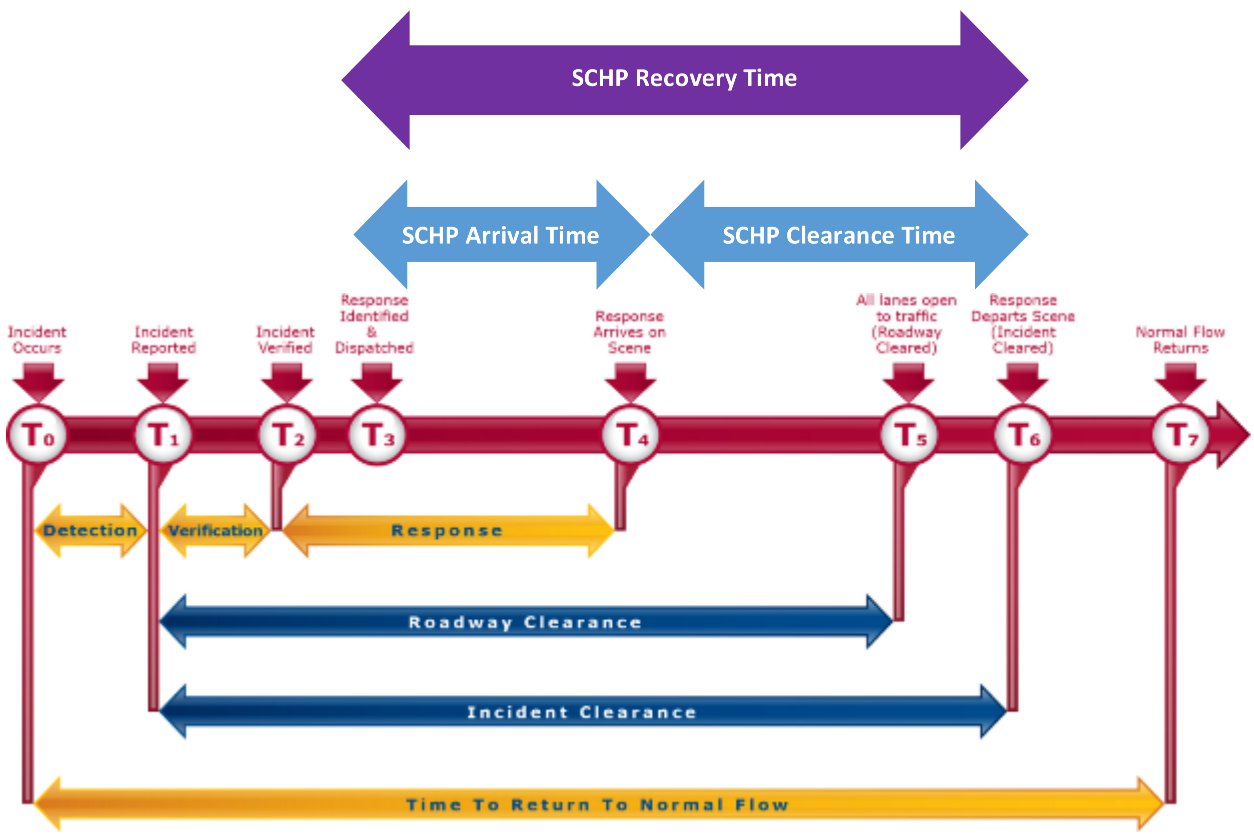


Figure 3.1 Incident Time Measurement

<u>In South Carolina, the eight time stamps (T0-T7) shown in Figure 3.1 are collected across three agencies</u>. The 9-1-1 call center logs T0, T1, and T2. The South Carolina Highway Patrol logs T2, T3, T4, and T6; and the SCDOT Traffic Management Centers typically record T2 and T5, and rarely T7 in Palguide, however, these are only logged for incidents in TMC coverage areas. The times and corresponding intervals for the SCHP CAD are noted in Figure 3.1.

Unfortunately, the three agencies use three disparate systems that do not connect to one another, nor do the agencies maintain unique identifiers for each incident that enable the time stamps to be matched at a later date.

3.1 DATA SOURCE COMPARISON

The research team collected data from the SCHP CAD system (See Table 3.1) and the SCDOT TMC Palguide log, as well as crash records maintained by SCDPS. An attempt was made to match the data with little success, but it did help explain the connection to the time stamps as laid out above. Of the three datasets, the SCHP CAD data contained the most complete and consistent data for initial assessment of the magnitude of incident response for the I-26 corridor. Currently, the SC Highway Patrol recovery time is most closely associated with the incident clearance minus the incident reported and incident dispatch times. There may be a future option for capturing the report and dispatch time within the CAD system (as these are generated from the 9-1-1 system, but the database retrieved from SCHP did not contain these fields.

Table 3.1 SCHP CAD Database Exported Time Fields

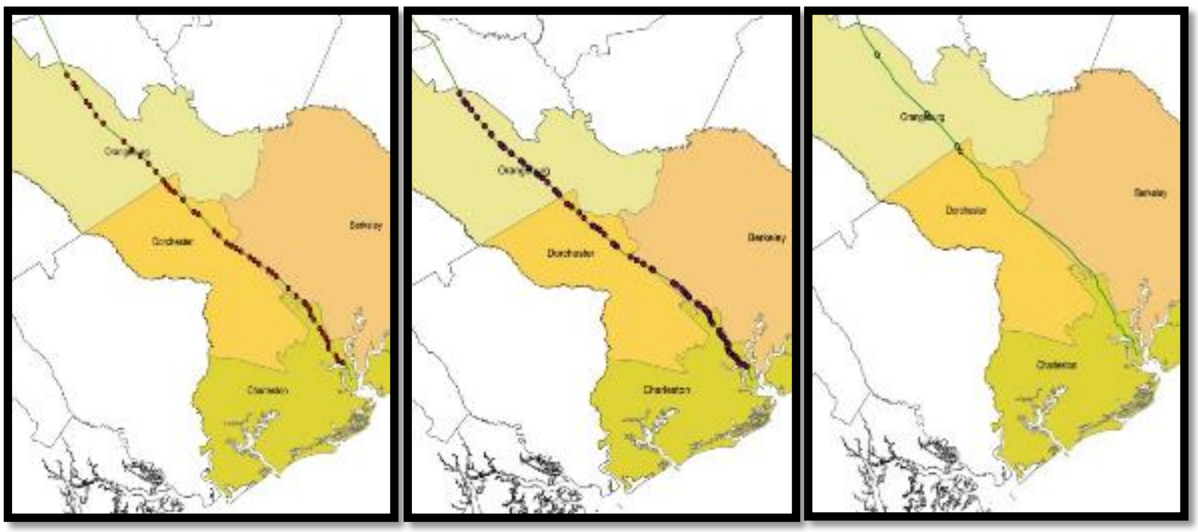
Incident Number	RLTC13CAD1700
Geo Area	TO1D
Complaint Type	HIT & RUN: NO INJURY
Date Received	7/17/2013
Year	2013
Received_Txt	17:13:34:217
Onscene_Txt	18:51:09:310
Closed_Txt	23:33:31:000
Arrival Time	97.58
Clearance Time	282.36
Recovery Time	379.95
Dispo	1
Location	I77SB NR FORT JACKSON BLVD [RICHLAND COUNTY]

From an evaluation stand point, the CAD data format is not very usable when comparing across datasets. The CAD time (RECEIVED_NUM) is in text format, which had to be converted to time format. The CAD location information has its own coding system which does not make it amenable to match the specificity of crash locations nor the SCDOT route number and milepoint format without significant reformatting. Some CAD locations do not represent a point location, rather a segment such as the location 'I26 BTWN 203 [205WB] x [UNIVERSITY BLVD] [NORTH CHARLESTON]'. When comparing to the location in the SCDOT TMC log, locations were specified 'I-26E @ MM187'. Further, the crash location was divided into four distinct fields: route category, route number, mile marker, and direction. If the data will not reside in one system, field consistency is very important for data interoperability and evaluation. If there is no data standard across all agencies, the evaluation will be difficult at best.

Three incident data samples were collected from SCHP CAD, SCDPS Crash Records, and SCDOT Palguide Logs for the first quarter of 2012. The data were all reformatted to attempt incident matching across the three datasets and to allow comparison of time stamps from the same incidents from three data sources. It is understood that crash data only contains vehicles involved in crashes, whereas TMC and CAD data may also contain abandoned vehicles, vehicle fires, and many other types of incidents that occur on Interstate facilities. The CAD data was queried for complaint type 'Collision' and 'Hit and Run' to better correspond with the data in the crash database. In the majority of matched cases, the crash data had the earliest notification time, which likely corresponds to the 9-1-1 call center reporting time. Data were collected for a four county area of South Carolina including: Orangeburg, Dorchester, Berkeley, and Charleston. For each of the data sources, the database query criteria and number of returned records are provided.

- SCHP CAD data:
  - Queried complaint type: 'Collision' and 'Hit and Run'
  - Queried location: I-26
  - Total number of recorded crashes for first three months of 2012: 344
  - Records without specific location: 6.5% did not have mile marker
- SCDMV Crash data
  - Queried crash locations for RCT 1 (Route Category 1 - Interstate) and RTN 26 (Route number 26)
  - Total number of recorded crashes for first three months of 2012: 296
  - Records without specific location: 8% did not have latitude/longitude location (C*harleston had 72.6% without latitude/longitude*)
- SCDOT Palguide DATA
  - Queried TMC Subtype: Accident
  - Queried Level of severity: 2 or 3
  - Total number of recorded crashes for first three months of 2012: 10

Once the subsamples were identified for each database, the researchers set out to find matches using location or proximity matching. Crash location points were plotted in ArcGIS software based on mile marker (CAD and TMC data) and Latitude, Longitude (Crash Data). Spatial joint of incident locations from CAD and Crash data were completed with a radius of 0.75 miles and two miles. Too few TMC records impeded the usefulness of this dataset for this comparison. The second level match was completed using a query in Microsoft Access using the date field of records from different databases. For crashes in close proximity with matching dates, a thorough inspection of the record content was completed to confirm the match. Figures 3.2 and 3.3 present the matched sets for both the EB and WB directions. Using a 0.75 mile buffer and data match, there were 79 successful EB matches between CAD and Crash, and 98 successful WB matches. For the matched crash cases, the time reported in Crash Data is the earliest report time in approximately 70-80% of cases. This makes sense because the CAD Data entry is typically secondary to the initial report of the incident to DPS. However, in some instances, the police officer may observe the incident in route and therefore his report time could be earliest reporting time for the incident.



CAD DATA CRASH DATA TMC DATA

Figure 3.2 I-26 EB Three dataset comparison for quarter 1 of 2012

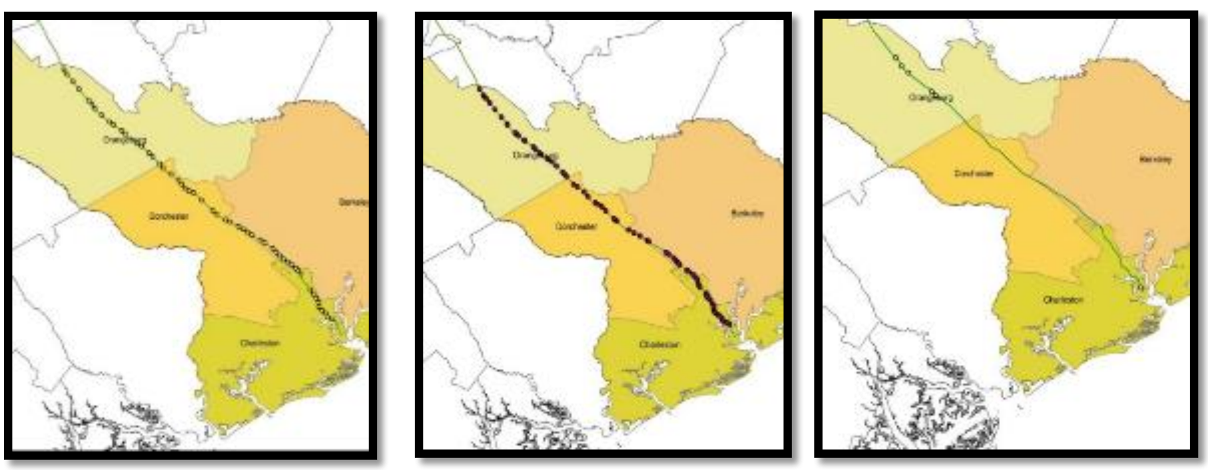


Figure 3.3 I-26 WB Three dataset comparison for quarter 1 of 2012

Another comparison was completed for CAD and TMC data using all incident types to compare clearance times for I-26 EB. In all instances, the TMC clearance time was used as the minimum clearance time. Note that the TMC value denotes the opening of all lanes (roadway cleared), not the removal of all response vehicles (incident cleared). Even after the lanes are open, significant delay can continue due to the roadside response team presence. In the analysis, the CAD response time and the TMC validity time were not consistent. The CAD response time was almost always earlier than the beginning TMC validity time.

Table 3.2 Summary of the minimum clearance time analysis

Route	CAD Data			TMC Data			
	Date	INCIDENT_N	CLEARANCE_TIME *(Difference between ONSCENE_NUM and CLOSED_NUM)*	ID#	Validity	Clearance Time (Minutes)	Minimum Clearance Time
I-26 EB	1/3/2012	CHTC12CAD000742	105.12	25175	5:57pm - 6:42pm	45	TMC
	1/3/2012	CHTC12CAD000741	117.2	25186	7:35am - 8:23am	48	TMC
	1/16/2012	CHTC12CAD004292	36.75	25567	3:52pm - 3:57pm	5	TMC
	1/18/2012	CHTC12CAD004713	55.12	25631	3:59pm - 4:21pm	22	TMC
	1/26/2012	CHTC12CAD006657	134.53	25884	7:15am - 7:17am	2	TMC
	1/30/2012	CHTC12CAD007836	126.28	26047	4:58pm - 6:12pm	74	TMC
	1/31/2012	CHTC12CAD007906	36.03	26073	7:28am - 7:45am	17	TMC
	2/2/2012	CHTC12CAD008375	68.73	26163	7:43am - 7:45am	2	TMC
	2/8/2012	CHTC12CAD010211	82.93	26372	10:49am - 11:22am	33	TMC
	2/10/2012	CHTC12CAD010962	103.58	26494	3:47pm - 4:09pm	22	TMC
	2/21/2012	CHTC12CAD014325	24.48	26896	7:39am - 8:12am	33	TMC
	2/24/2012	CHTC12CAD015624	105.97	27132	6:40pm - 7:12pm	32	TMC
	3/3/2012	CHTC12CAD017993	118.38	27119	12:38pm - 1:11pm	33	TMC
	3/3/2012	CHTC12CAD018080	19.53	27433	8:22pm - 9:02pm	40	TMC
	3/22/2012	CHTC12CAD024229	34.62	28296	11:37am - 11:39am	2	TMC
	3/22/2012	CHTC12CAD024173	23.3	28314	6:13pm - 6:21pm	8	TMC
	3/22/2012	CHTC12CAD024328	38.78	28288	8:04am - 8:08am	4	TMC

While this comparative analysis did not give the research team the more comprehensive database that was hoped for, it did paint a clear picture of the accuracy, completeness, and interoperability of the multiple datasets that would support measurement of any future traffic incident management enhancements.

3.2 MAGNITUDE OF TRAFFIC INCIDENTS ALONG I-26

Given the results of the analysis of the three datasets, the SCHP CAD data provided the most comprehensive picture of incidents occurring on Interstates in South Carolina. There were 61,051 and 57,827 incidents in 2012 and 2013 respectively. Of the almost 119,000 incidents statewide and the 44,000 occurring on I-26, there was a similar breakdown by incident type for both, as can be seen in Figure 3.4 below.

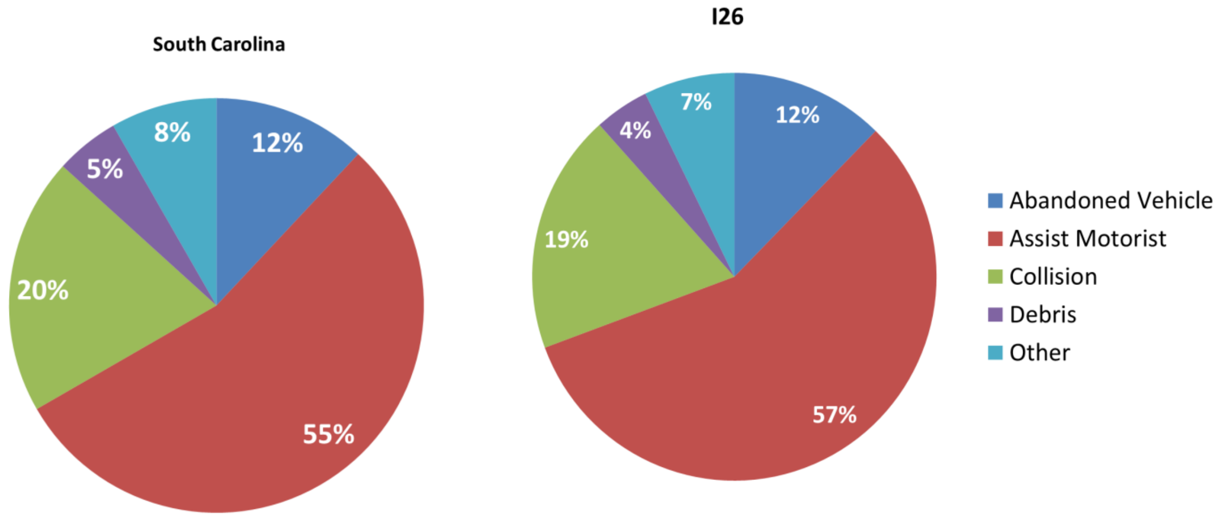


Figure 3.4 Proportion of Traffic Incident Types in SC and along I-26 form SCHP CAD

The most common type of incidents that SCHP responded to were motorist assist, collision, abandoned vehicles, and debris in the roadway, respectively. All other response types fell in the "other" category, and only counted for 4-5% of incidents. The other incident type includes things such as:

- Drag Racing
- Escapee
- Fire: Woods
- Fuel Spill
- HAZMAT Incident
- Ice/Snow on Roadway
- Medical Complaint
- Pedestrian: In Roadway
- Power Lines in Road
- Traffic Hazard
- Tree in Roadway

Further investigation of incident types and corresponding incident lengths can be found in Table 3.3. In this table, it can be seen that for 57% of incident types, the recovery time is under 30 minutes. The only exception of these incident types are collision incidents. The majority of collisions lasted between 30 and 90 minutes, with 21.5% lasting more than 120 minutes. Another data issue identified in this analysis was the presence of max clearance times that were unrealistically high. This suggests that incidents could be timing out in the system if they were not closed properly. Due to the frequency of this occurrence, developing a protocol for closing incidents in a timely manner could be beneficial.

Table 3.3 Incident Types and Time Distributions (2012-2013)

Time (min)	Abandoned Vehicle	Assist Motorist	Debris	Collision	% Collision	Total	%
<30	12362	43258	4004	2517	10.6%	62141	57.0%
30-60<	1031	12224	1118	5925	24.9%	20298	18.6%
60-90<	385	5119	411	6453	27.1%	12368	11.3%
90-120<	155	2172	172	3758	15.8%	6257	5.7%
120-720<	281	2234	219	5130	21.5%	7864	7.2%
Timeout (>720)	17	8	2	53	0.2%	80	0.1%
Total	14231	65015	5926	23836	100.0%	109008	100.0%

Figure 3.5 provides the distribution of SCHP response times – the time between dispatch and arrival on scene. The majority of response times are within 30 minutes (66%) with 21% over 30 minutes. As noted previously, the dispatch and report time can be the same if the police officer arrives on scene before the incident has been reported to the 9-1-1 call center.

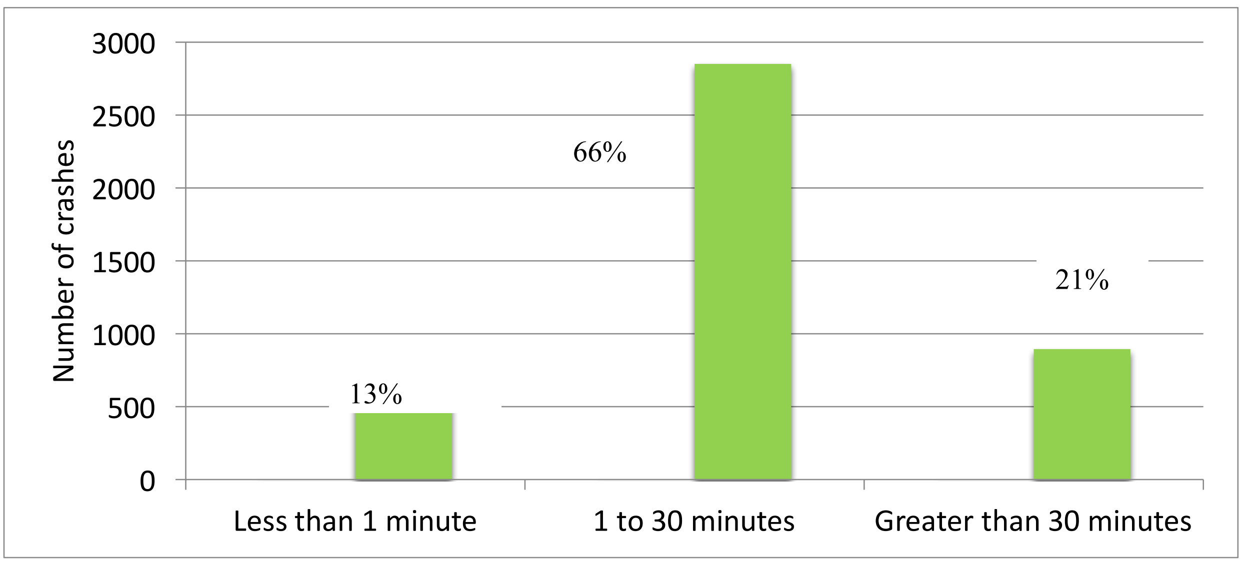


Figure 3.5 SCHP Response Time Distribution

Multiple different incident types were described above. The following Figures 3.6-3.12 offer distributions of SCHP recovery time (the time from the CAD recorded dispatch time stamp to incident cleared time stamp for an array of incident types on all Interstate facilities for the period 2012-2013. For example, Figure 3.6 shows the recovery time distribution for 62,017 motorist assist incidents on SC Interstates. Notice that the time range on the chart spans to 300 minutes, and the distribution on the right side is truncated at 300 minutes. For most all of the recovery time distributions, there were some instances of recovery times reaching above 1400 minutes. In meetings with the project steering committee, this phenomenon was assumed to be caused by incidents that were left open in the SCHP CAD system and closed at the end of a 24-hour period. These suspect high recovery times can inflate the average time values, so the median or 50th percentile was chosen to represent the central measure in the analysis. On the chart, an outlier threshold value of 95.8 min is shown as the 94th percentile – this value is unique for each distribution. For this research, it was assumed that the outlier threshold represents the best estimate of the maximum recovery time, noting discussions indicating the likelihood that numerous records timed out in the system after 24 hours. The outlier threshold is found by adding 1.5 times the inter-quartile ranges to the Q3 (75th percentile) value. The interquartile range is simply the value difference between Q1 and Q3, or the middle half of the ordered values. For this research, it was assumed that the outlier threshold represents the best estimate of the maximum recovery time, noting discussions indicating the likelihood that numerous records timed out in the system after 24 hours. Each chart shows the Q1 (25th percentile), Q2 (median or 50th percentile), Q3 (75th percentile), and the outlier threshold value and percentile. The motorist assist recovery time distribution chart indicates that 25 percent of motorist assists recover within four minutes, 50 percent within 15.6 minutes, 75 percent within 40.7 minutes, and the expected maximum recovery time is 95.8 minutes.

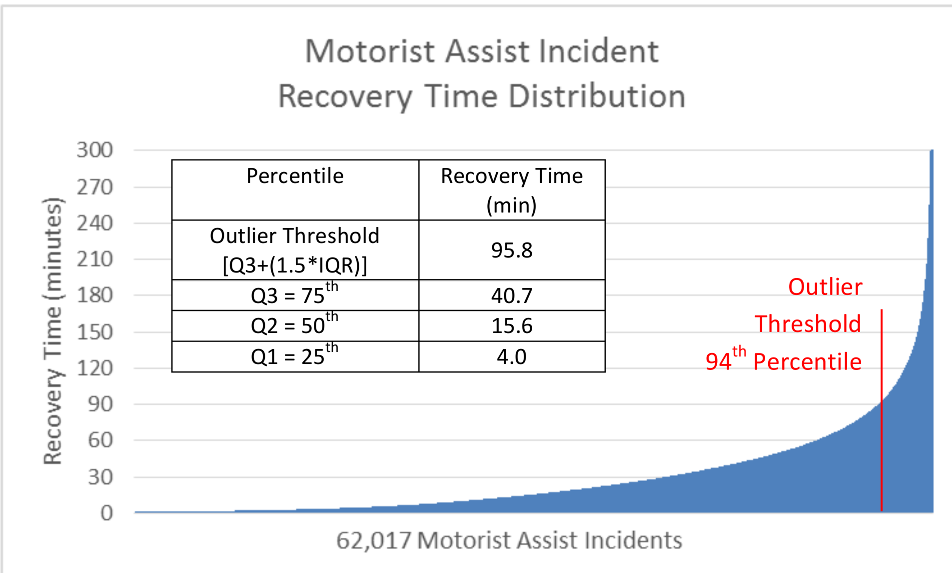


Figure 3.6 Recovery time distribution for 'Assist Motorist' Incidents

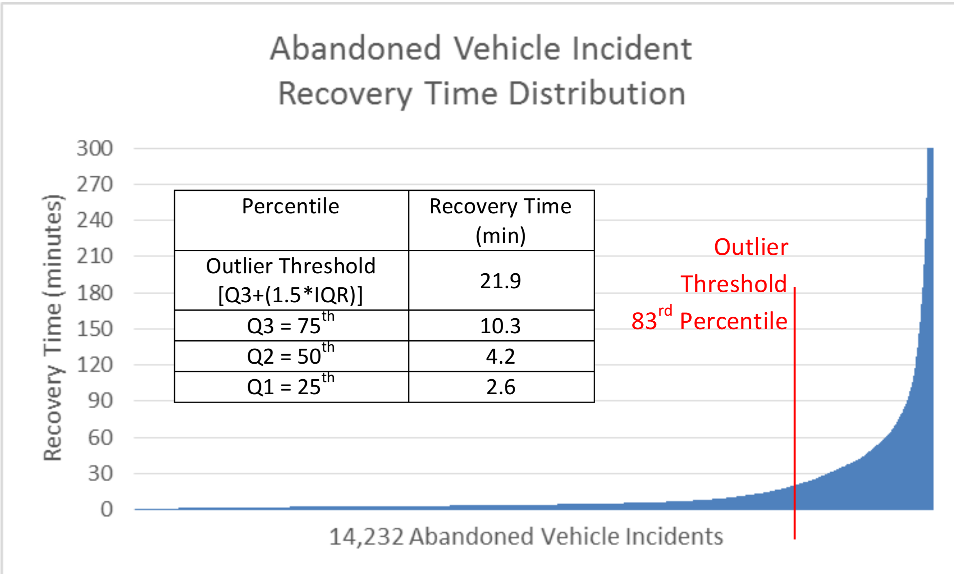


Figure 3.7 Recovery time distribution for 'Abandoned Vehicle' Incidents

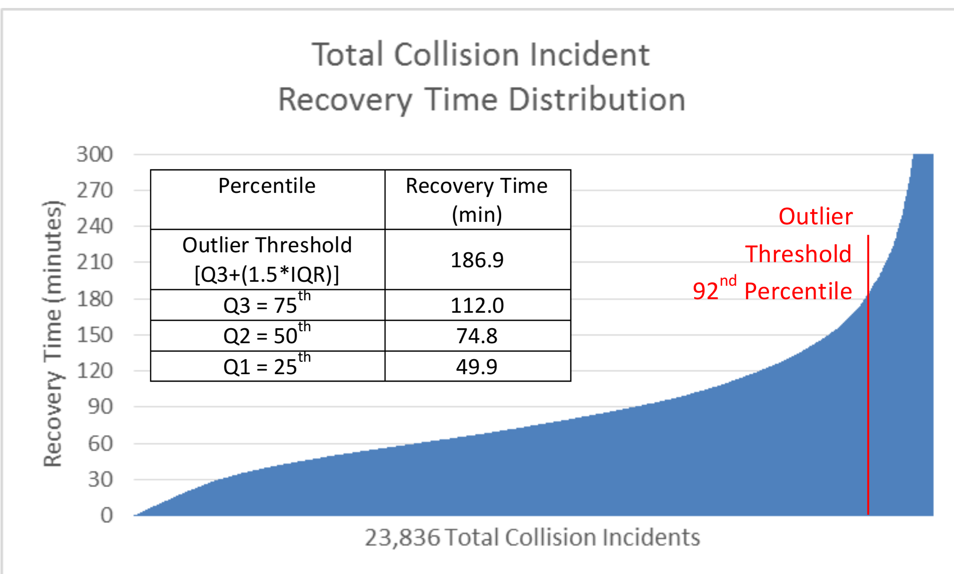


Figure 3.8 Recovery time distribution for Total 'Collision' Incidents

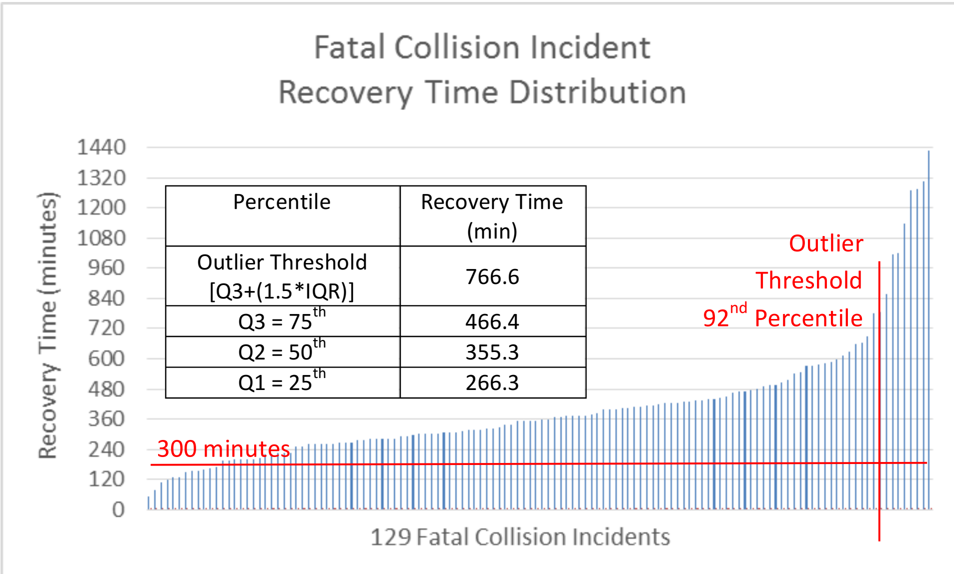


Figure 3.9 Recovery time distribution for 'Collision: Fatal' Incidents (**Note Scale Change**)

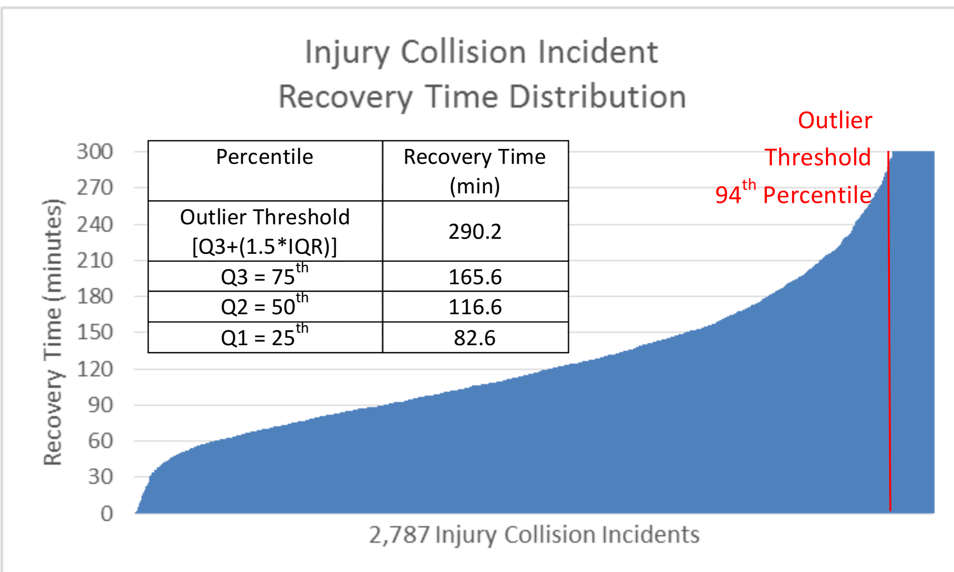
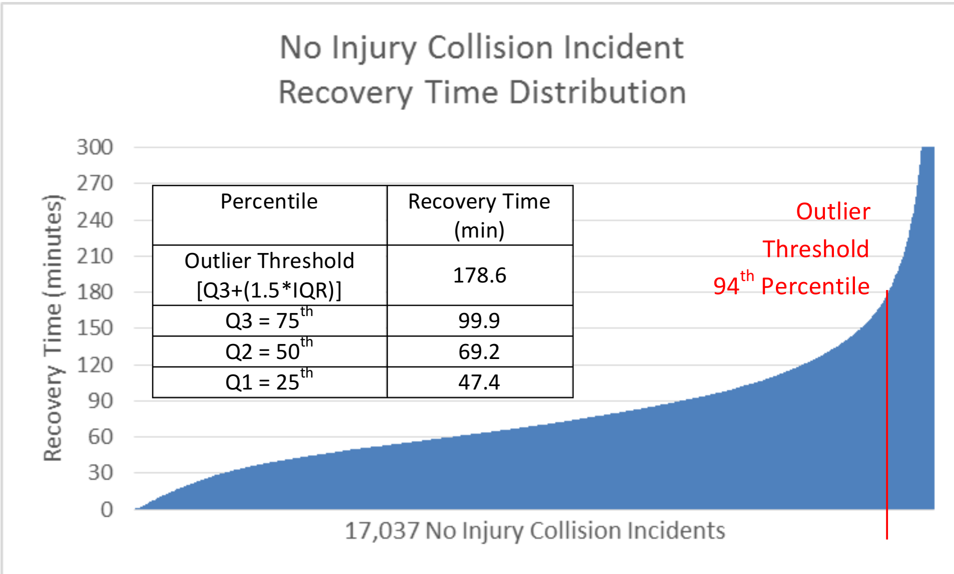
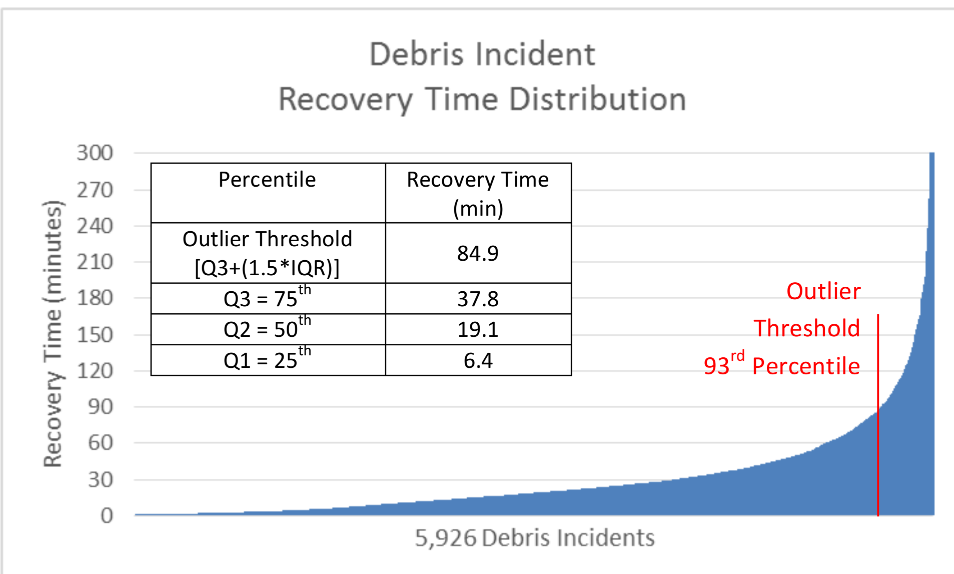


Figure 3.10 Recovery time distribution for 'Collision: Injury' Incidents



Percentile	Recovery Time (min)
Outlier Threshold [Q3+(1.5*IQR)]	178.6
Q3 = 75th	99.9
Q2 = 50th	69.2
Q1 = 25th	47.4

Figure 3.11 Recovery time distribution for 'Collision: No Injury' Incidents



Percentile	Recovery Time (min)
Outlier Threshold [Q3+(1.5*IQR)]	84.9
Q3 = 75th	37.8
Q2 = 50th	19.1
Q1 = 25th	6.4

Figure 3.12 Recovery time distribution for 'Debris' Incidents

Combining all collisions together (fatal, injury, and PDO), the median (50th percentile) total collision incident recovery time is 74.8 minutes. This indicates that half the time, the officer has left the scene within one hour and minutes. However, the 75th percentile total collision incident recovery time is closer to two hours. Breaking incidents down by severity level, the fatal and injury crashes have much higher recovery times.

By far, the highest of recovery times is for the fatal crashes. There were 129 fatal collisions recorded on SC Interstates in 2012 and 2013. The fatal crash recovery time distribution chart indicates that 25 percent of fatal crashes have recovery times of 266 minutes or less, 50 percent within 355 minutes, 75 percent within 466 minutes, and the expected maximum recovery time is 766 minutes. Looking further to injury crashes, the Q1 (25th percentile) recovery time is over 82 minutes, the median recovery time is 116 minutes, the Q3 (75th percentile) is 165 minutes, and the estimated maximum value for recovery of injury crashes is 290 minutes. These clearance and recovery times are significantly higher than other states, especially states which have implemented enhanced ICS and TIM procedures and have achieved major incident clearance times of 90 minutes or less.

Another analysis of recovery times along the I-26 corridor broke down times by highway patrol troops between Columbia and Charleston along the corridor. There was a lot of variation among the average recovery time by location. Throughout the state, this time was 42.6 minutes and along the I-26 corridor, it was 40.35 minutes. When looking at these average times broken down by county (Lexington = 63 min, Richland = 61 min, Orangeburg/Calhoun = 61 min, Dorchester = 45 min, and Berkeley/Charleston = 27 min), it can be seen that the average times are over 30 minutes longer around Columbia than they are around Charleston. A two-tailed t-test was performed, and the difference between the Columbia and Charleston means was determined to be statistically significant ($p<0.0001$). These differences could be due to high congestion levels, higher severity incidents, which naturally have longer recovery times, or inefficient incident management practices. Further, the only known difference in incident management practices between Columbia and Charleston is the dual/optimized dispatch and towing zone contracts already in place in Charleston. This could possibly contribute to the lower recovery time observed in this area.

Incidents along I-26 were also analyzed by severity. Severity was reported for collision and hit and run incidents, both of which were included in this analysis. The severities included were property damage only (PDO), injury, fatal, private property damage, and incidents involving deer or animals. The breakdown of severity along the corridor can be seen below in Figure 3.13.

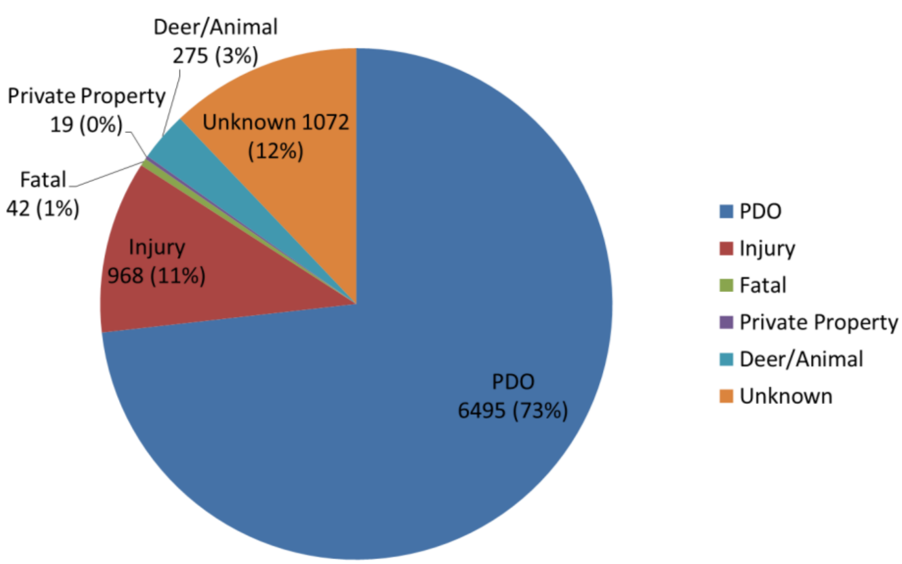


Figure 3.13 Incident Severity on I-26 (2012-2013)

As can be seen in the figure, 73% of the incidents are property damage only (PDO) incidents, while injury and fatal incidents are only 11% and 1% respectively. The values could also be misleading because incidents involving deer, or even private property, could also cause property damage, injury, or even fatalities. There could be additional benefit to coding such incidents involving animals, instead as just fatal, injury, or PDO.

Some of these severities are combinations of collision and hit and run incidents. Severities reported for collisions were: fatality, injury, no details, no injury, private property, vs. animal, and vs. deer. Conversely, the severities reported for hit and run incidents were: fatality, injury, no injury, private property, and unknown. While several of these severity levels do overlap, there is still room for improvement in severity reporting. For instance, vs. deer could also fall in the category of PDO, injury, or fatality; and reporting one of these severities would provide more information indicative of the incident. Further, 12% of these incidents were reported as an unknown severity. This high proportion of severities not being recorded indicates much room for improvement in reporting practices. <u>One way this could be achieved is through utilizing the already established severity levels of 1 through 4 for traffic incidents, making severity less subjective.</u>

3.3 INCIDENT DATA RECOMMENDATIONS

In the following sections of the report, the research team recommends a number of program enhancements to reduce clearance and recovery times. The data reporting improvements should take these programs into consideration and determine the necessary time stamps to record to satisfy the MOE evaluation component. The official data repository for program evaluation must be defined. A number of questions must be asked: *Is data going to be collected and maintained in three different databases? If so, what is needed to insure compatibility of the databases? When and how will the compilation of databases occur? Who is going to own it? Who is going to pay for maintaining it? How can the accuracy be verified?* Currently the SCHP CAD system has the most detailed information, but it still lacks information on arrival and departure for responders such as towing, MAIT, and coroner, as well as time stamps indicating that all lanes have been reopened to traffic.

Another factor to consider is definition of common terms and development of a data dictionary to ensure that recovery time in the official database is most nearly the incident clearance minus the verification and dispatch times, which is in keeping with national TIM data standards. All time intervals should be recorded in one database, but if multiple databases will be used, there must be a unique incident ID that is maintained in each database so they can all be easily matched. Data sharing agreements among stakeholder agencies, and interoperability of systems are all issues that need attention.

Once the key data have been defined and the final repositories have been identified, metrics for data accuracy, completion, and timeliness can be established. The necessary data improvements are not inconsequential, and funding should be put into place to ensure long-term maintenance of the system for the future. While the potential problems and issues identified in this section may increase the work load of the officers in the field, the lack of resolution will render program evaluation nearly impossible.

The following represent lessons learned with respect to data collection and sharing amongst stakeholders to enable performance measurement (from TIM Handbook):

- **Establish agreements between law enforcement and DOTs to preclude compromising sensitive data:** For example, some States had to define specific data elements to be provided. These restrictions can then be executed via system filters.
- **Establish technical committees to develop common data dictionaries:** Different agencies frequently collect the same information in different formats. To address this issue, technical committees can help develop common data dictionaries or translators that enable different systems to identify and match information.
- **Establish a common time stamp and common geographic coordinates necessary for data exchange and reporting functions:** Incident management agencies may define incident events differently. For example, an enforcement agency may time stamp the closing of an incident as when the last enforcement vehicle departs the scene, while DOT or other responders may still be on site. It is important to agree on a common time stamp that establishes incident start and close times, since sharing this information among agencies is critical to properly measuring incident duration.
- **Identify and agree to a defined standard or group of standards for data exchange:** To ensure interoperability among all stakeholders, it is critical to identify and agree to a particular standard or group of standards. It also is helpful to develop and use a common ITS architecture to identify standards that are to be used by different agencies.
- **Identify and agree upon methods of integrating text, video, and audio formats for data exchange:** When the stakeholders are able to integrate agreed upon formats from multiple types of data exchange via text, video, and audio, this approach can result in the identification of a more appropriate response strategy. This approach enables accurate information exchange with respect to 511 or Web-based traveler information systems and the enhanced ability to notify media improves overall incident management. This approach also may support the allocation of funds and resources needed for legacy system modifications.
- **Identify and agree upon consistent data collection practices within and between agencies:** Inconsistent data collection practices within and among agencies is especially problematic. Specific solutions may include the use of automated data entry wherever possible (GPS, time stamps); utilization of a single point of data entry with emphasis on a simplified means of entry (e.g. drop-down menus); encouragement for the need for a "lane clear" time stamp; and promotion of common and consistent training among all incident responders (DOT, law enforcement, and so forth) for data collection techniques to ensure common practices.

Some states have successfully addressed issues of data interoperability between different response agencies, and have actually developed integrated statewide systems where each agency maintains their own system, but the data flows to a central repository. There are hand-offs between 9-1-1, CAD, and TMC, thus no one agency is responsible for it all. In Georgia, the HERO TMC operation actually monitors the TRIP program, thus highway patrol officers are not responsible for identifying when the towing company arrives on scene or when they start or end their operation.

In Georgia, the TRIP program is activated for incidents involving the following vehicle and incident types:

Vehicle Types:	Incident Types:
• Truck Tractor Semi-Trailer Combo (US DOT Class 8) • Trucks > 26,000 lbs (Class 7 or 8) • Large Motor Homes & Motor Coaches (Class 5 or 6) • Busses ≥ 16 passengers (Class 6, 7, or 8) • Aircraft • Major Transportation Emergency or Discretionary	• Rollover blocking any travel lanes • Multiple truck crash • Jack-knifed and not drivable • Lost Load on or affecting travel lane(s) • Load Shifted on or affecting travel lane(s) • Lost tandems / axle or buckled trailer affecting travel lane(s) • Fire with tires burned off or cargo spilled • Major impact with guard rail, bridge support or structure on top of barrier wall • Bus crash with multiple injuries

When an incident involving one of these vehicle/incident types is verified in the field, either the 9-1-1 dispatchers, HERO Supervisor, or Police will notify the GDOT Traffic Management Center to activate TRIP. The GDOT TMC personnel verify the incident and determine the necessary equipment to clear the incident through video feed and communications with response personnel in the field. The GDOT TMC personnel then notify the appropriate TRIP towing company (based on route assignments) to activate TRIP. This call marks the first time stamp collected for the trip program evaluation. HERO personnel in the field verify TRIP ID badges upon arrival of the towing company at the scene (arrival time stamp recorded), and coordinate notice to proceed with TMC personnel (NTP time stamp recorded). Once the vehicle(s) and any debris are cleared, the clearance end time is reported by the HERO Supervisor to the TMC. The towing company is also responsible for maintaining verification times and providing details on an invoice within 10 days of the TRIP activation. Invoices are paid monthly and require the towing companies to be present at a monthly AIR meeting.

While the TRIP system is operated by GDOT and TRIP data is maintained by GDOT TMC personnel, there is seamless integration of the data with the police dispatch system through a common incident identifier. One thing to note is that the TRIP system is contained to a single urban area, thus there are small numbers of individuals that need to understand the activation and data collection system in Georgia. Further, the involvement of the HERO Supervisors in the field are a key component to the oversight of field operations and collection of accurate time stamps. To conduct an incentive-based towing system statewide in South Carolina would require significant training and data collection program development.

There are several basic time stamps that most TIM states are collecting, and thus are recommended for South Carolina. The current SCHP CAD system is capable of capturing these records, but officers would need to be trained on the purpose and importance of this information as well as the specifics of the data capture. Referring back to Figure 3.1, the basic set of time stamps are T1-T6. Currently, the 9-1-1 collects T1 (incident reported) and T2 (incident verified). T3 (response identified and dispatched) is captured by 9-1-1 and SCHP CAD. The SCHP CAD system also captures T4 (response arrival on scene), and T6 (response departs scene). The only basic element that is not currently being captured is T5 (roadway cleared – all lanes open to traffic). The TMC does capture this time stamp in the Palguide System, but attempts to match this data to SCHP CAD data were unsuccessful due to the lack of a common identifier. It seems prudent to add this one data item to the SCHP CAD system, so that it will be collected for all incidents and not just those that fall within the realm of the TMC observation area.

Finally, there are several recommended response program improvements in addition to incentive-based towing. Each of these programs is very specific, and data on arrival at the scene and departure from the scene for each program would need to be collected to establish success in reduction of response and clearance times. The programs include MAIT, coroner, and hazmat responses. There are a number of ways to track these individual responses, such as GPS tracking devices for response vehicles, proximity detection systems for specific wireless radios and phones, as well as simply indicating presence to the scene commander, and recording the information in open text in the existing CAD. Further CAD enhancements would allow for custom fields to capture these items, but the burden on the scene commander must be taken into account.

4 REVIEW OF ICS/TIM BEST PRACTICES

4.1 PROGRAM FUNCTIONAL AREAS

The five functional areas of TIM activities (9) are: Detection and Verification, Traveler Information, Response, Scene Management and Traffic Control, and Quick Clearance and Recovery. In the following paragraphs, both the challenges and their solutions in each of these areas will be addressed. (Carson, 2010)

4.1.1 DETECTION AND VERIFICATION STRATEGIES

When it comes to the detection and verification of incidents, many states face challenges regarding the notification of responders. Typical issues include inconsistent notification, inaccurate incident reports, dispatcher overload, and slow detection. These issues have been combatted with the implementation of field verification, closed circuit television cameras (CCTV), frequent/enhanced roadway reference markers, enhanced 9-1-1/automated positioning systems, INRIX data, and automated collision notification systems. Field verification requires the first personnel dispatched to the scene assessing the incident and determining the appropriate response. CCTV cameras provide a way to monitor traffic through the use of limited-access video images. They can provide field verification, but have limited incident detection capabilities. Roadway reference markers, also referred to as "mile markers," make certain that motorists can accurately report incident locations. Enhanced 9-1-1 and Automated Positioning Systems can automatically determine the location of the caller and provides a physical address to the dispatcher, and can even route the call to the appropriate dispatcher. Automated Collision Notification Systems (ACNSs) detect incidents, typically in remote areas, through automatic or motorist initiated activation of an alarm, such as the commercially available OnStar system. The incident location is then verified via the transmission of location data, most commonly through GPS coordinates.

4.1.2 TRAVELER INFORMATION STRATEGIES

In a TIM system, it is imperative that roadway users are kept informed of changing conditions. This is often difficult to do when states have inaccurate traveler information and inconsistent changeable message sign (CMS) use. Issues, such as these, can be alleviated through the use of 5-1-1 systems, traveler information websites, media partnerships, CMS, and standard CMS message sets/use protocol. The national number for traffic and travel information, 5-1-1 provides information on routes and roadways, including incidents, roadway blockages, weather, and transit. Traveler information websites allow transportation agencies to communicate real-time traffic, construction, and other transportation related data. Media partnerships ensure that traffic information is shared over AM and FM radio and television channels. Dynamic/Changeable Message Signs (DMS/CMS) are electronic signs with changeable messages that provide real time advanced warning or rerouting on roadsides. Standard CMS message sets ensure that appropriate messages are posted, make posting messages more efficient for personnel, and make certain that driver expectation is not violated.

4.1.3 RESPONSE STRATEGIES

Response is defined as the “activation of a ‘planned’ strategy for the safe and rapid deployment of the most appropriate personnel and resources to the incident scene” (Carson, 2010). Difficulties in achieving this goal are caused by under/over-response and difficult scene access. These can be overcome through personnel/equipment resource lists, towing and recovery vehicle identification guide, instant tow dispatch procedures, towing and recovery zone-based contracts, enhanced computer aided dispatch (E-CAD), dual or optimized dispatch procedures, motorcycle patrol, and equipment staging areas/pre-positioned equipment. Personnel/equipment lists reduce indirect communication and unnecessary calls by compiling the protocols and contact information required in different response scenarios. Towing and recovery vehicle identification guides are laminated 8.5 by 11 inch cards that can be carried by responders to ensure that the necessary information is provided when towing response is requested. Instant Tow Dispatch Procedures eliminate the on scene verification process by initiating response from recovery and law enforcement personnel at the same time.

Towing and recovery zone-based contracts require that a single private towing agency is assigned to respond to incidents in a predefined geographic area. This also facilitates a high level of knowledge among tow responders of their towing zone and its typical incident types. Enhanced Computer Aided Dispatch (E-CAD) are continuously updated systems that use automatic vehicle location technologies to locate, route, and dispatch the closest emergency vehicles to incident scenes – also referred to as optimized dispatch. Dual dispatch procedures dispatch units from two different approach directions and the first unit to locate the incident provides response. This is used in areas with high traffic volumes, long distances between interchanges or crossovers, or when the location or direction of an incident has not been verified.

Motorcycle patrols are beneficial in congested areas, as they allow for better maneuverability than larger response vehicles. Equipment staging areas/pre-positioned equipment allows for organizing of equipment and designation of its use; thereby decreasing lost time from slow mobilization and intermittent arrival.

4.1.4 SCENE MANAGEMENT AND TRAFFIC CONTROL STRATEGIES

Scene Management “occurs after responding agencies have arrived at the scene” (9) and increases in complexity as the severity of the incident increases. Challenges faced when managing a scene include: confusion over authority/roles, difficult on-scene maneuverability, responder safety, secondary incidents, and excess delay. Common solutions to these challenges that have been adopted are incident command systems, response vehicle parking plans, high visibility safety apparel/vehicle markings, on-scene emergency lighting procedures, move-over laws, on-site traffic management teams, end of queue advanced warning systems, and alternate route plans. The Incident Command System (ICS) is a federal protocol that creates consistency in TIM protocols by defining command, communication, and resources. It relies on the concept of unified command, whereby management responsibility is shared among agencies. Response Vehicle Parking Plans preserve maneuverability, safety, and traffic flow at the incident scene through guidelines and policies about how and where vehicles should park so travel lanes can be gradually reopened. High-visibility safety apparel/vehicle markings improve on-scene safety of responders by increasing visibility of responders through retroreflective and contour markings, and is required by all responders that respond on the right-of-way. On-scene emergency lighting procedures set guidelines for emergency lighting use to improve visibility and safety and reduce distraction and harm to other road users. Move-over laws require drivers approaching an incident scene to either change lanes when possible and/or reduce their speed. On-scene traffic management teams rapidly deploy traffic control devices at incident scenes to improve safety and reduce risk of secondary incidents. End-of-queue Advanced Warning Systems can be static, arrow board, or changeable message signs and warn approaching motorists of downstream traffic queues. Alternate route plans can reduce traffic demand at the incident scene by rerouting traffic around the location.

4.1.5 QUICK CLEARANCE AND RECOVERY STRATEGIES

Clearance and recovery are the final stages of the TIM process and essential to returning the roadway back to normal conditions. This process is made more difficult when faced with abandoned vehicle hazards, lengthy minor incident clearance, lengthy major incident clearance, or liability concerns. Difficulties, such as these, can be resolved through abandoned vehicle legislation, driver removal laws, service patrols, vehicle mounted push bumpers, incident investigation sites, authority removal laws, quick clearance/open roads policies, non-cargo vehicle fluid discharge policies, fatality certification/removal policy, expedited crash investigation, quick clearance using fire apparatus, towing and recovery quick clearance incentives, and major incident response teams. Abandoned vehicle legislation/policy that distinguishes removal actions by response personnel of abandoned vehicles, reduces time to clear minor incidents and the risk of struck-by incidents. Driver Removal laws speed the clearance of PDO incidents by encouraging or requiring involved drivers to move their vehicle(s) out of the travel lanes if they can do so safely. Service patrols can serve a variety of locations and hours, and can verify incidents, provide scene protection, request response, and provide traffic control. Vehicle-mounted push bumpers are mounted on response vehicles and quickly and safely remove disabled vehicles from shoulders or travel lanes, and out of immediate danger. Incident Investigation Sites provide a safe refuge off the main travel way to further investigate and document an incident. Authority Removal laws authorize a pre-designated set of public agencies to remove damaged or disabled vehicles, as well as spilled cargo, from the roadway. Quick clearance/open roads policies bind agencies to quick clearance by setting implied or explicit goals for clearing incidents. Non-cargo vehicle fluid discharge policies exempt non-cargo vehicle fluid spills from hazardous materials response procedures, as long as the spill is contained on the pavement. Fatality certification/removal policies allow a designated EMS unit to certify death, rather than a coroner, to decrease delays from waiting for the coroner to arrive. Expedited Crash Investigation uses photogrammetry, and other technology, to more efficiently collect data at the incident scene. Quick clearance using fire apparatus allows the use of tow straps on fire department vehicles to pull disabled or blocking vehicles out of travel lanes to the side of the road. Towing and recovery quick clearance incentives combine financial incentives for quick clearance as well as disincentives for slow performance to improve towing performance and reduce clearance times. Major incident response teams are comprised of high-ranking officials from a variety of agencies who train and respond to major incidents, and are also available 24/7.

Based on implementation of these TIM programs, it is possible to measure their impact by observing the improvements to the selected performance measures. Benefits of TIM programs have been observed in several states. In 2005, Maryland DOT's CHART reduced average incident duration by 23%, assisted in 20,515 lane blockage incidents, reduced travel delay by 37 million vehicle-hours, saved users 6.4 million gallons of fuel, reduced secondary incidents by 290 incidents, and benefited highway users $578 million based on travel delay reductions (NTIMC, 2006). Similar results were observed by the Hudson Valley's Highway Emergency Local Patrol (H.E.L.P.). In 2005, this motorist assistance patrol responded to 129 incidents, with an average clearance time of 36 minutes, compared to an average clearance time of 42 minutes for 86 incidents that occurred after their weekday operating hours (NTIMC, 2006). Additionally, the Georgia DOT Towing and Recovery Incentive Program (TRIP) saved, on average, 163 minutes of clearance time per incident (TRIP, 2012).

4.2 PERFORMANCE MEASURES

With so many intangible impacts, it is hard to quantify the benefits of a TIM plan. In an effort to measure these advantages, several performance measures are commonly used, including: number of service patrol assists, average elapsed time from incident occurrence to detection, average elapsed time from point at which the incident response team is called out until its arrival on-scene, and average elapsed time to normal traffic flow restoration (12). The effectiveness of TIM plans and training exercises have been measured using metrics like these in several states. In Maryland, the Coordinated Highways Action Response Team (CHART) has measured the effectiveness of their programs based on incident response rate, which is the ratio between the number of incidents reported to and those managed by CHART. It was found that “responders are more likely to compute performance measures if they are already collecting the data to support them” (12). CHART responders typically reported Incident frequency, detection time, response time, and clearance time. These measures will allow effectiveness to be measured and allow identification of ways to improve TIM response and determination of performance.

Table 4.1 Candidate Program Level TIM Objectives and Performance Measures

Candidate Objective		Proposed Performance Measure(s)	Responsible Parties
1	**Reduce incident notification time** (defined as the time between the first agency's awareness of an incident, and the time to notify needed response agencies).	The time between the first agency's awareness of an incident, and the time to notify needed response agencies.	Patrol, Dispatch
2	**Reduce roadway clearance time** (defined as the time between awareness of an incident and restoration of lanes to full operational status.	Time between first recordable awareness (detection/ notification/ verification) of incident by a responsible agency and first confirmation that all lanes are available for traffic flow.	Patrol, Dispatch
3	**Reduce incident clearance time** (defined as the time between awareness of an incident and removal of all evidence of the incident, including debris or remaining assets, from shoulders).	Time between first recordable awareness (detection/ notification/verification) of incident by a responsible agency and time at which all evidence of incident is removed (including debris cleared from the shoulder).	Patrol, SHEP
		Time between first recordable awareness and time at which the last responder has left the scene.	
4	**Reduce "recovery" time** (defined as between awareness of an incident and restoration of impacted roadway/ roadways to "normal" conditions).	Time between awareness of an incident and restoration of impacted roadway/roadways to "normal" conditions. (NOTE: Participants noted that "normal" conditions could be difficult to define.)	Patrol, SHEP, TMC
5	**Reduce time for needed responders to arrive on scene after notification.**	Time between notification and arrival of first qualified response person to arrive on incident scene.	Response Agencies

6	**Develop and ensure familiarity with regional, multi-disciplinary TIM goals and objectives and supporting procedures by all stakeholders.**	Existence/availability of program-level plan for implementing traffic control devices and/or procedures.	TIM Training
		Existence of/participation in multi-agency/jurisdictional training programs on the effective use of traffic control/staging devices and procedures.	
		% of workforce trained on National Incident Management System as well as local/ regional/ "program-level" procedures.	
		% of agencies with active, up-to-date Memoranda of Understanding (MOUs) for program-level TIM.	
		# of certified courses taken.	
		# of attendees at various courses.	
7	**Reduce number of secondary incidents and severity of primary and secondary incidents.**	# of total incidents (regardless of primary or secondary) and severity of primary incidents (National Highway Transportation Safety Administration [NHTSA] classification).	Patrol
		# of secondary of incidents and severity (NHTSA classification).	
		# fatalities.	
8	**Improve communication between responders and managers regarding the status of an incident throughout the incident.**	# or % of agencies with a need to communicate, who are able to communicate (sharing information or communications systems) within an incident.	AAR's, etc.
9	**Provide timely, accurate, and useful traveler information to the motoring public on regular basis during incident.**	Comparison of information provided at any given time to what information could have been provided.	TMC, Patrol and SCDOT Social Media Accounts
		Customer perceptions on usefulness of information provided.	
		Time of updates to various sources.	
		# of minutes it takes to disseminate informational updates to the public (after something changes regarding incident status).	
		# of sources of information to the public.	
		# of system miles that are covered/density of coverage by traveler information systems (seek to increase these).	
10	**Regularly evaluate and use customer (road user) feedback to improve TIM program assets and practices.**	% incidents managed in accordance with program-level procedures.	Feedback from users
		% of incidents for which multi-agency reviews occur.	
		Perceived effectiveness (by involved stakeholders) of use of traffic control devices to achieve incident management goals developed for each incident.	
		Correlation of use of program-level traffic control devices by incident type.	
		# of instances of sending the needed equipment (presumes that needed quantities and types of equipment are defined) for the incident.	
		Frequency of dissemination of multi-agency/program-level and customer feedback back to partners.	
		Measures of customer feedback	

5 GAP ANALYSIS

To conduct the gap analysis, the research team scheduled a lengthy meeting with the steering committee to review the best practices and discuss which ones were implemented or planned for South Carolina. In this manner, The FHWA best practices identified in the literature were compared to the current practice in the state of South Carolina to determine those that are implemented, planned, or that the state is interested in implementing.

Several detection and verification strategies recommended nationally are being practiced in SC. Those being used by SCDOT include field verification by on-site responders, CCTV, enhanced 9-1-1, and automated collision notification systems, as well as an automated positioning system that is in the process of being developed and implemented. Currently, South Carolina employs the use of the INRIX software for collision notification. However, the state does not currently use any of the other recommended measures. Due to high maintenance costs, frequent/enhanced roadway reference markers are not considered feasible in SC. Additionally, motorist aid call boxes were deemed unnecessary with such a high proportion of road users carrying cell phones. Further research has previously been done to investigate the use of traffic sensors on SC interstates and the associated benefit-cost analysis. This research can be read in “Incident Detection with Sensors on Urban Highways” (14). These programs can be seen below in Table 5.1.

Table 5.1 SC Detection and Verification Practices

	Implemented	Planned	Interested	Not Implemented
Field Verification by On-Site Responders	•			
Closed-Circuit Television Cameras	•			
Frequent/Enhanced Roadway Reference Markers				•
Enhanced 9-1-1/Automated Positioning Systems	•	•		
Motorist Aid Call Boxes				•
Automated Collision Notification Systems	•			

South Carolina uses all of the nationally recommended traveler information strategies. Media partnerships with the state are typically only used for major incidents, but all other best practices are used daily on state roads. These implemented strategies can be seen in Table 5.2.

Table 5.2 SC Traveler Information Practices

	Implemented	Planned	Interested	Not Implemented
5-1-1 Systems	•			
Traveler Information Websites	•			
Media Partnerships	•			
Dynamic Message Signs	•			
Standardized Message Sets/Use Protocol	•			

Compared to the other functional areas, South Carolina is lacking the most in the area of response strategies. While they do have personnel/equipment resource lists, towing and recovery vehicle identification guide, motorcycle patrols (used for enforcement), and equipment staging areas, there are a number of areas where the steering committee agreed that there was potential for improvement in standard practices and policies. There are currently no incentive-based tow dispatch procedures, towing and recovery zone-based contracts, ECAD, or dual/optimized dispatch procedures. There are limited motorcycle patrols (10 statewide) that are used for collision investigation response. Motorcycle patrols are more maneuverable than police vehicles and can be an asset for reaching incident sites quickly. The state is interested in developing these programs which require additional funding for expansion. Planned and implemented programs can be seen in Table 5.3.

Table 5.3 SC Response Strategies

	Implemented	Planned	Interested	Not Implemented
Personnel/Equipment Resource Lists	•			
Towing and Recovery Vehicle Identification Guide	•			
Instant Tow Dispatch Procedures				•
Towing and Recovery Zone-Based Contracts				•
Enhanced Computer-Aided Dispatch				•
Dual/Optimized Dispatch Procedures				•
Motorcycle Patrols	•		•	
Equipment Staging Areas/Pre-positoned	•			

All of the best practices in scene management and traffic control are either being used in South Carolina today or are planned. Response vehicle parking plans and on-scene emergency lighting procedures are currently in the planning phase and SCDOT is conducting training of responders to implement these practices. All other recommended strategies in this area are practiced, and all can be seen in Table 5.4.

Table 5.4 SC Scene Management and Traffic Control Strategies

	Implemented	Planned	Interested	Not Implemented
Incident Command System	•			
Response Vehicle Parking Plans		•		
High-Visibility Safety Apparel/Vehicle Markings	•			
On-Scene Emergency Lighting Procedures		•		
Safe, Quick Clearance Laws--Move Over	•			
Effective Traffic Control Through On-Site Traffic Management Teams	•			
End-of-Queue Advance Warning Systems	•			
Alternate Route Plans	•			

Several quick clearance and recovery strategies are practiced in South Carolina. These strategies are: abandoned vehicle legislation/policy, driver removal laws, service patrols, vehicle-mounted push bumpers, authority removal laws, expedited crash investigation, and quick clearance using fire apparatus. Of the remaining gaps, the state cited towing and recovery quick clearance incentives as something they were interested in possibly developing and determining the feasibility. The state is interested in possibly implementing all remaining strategies; these are outlined in Table 5.5.

Table 5.5 SC Quick Clearance and Recovery Strategies

	Implemented	Planned	Interested	Not Implemented
Abandoned Vehicle Legislation/Policy	•			
Safe, Quick Clearance Laws--Driver Removal	•			
Service Patrols	•			
Vehicle-Mounted Push Bumpers	•			
Incident Investigation Sites			•	
Safe, Quick Clearance Laws--Authority Removal	•			
Quick Clearance/Open Roads Policy			•	
Non-Cargo Vehicle Fluid Discharge Policy			•	
Fatality Certification/Removal Policy			•	
Expedited Crash Investigation	•		•	
Quick Clearance Using Fire Apparatus	•			
Towing and Recovery Quick Clearance Incentives			•	
Major Incident Response Teams			•	

6 PROGRAMMATIC RECOMMENDATIONS FOR GAPS

After analyzing the current best practices, the potential areas for improvement could be identified. Based on the implementation tables, the areas most in need of improvement were response and clearance strategies. The major gaps existed in towing, coroner, HAZMAT, and crash investigation procedures. The following sections will review current SC policies in each of these areas, and present alternatives used in other states with proven success.

6.1 TOWING

In South Carolina, towing operations are conducted on a rotation dispatch system. Currently there are 3 wrecker lists, divided by class, and assigned to each zone. Once the SCHP calls one of the wrecker companies on the wrecker list, the company has 45 minutes to arrive at the scene of the accident. The next dispatch call will go to the second company on the list, and then the third. This pattern repeats to ensure fair distribution of towing cases. The wrecker fees for Class C vehicles are $300/hour and can vary upwards based on incident type for commercial vehicles. The rotation arrangement is similar to prior programs in Washington, Georgia, Florida, North Carolina, and Virginia before they implemented incentive based towing programs. With the current system in South Carolina, there is no motivation for the towing companies to get the job done quickly, because the longer they work the crash scene the more money they earn.

Because of the similarities between South Carolina's current regulations and the previous regulations in states that now have incentive based programs, it is possible to see the potential economic and clearance time benefits in SC. For example, in 2008 Georgia implemented the Towing and Recovery Incentive Program (TRIP) which compensates certified, inspected heavy-duty recovery companies to expedite clearance at major incident scenes. The program requires minimum equipment levels, prompt response and 24/7 equipment availability, highly trained operators, and fluid spill mitigation capabilities. In the first year, the clearance time dropped from 216 minutes to 49 minutes (see Figure 1.2) with the transition from pay by the hour to incentive pay to clear within 90 minutes (disincentives are also used for clearance times over 3 hours). Over the seven years that the program has been in operation, there have been 515 activations and clearance times have dropped from 216 to under 40 minutes (38 min in 2014). The number of activations have doubled over the same time period from 59 in 2008 to 119 in 2014. Total incentives paid from 2008-2014 equal $1,242,420. An independent evaluation of the program in 2011 indicated a cost savings per incident of $456,396 (or 71% savings). The financial benefit of TRIP for 2008 and 2009 was over $9 million dollars providing a cost benefit ratio of 11:1.

Table 6.1 summarizes a few of the incentive-based programs used by Washington, Georgia, and Florida in comparison to the South Carolina regulations. As seen in the table, the incentive rate ranges from $2500/1.5hr to $3500/1.5hr with additional penalties applied in Georgia and Florida if the required clean-up time is not met. These programs have resulted in large reductions in incident duration. In Georgia, between 2007 and 2009, the Towing and Recovery Incentive Program (TRIP) has seen the average duration of all incidents decrease from 4 hours and 43 minutes to 1 hour and 37 minutes, a 66% improvement. They have also seen the average duration of "typical" incidents decrease from 4 hours and 52 minutes to 1 hour and 30 minutes, a 69% improvement. There have been 515 activations of the TRIP program, with the number of activations doubling from 59 in 2008 to 119 in 2014. As of the end of 2014, total incentives paid to TRIP members were $1,242,420. The cost savings per incident is estimated at $456,396 or 71%. The financial benefit of TRIP for 2008 and 2009 alone was $9,154,431, and equates to a benefit-cost ratio of 11:1.

Funding for the TRIP program originally was provided by Congestion Mitigation and Air Quality (CMAQ) federal funds. To qualify for these funds, the program must exist in a federally approved non-attainment region. CMAQ funding of $2.2 billion was carried over into MAP-21 funding for 2013-2014. These funds are typically only used to start and establish a program during its first three years. GDOT, and the TRIP program, have switched from funding from CMAQ to funding from State Farm sponsorships of the HERO units, which include logos on HERO trucks and sign placements within the DOT right of way. State Farm currently provides $1.7 million/year of funding, which is used to compensate members of the TRIP program. While this type of funding arrangement sounds promising on the surface, there are downsides. In many states, including South Carolina, the highway service patrols are the most common branch of the DOT to be associated with a positive public perception. Rebranding the patrol units would be a great loss to the SCDOT public image.

Members of the TRIP program must complete a stringent application process and once approved, are required to maintain a staff of supervisors and operators that have completed national and industry certifications. They are also required to maintain up-to-date equipment, including heavy-duty wreckers and support vehicles with traffic control and fluid spill mitigation equipment. When an incident involving a commercial vehicle occurs that requires TRIP, designated personnel (such as a GDOT HERO supervisor) must activate the response. Once declared a TRIP incident, and the responder is notified, the company supervisor must arrive on the scene within 30 minutes of notification and all basic equipment must arrive within 45 minutes if called between 5:30 am and 7:00 pm, Monday through Friday; at all other times equipment is allowed 60 minutes to arrive at the scene. The company then remains on scene until they receive official notice to proceed and clear the incident. After receiving notice, the roadway must be cleared and open to traffic within 90 minutes. Monthly After-Incident-Reviews (AIR) are held by GDOT HERO to discuss and evaluate incident timelines and determine eligibility for incentives. TRIP incentive bonus payments are as follows:

- $600 if the TRIP company is called, responds within the specified time, but is not needed.
- $2,500 if the TRIP company is called, responds within the specified time, and has the roadway cleared and opened to traffic within 90 minutes after receiving the notice to proceed.
- An extra $1,000 is paid if additional special equipment was required and provided, and all time requirements were met.

Based on results found in neighboring states, the implementation of an incentive-based towing system in South Carolina would provide a significant reduction in clearance times of major incidents involving commercial motor vehicles. The 2009 South Carolina Commercial Motor Vehicle Traffic Collision Fact Book reported that 736 of 2293 (32.1%) total CMV crashes occur on interstates, and 19 of those involve fatalities. Unfortunately, the TR-310 crash report form does not distinguish between towing of CMVs or other vehicles. This might be an important crash data collection item to include in future system enhancements. However, based on a median fatal crash recovery time of 355 minutes in South Carolina, and a 66% improvement in incident duration resulting from the implementation of the TRIP program in Georgia, an estimated 234 minutes could be saved for a single fatal incident. This is a significant improvement which would greatly reduce time that personnel are in harm's way, the chances of secondary crashes, and congestion resulting from lane closures.

Currently, the South Carolina Code Chapter 38 under Department of Public Safety Wrecker Regulations (38-600) section C specifies a rotation-based system within each county. Implementation of an incentive-based towing system would require new regulations to address training of towing personnel, development of an inspection and certification verification program, and new data management programs. Further, the code currently states that, “Wreckers shall respond only upon the request of the Department of Public Safety.” It is likely that changes in towing operations, similar to Georgia TRIP, may place this expedited clearing program under the authority of the Department of Transportation with requirements for activation, clearance time monitoring, and payments. However, the large majority of standard towing operations would be handled by SCDPS. A legislative review would be in order to ensure changes comply with existing legislation.

Table 6.1 Comparison of SC Towing Regulations and Incentive-based Towing in Three States

	SCDOT Regulations	WSDOT (MIT)	GDOT (TRIP)	FDOT (RISC)
Specialized wrecker list for quick clearance?	No	Major Incident Tow	Towing & Recovery Incentive Program	Rapid Incident Scene Clearance
Separate list for each wrecker category?	Yes	No	No	No
Additional training or equipment required?	No	Yes	Yes	Yes
Required wrecker business hours?	8:30 A.M. - 5:00 P.M. Monday - Friday	24/7 7 days a week	24/7 7 days a week	None Established (assume standard 8:00A.M.-5:00P.M. M-F)
Can passing wrecker respond to accident?	No; not unless contacted by SCHP	Yes; wrecker would be on a route during peak traffic	No	No
Time allocation wrecker has to arrive on scene?	45 minutes	15 minutes (business hours)	45 minutes (business hours)	60 minutes
Total Time allocation for wrecker to clean area?	None Established	90 minutes	90 minutes	90 minutes
Incentive Bonus?	None	$2,500	$2,500 standard + $1,000 equipment bonus = $3,500 total	$2,500 standard + $600/$1000 equipment bonus = $3,500 total
Minimum wrecker requirements?	One Class A, B, or C wrecker	Two Class C wreckers	Two Class C wreckers and a support vehicle	One Class C wrecker
Reimbursement for services not rendered?	None	$600	$600	$600
Penalized for excessive cleanup time?	No	No	$600 flat or $600/hr	$600/hr

6.2 HAZMAT

The South Carolina Commercial Motor Vehicle Traffic Collision Fact Books contain information on crashes involving hazardous materials. Hazardous materials crashes are reported in the TR-310 supplemental report for truck and bus crashes. In 2009, there were 71 CMV's with hazard placards involved in crashes, and 66 were actually carrying hazardous materials when the crash occurred. Overall, 96% of the units involved in CMV crashes did not release any hazardous materials – leaving 12 CMV crashes with some level of hazardous material spills. Of these roughly one-third (5) occurred on Interstates. Hazardous materials spills can pose a significant threat to human and wildlife health, the environment, and property; with some escalating to involve fire and explosions. Regardless of the seeming rarity of these events, state agencies must remain knowledgeable and vigilant in their response.

The USDOT Pipeline and Hazardous Materials Safety Administration (PHMSA) has developed training modules from the perspective of the HAZMAT carrier. Such training covers carrier requirements, national and local regulations, methods for handling spills, and procedures for reporting spills. PHMSA also developed an Emergency Response Guidebook (ERG) in 2012 for first responders to aid in on-scene procedures and identifying spilled hazardous materials. This guidebook is also available as a smartphone app for easy access and quick response during the crucial moments after an incident occurs. A similar ERG was developed in 2008, and features initial isolation and protective action distances developed by Argonne National Laboratory. In addition to all of these training materials, courses and materials have also been created by the Federal Emergency Management Agency (FEMA), FHWA, NTIMC, as well as individual states - including Virginia and Florida. Non-governmental agencies, such as the International Association of Firefighters and the Security and Emergency Response Training Center, have also developed training programs.

Many of these training courses and reference materials contain direction on identifying materials after they have been spilled. Typically, it is up to the carrier to notify appropriate authorities about the material and any other pertinent information about the spill. This can be determined via the placard on the sides and end of the vehicle. Each vehicle transporting HAZMAT should have one or more of these diamond-shaped placards featuring a 4-digit ID number. This ID number is usually on each placard or on an adjacent orange panel and can be used to identify the type of HAZMAT spill. Other than the placards, container labels, shipping documents, Material Safety Data Sheets (MSDS), the 2012 ERG, and the knowledge of persons on scene can be used to identify spilled materials. There are nine categories of HAZMAT (e.g. explosives, gases, oxidizing substances, organic peroxides, etc.) with specific response protocols for each category as indicated in the 2012 ERG.

In most states, the HAZMAT carrier is responsible for procuring and funding clean-up activities. To study differences in standard operating procedures among several states, the research team developed HAZMAT procedural flow charts for each state. Figures 6.1-6.3 show varying procedures in SC, MA, and OH. Currently, South Carolina requires that the carrier notifies the Department of Health and Environmental Control (DHEC) for each HAZMAT incident requiring clean-up. DHEC is primarily responsible for monitoring the clean-up process, but does not have to be involved in immediate incident response. Should the fire department responders determine that it is a severe HAZMAT incident, a request can be made to have DHEC become involved in the clean-up process.

In reviewing procedural flow charts for MA and OH, a few differences were noted which could provide significant time savings. In Massachusetts, if immediate action must be taken or the clean-up is outside the scope of the carrier, the authoritative state agency will call in a contractor to clean up the spill, and then bill the carrier after-the-fact for up to three times the cost of the clean-up (See highlighted area in Figure 6.2). Typically, when a spill is referred to as HAZMAT, one would think about a gasoline tanker laying on its side spilling its contents; however, a standard passenger car crash with a leaking fuel tank is far more probable. In many states, such as Ohio, there is a statewide policy for immediate cleanup of spills less than 25 gallons by one or more response agencies – usually fire (See highlighted area in Figure 6.3). Both of these policies have merit in reducing the response time, as well as the need for traditional HAZMAT response.

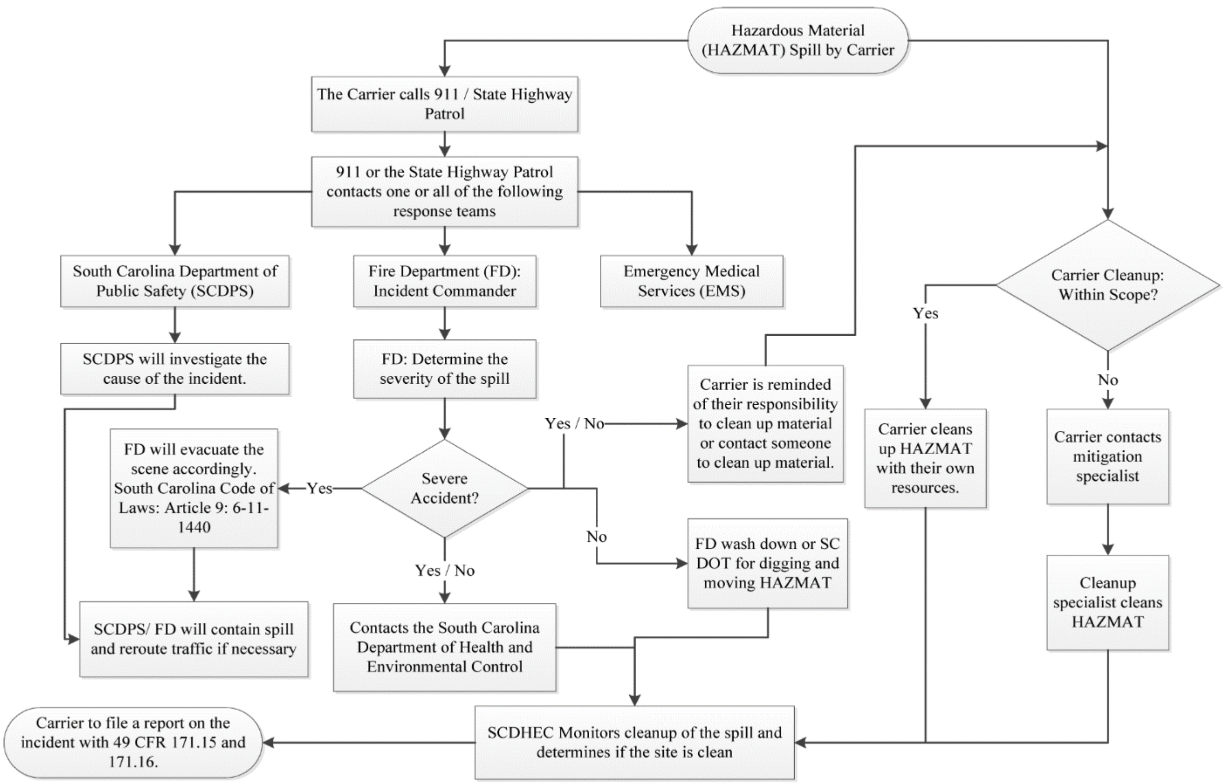


Figure 6.1 SC Hazmat Procedural Chart for Traffic Incidents

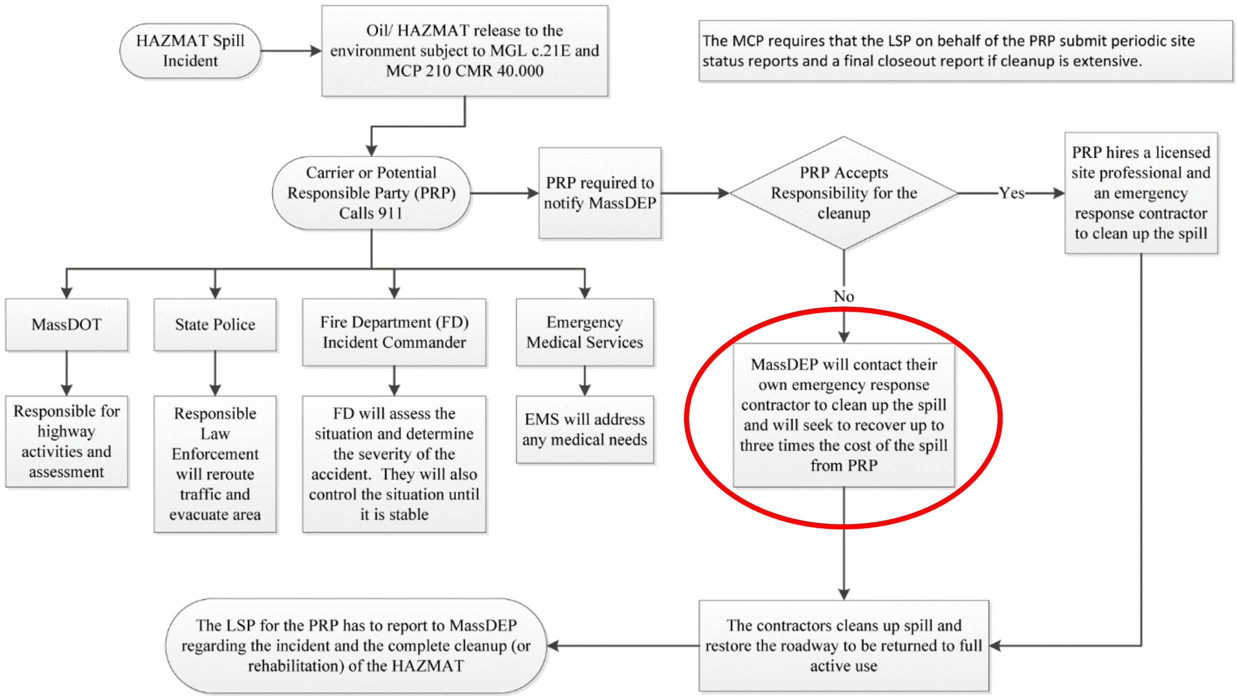


Figure 6.2 MA Hazmat Procedural Chart for Traffic Incidents

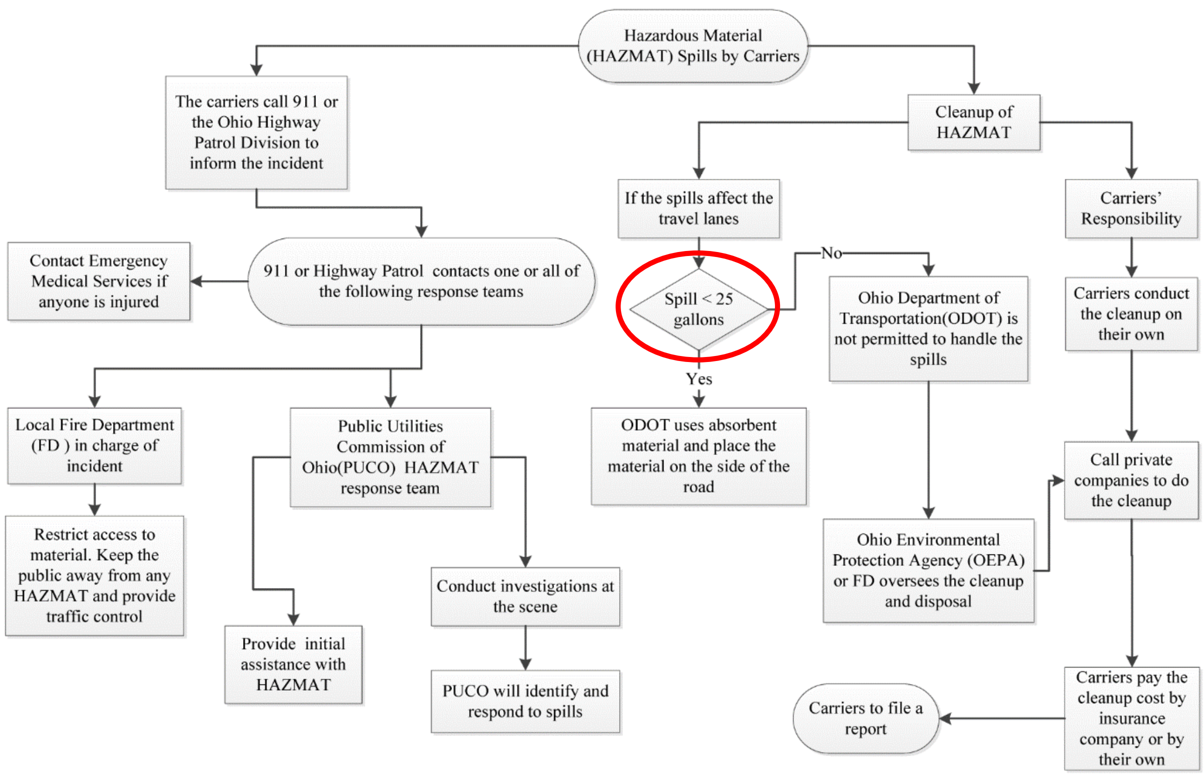


Figure 6.3 OH Hazmat Procedural Chart for Traffic Incidents

An article in the *Carolina Fire Journal* by Jason Krusen, a Special Operation Chief for the Columbia Fire Department in Columbia, SC, indicates that more often than not, the amount of fuel spilled is overestimated by on-scene response potentially resulting in unnecessary response. Accurately identifying that an incident does not require a hazmat team response means quicker clearance of the incident. It is important for first responders to understand and be able to recognize the reportable amounts for fuel spills. In live training classes, it is effective to create one, five, and 25-gallon spills using water in a parking lot to highlight the differences in quantities on the ground. This is a cheap and easy way to help first responders make clear assessments of the amount of fuel spills. The Ethanol Emergency Response Coalition (EERC) and Pipeline and Hazardous Materials Safety Administration (PHMSA) are also great resources for responders. The EERC created a training program in conjunction with the International Association of Fire Chief's (IAFC) which is a free online course.

Regulations for fuel spill response varies from state to state to state, and sometimes even county to county which can complicate response because local governments may have a more stringent reporting quantity based on local codes. A statewide policy helps to provide consistency and formal protocols for dealing with fuel spills. In South Carolina, the Columbia Fire Department issued a standard operating guideline (OPS-035)[4] for response to fuel and oil spills. The policy separates minor and major spills and expresses the role of DHEC as either receiving notification only or having necessary response. The details of the policy are stated as follows:

- Minor Spills
    - A. Minor spills of petroleum based fuels and motor oils pose a lesser threat to property and the environment than major spills. However, it is still important to take protective measures in response to these incidents. The following type incidents are to be considered minor, unless additional information warrants them being upgraded:
        1. Spills less than 25 gallons on the hardtop
        2. Spills less than five gallons on soil
    - B. The following actions should be taken as a minimum on this type incident:
        1. Prevent the spread of product by using damming, diking and diverting techniques.
        2. Eliminate any possible ignition sources.
        3. Isolate the area to a safe distance until the spill is controlled.
        4. Have Columbia Central to notify DHEC of the spill. Advise Central that no response is necessary that this is a notification only. Provide the following information:
            - a. Type of product spilled (e.g., motor oil, diesel, etc.)
            - b. Approximate amount of spill
            - c. Type of surface on which spill is located (e.g., soil, pavement, etc.)
            - d. Indication of whether the spill is/is not threatening a water source
        5. If vapors are suspected, as in gasoline spills, Haz-Mat 1 may need to be requested
- Major Spills
    - A. Major spills of petroleum based fuels and motor oils can pose a significant threat to property and the environment. These incidents can quickly escalate and cause damage to property and the environment. Ensure all protective measures are taken to minimize the spill. The following types of incidents are to be considered major incidents.:
        1. Spills greater than 25 gallons on the hardtop
        2. Spills greater than five gallons on soil
        3. Spills of any size threatening a waterway
        4. Spills of any size in a waterway

[4] http://www.columbiascfire.net/Ops%20Guidelines/OPS-035-Response-to-Fuel-and-Oil-Spills-2010.pdf

5. Spills with impending bad weather that could cause an issue

B. The following actions should be taken as a minimum on this type of incident:
   1. Ensure that Haz-Mat 1 is responding to the incident
   2. Prevent the spread of product by using damming, diking, and diverting techniques
   3. Eliminate any possible ignition sources. If there is a potential for ignition, a foam blanket should be applied
   4. Isolate the area to a safe distance until the spill is controlled
   5. Have Columbia Central to notify DHEC of the spill. Advise Central that a response from DHEC is necessary. Provide the following information:
      a. Type of product spilled
      b. Approximate amount of spill
      c. Type of surface on which spill is located (e.g., soil, pavement, etc.)
      d. Indication of whether the spill is/is not threatening a water source
      e. A call back number for DHEC to call (preferably Haz-Mat 1 or the responding Battalion Chief's phone)
      f. Status of the spill (e.g., contained, continuing to spread, etc.)

Delays in HAZMAT response and clean-up may occur when DHEC resources are requested unnecessarily to incident sites which should be notification-only events. By explicitly defining and developing standard statewide operating procedures and interactive spill training, hazardous material spills could be handled more quickly and efficiently by using the closest resources. Maintaining a contact list of personnel, skills, and materials possessed by typical responders (i.e. fire and towing), as well as a geolocated listing of DHEC approved private HAZMAT response companies by specialty and expertise, can further reduce the time to identify the nearest response teams that can handle the HAZMAT release scene. As private companies and public resources may change often, these lists should be updated on an annual basis in conjunction with DHEC contractor approval schedules.

6.3 CORONER

Currently in South Carolina, state legislation allows removal of a deceased body from a fatal crash scene only after a formal investigation and authorization by a coroner, deputy coroner, medical examiner, or deputy medical examiner.

> ***SC CODE SECTION 17-5-580.*** *Authorization for removal of dead body; penalties; coroner's jury.*
>
> *(A)(1) It is unlawful for any person to move or authorize removal of a body from the place where the body is found until the investigation is completed and the removal is authorized by the coroner, deputy coroner, medical examiner, or deputy medical examiner in charge.*
>
> *HISTORY: 2001 Act No. 73, Section 1.*

According to NCHRP Synthesis 318 on Safe and Quick Clearance of Traffic Incidents (NCHRP, 2003), roughly 15 out of 21 responding states had a similar policy requiring coroners or medical examiners to respond to the site before the deceased can be removed. In many jurisdictions, incident responders are not allowed to disturb the victim's body in any way, either by moving the body or the vehicle containing the body. This type of legislation can significantly delay incident clearance and increase congestion as numerous responders may sit idle with vehicles blocking the travel way while awaiting the arrival of the coroner. To compound the effect, there are typically a limited number of qualified individuals that may investigate and authorize the removal of deceased from a traffic incident scene.

There are three key factors that impact the arrival of the coroner or medical examiner on scene: 1) initial response to the dispatch call; 2) the current availability of the coroner or medical examiner on duty; and 3) the travel time required to arrive on scene. While the initial response and availability of the coroner are currently unknown, the travel time component can be adequately estimated using geographic information systems. The research team queried the 2012 SCDOT Crash Database to identify all fatal crashes occurring on interstate facilities. A total of 86 fatal crashes were returned. For each of these crashes, the location of the crash was matched with the responding coroner by jurisdiction. For six crashes, either the crash or coroner location could not be determined - these were removed from the analysis. For the remaining 80 fatal crashes, an analysis was performed to determine the travel time and distance under ideal conditions (i.e., assuming no traffic congestion and shortest distance routing). Overall, ideal travel times ranged from 4 minutes to 41 minutes with the median being 15 minutes. The travel distance ranges from 2.6 miles to 32.7 miles with 10.6 miles as the average. *Figure 6.4* shows the distribution of ideal travel times for all 80 geolocated fatal crash events on interstates in 2012. Assuming that the traffic conditions in the area of the crash will generate less than ideal conditions for the coroner approaching the incident, the times shown here are considered best case scenario. Also, recall that these times to do include initial response and readiness time requirements.

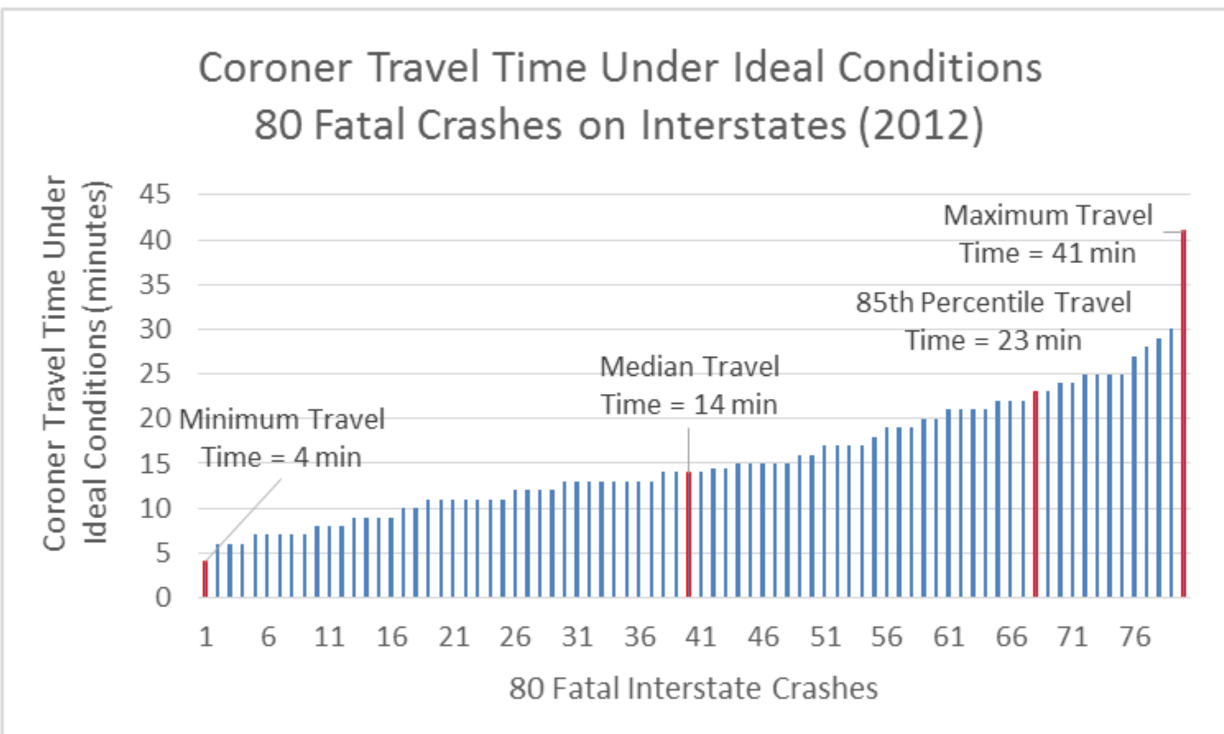


Figure 6.4 Calculated Coroner Travel Time under Ideal Conditions for 80 Fatal Crashes on Interstates in 2012

In states where delegation of the investigation and removal authority is not expressly prohibited, coroners and medical examiners may allow responders (i.e., law enforcement or fire response) to assert death, take appropriate digital photographs for later investigation, and then remove the deceased victim from the roadway. Some jurisdictions are required to notify the coroner or medical examiner to get verbal approval prior to the removal. However, even with this notification requirement, allowing the authority to remove the deceased can lead to quicker incident clearance and have a positive impact on public safety. Approximately half of the 21 states surveyed for the NCHRP Synthesis 318 indicated that they have legislation or policies establishing procedures and responsibilities for removing deceased from traffic crash sites. In Maryland, the Chief Medical Examiner developed a set of 3 steps that law enforcement agencies must follow when "special situations" necessitate immediate removal of a fatal crash victim. These steps include: 1) completing a form describing the characteristics of the crash; 2) take instant photographs of the incident scene, including the decedent's body and its position; and 3) contact the 24-hour Medical Examiners center to request permission to relocate the body.

Further, other states including Texas, Tennessee, and Louisiana have implemented traffic fatality certification laws. These laws are a combination of quick clearance and hold harmless acts to address the removal of deceased victims from the crash scene where the location obstructs or presents a hazard to adjacent traffic flow. Quick clearance objectives can be handled by allowing temporary removal of the deceased from the highway, and/or certification of the fatality by someone other than the coroner. Options may allow for certification of a fatality by a predesignated responding agency, or certification through remote communication with the coroner. Fatality certification laws are also considered hold harmless laws because they protect the responders from liability associated with moving the deceased and possibly contributing to the fatality.

For instance, Texas has a State Law that explicitly requires the quick removal of deceased from runways, railroads, and highways, which reads as follows:

> ***TEX CR. CODE ANN. Article 49.25 Section 8***
>
> *When any death under circumstances set out in section 6 shall have occurred, the body shall not be disturbed or removed from the position in which it is found by any person without authorization from the Medical Examiner or authorized deputy,* ***except for the purpose of preserving such body from loss or destruction or maintaining the flow of traffic on a highway, railroad or airport****. [emphasis added]*

The legislation in Tennessee is very similar stating:

> ***Tenn. Code Ann. § 38-7-108 (b)***
>
> *When a death occur s under the circumstances set forth in the Act, under Tenn. Code Ann. § 38-7-108 (b) the body "shall not be removed from its position or location without authorization by the county medical examiner,* ***except to preserve the body from loss or destruction or to maintain the flow of traffic on a highway, railroad, or airport.****" [emphasis added]*

Finally, in 2013 Louisiana revised their statutes for 'removal of bodies' within the Motor Vehicles and Traffic Regulation Title 32:

> ***LA Rev Stat § 32:154***
> ***§154. Removal of bodies***
>
> *Notwithstanding any other law to the contrary, particularly but not limited to R.S. 13:5712(B) or 5713(B)(3) when a death occurs in which a moving conveyance is involved, the body of the deceased person shall not be disturbed from the position in which it is found by any person without authorization from the coroner, or his designee,* ***except the investigating law enforcement agency may disturb the body in order to obtain the identification of the deceased, preserve the body from loss or destruction, or maintain the flow of traffic on a highway or railroad.*** [emphasis added]
>
> *Acts 2009, No. 408, §1; Acts 2010, No. 885, §1, eff. July 2, 2010.*

The State of Washington has taken a slightly different approach by developing an off-site extrication policy. The Washington State Patrol (WSP) and the Washington State Department of Transportation (WSDOT) have executed a series of memoranda with County Coroner's Offices titled, "Guidelines for Off-Site Removal of Deceased Persons at Collisions," which establish the procedures under which a body may be moved after a fatal accident. In essence, the lengthy extrication functions are conducted off-site after properly securing, covering, and moving the vehicle and body to a more private location. This procedure reduces hazards for responders conducting the extrication on site and expedites opening of travel lanes, while ensuring the privacy and dignity of the victim. Figure 6.5 shows one example of the agreement reached among the WSP, WSDOT, and Thurston County:

THURSTON COUNTY
WASHINGTON
SINCE 1852

OFFICE OF THE CORONER
JUDY ARNOLD

Mailing Address: Courthouse, Olympia, WA 98502-6045
Physical Address: 2925 37th Ave SW, Tumwater, WA 98512
Office: (360) 586-2091 Fax: (360) 357-2485

Guidelines for Off-Site Removal of Deceased Persons at Collisions

Fatality traffic collisions frequently result in long road closures affecting thousands motorists. When a fatality occurs at a traffic collision, it is considered to be a crime scene and the appropriate law enforcement agency conducts a collision investigation and the county coroner conducts a death investigation. During these investigations, it is important to balance the need to conduct thorough investigations with the need to respect the dignity and privacy of the deceased and the deceased's family. It is also important to prevent on-lookers from viewing the deceased whenever possible and to restore the flow of traffic as soon as possible

The Washington State Patrol, Washington State Department of Transportation, and Thurston County Coroner recognize there are times when extrication of deceased victims trapped inside vehicles is best accomplished at another location out of public view. In these cases, transporting the vehicle to another location maintains the privacy and dignity of the victim and the victim's family, provides a safer environment for Fire/EMS responders to perform the extrication and expedites reopening the roadway.

THEREFORE: When off-site extrication of remains is a possibility, we have agreed to the following guidelines:

1. Law enforcement has jurisdiction over the scene. The coroner has jurisdiction over the deceased. The decision to remove a vehicle with a deceased inside for off-site extrication will be a mutual decision between the incident commander(s) and coroner/deputy coroner at the scene.

2. If the vehicle is to be removed, WSDOT Incident Response personnel will securely tarp the vehicle to ensure the human remains are not visible and that no evidence and/or property is lost during transport.

3. The vehicle will be transported on a flatbed transport vehicle to a mutually agreeable facility out of public view for extrication.

4. During transport, the deputy coroner (and other investigating officer(s) if appropriate) will follow the transporting vehicle to the off-site facility to preserve the chain-of-evidence.

5. After the deceased has been removed from the vehicle, the investigating law enforcement agency will assume control of the vehicle for evidentiary and disposition purposes.

Chief John R. Batiste, Washington State Patrol

Judy Arnold, Thurston County Coroner

Secretary Douglas B. MacDonald, Department of Transportation

Figure 6.5 WA Memoradum on Guidelines for Off-Site Removal of Deceased Persons at Collisions ***(Source:*** **http://www.i95coalition.org/i95/Portals/0/Public_Files/uploaded/Incident-toolkit/documents/MOU/MOU_Coroner_WA.pdf*)***

The State of Georgia Open Roads Policy contains language similar to that in Washington with regard to off-site removal:

> ***State of Georgia Open Roads Policy***
>
> *Once the police investigator has completed taking photos of the deceased person(s) and the incident scene, the Office of Medical Examiner agrees to the movement of deceased person(s) from the travel lanes. The movement of deceased persons may include ejected deceased persons and vehicles containing deceased persons to the shoulder of the roadway, to off ramps, accident investigation sites, or other safe areas off the travel lanes for completion of investigation to reduce the delays and secondary crashes associated with motorists slowing to view the incident scene.*

The implementation of traffic fatality certification laws in South Carolina is another response mechanism that could provide significant reductions in clearance time. Currently in South Carolina, state legislation allows removal of a deceased body from a fatal crash scene only after a formal investigation and authorization by a coroner, deputy coroner, medical examiner, or deputy medical examiner. In terms of response, there are limited individuals in any county that are allowed to investigate and authorize fatalities. Considering that the deceased cannot be disturbed until after an investigation has been conducted, significant delays can accrue for vehicle clearance, clean-up, and resuming traffic flow on affected lanes. While the coroner is concerned with establishing the manner and cause of death in all unknown-cause deaths, the precipitating events leading to most motor vehicle crash fatalities can easily be documented. Quick clearance objectives can be handled by allowing temporary removal of the deceased from the highway, and/or certification of the fatality by someone other than the coroner. Options may allow for certification of a fatality by a predesignated responding agency, or certification through remote communication with the coroner.

6.4 CRASH INVESTIGATION

In 1995, the South Carolina Department of Public Safety and Highway Patrol established a special unit, the Multidisciplinary Accident Investigation Team (MAIT), to conduct in-depth investigations of traffic collisions involving complex circumstances such as fatalities, felony cases, etc. MAIT consists of three teams of highly trained state Troopers who have specific skills in accident reconstruction, traffic engineering, and automotive engineering. The overall objective of in-depth MAIT investigations is to determine the collision events which are significant in collision or injury production. Investigations may also determine if any laws were violated which caused or contributed to the collision. While much of the investigation is typically conducted in the field at the time of the incident, some parts may be conducted after the fact. Most of the data collected at the scene is required to reconstruct the crash through speed calculations; determination of pre-impact, post-impact and at-impact locations; vehicle crush measurement and energy calculation; time, distance, and acceleration calculations; and crash simulation and scale drawings. At-scene data typically include:

- Crash data retrieval - data from air bag deployment system
- Collision and crime scene documentation by Total Station Survey System

- Forensics - processing for trace evidence (e.g. Hair, blood, paint, tissue, fingerprints, shoe imprints, tire imprints), and forensic mapping
- Vehicle inspections including brakes, steering suspension, acceleration, lamp exams, tire exams
- Photos and Video of scene including microscopic photos of safety belts and other examined components
- Environmental conditions (e.g., weather, signing, marking, lighting)
- Location of occupants during and after collision

The South Carolina Department of Public Safety's MAIT has two levels of response – immediate and deferred. Immediate response occurs for the following collision types:

- All collisions that will result in a General Session Charge
- All non-departmental police pursuit collisions resulting in a fatality or life threatening* injuries
- All hit and run collisions resulting in a fatality or life threatening* injuries

Note that life threatening injuries are injuries sustained which have a high probability to result in death (i.e., subject 'coded' on scene or 'coded' en route to the medical facility). Deferred response occurs the next available business day, barring exigent circumstances. Deferred response is likely to occur where the contributing party survives, also most magistrate level charges are deferred. It is also possible that a General Session charge may be made and result in MAIT reconstruction. Finally, if MAIT is notified of an immediate response after the scene is cleared, then it reverts to the deferred response category. For all MAIT CORE 5 collisions, a MAIT supervisor must be on scene at the level of Corporal or above. These five collision types include:

- Hit and run with death
- Felony DUI w/death (involving non-occupants of the at fault vehicle)
- Police chase with death
- Police Officer death
- High profile cases with a large amount of media attention

Noting the complexity of these types of incidents, MAIT investigations are associated with the lengthiest incident durations. Depending on the complexity of the collision scene, MAIT investigations can last between two to eight hours at-scene. This estimate does not include the time that Troopers are at-scene before the decision to call MAIT is made. Typically, the decision to call MAIT is made between one to one and a half hour after the first Trooper has arrived on scene. This delay takes into account the initial Trooper's arrival and assessment, a First line supervisor's arrival and assessment, and the routing of the request. A study of MAIT investigations by SCDPS was ongoing at the time of publication and may provide more detailed assessment on-scene times for future evaluations.

A significant reduction in clearance time could be achieved by cutting the time to collect data in the field. **In most MAIT investigations, the location of vehicles and evidence at the scene are typically collected using traditional total station survey equipment and followed by on-scene photography. Total station surveys often require multiple personnel to man the electronic theodolite and distance measurement device, and an assistant to hold the reflector at the location of the item of interest. While advancements have been made to allow operators remote control of the instrument with robotic total stations, the number of points collected directly impacts the time required in the field. While each and every MAIT investigation is different, current operations with the total station typically require two officers to collect 500-1000 points. During measurement of the scene, no other**

investigative activities can be conducted during the data collection. Further, total station operation requires personnel to move around the crash scene and potentially places the operator in hazardous areas.

In 1992, Jacobsen et al. conducted a study to determine the time savings associated with transitioning from coordinate measurements using tapes to collecting measurements with a total station. At the time, the researchers boasted a 70% reduction in data collection time with a new output of roughly 50 points per hour. With continued improvements in technology, a number of alternative technologies have been introduced in the last decade that can achieve much shorter at-scene investigation times, including both 3D LIDAR scanning and drone cameras. Once again, these new technologies allow crash scene measurements to be completed in a fraction of the time of total stations, with exponentially more data collected. For instance, Figures 6.6 and 6.7 provide visual examples of the magnitude of difference in the quantity and quality of the data from total station and 3D laser scanning. In the total station representation, it is impossible to know what you are looking at much less discern the lighting illumination patterns that are clearly viewed in the LIDAR representation. Both 3D LIDAR scanning and drone cameras will be reviewed in the following sections. These technologies have potential to significantly reduce time at the scene, but each have their own pros and cons regarding environmental operating conditions and the perspective with which the scene is observed.

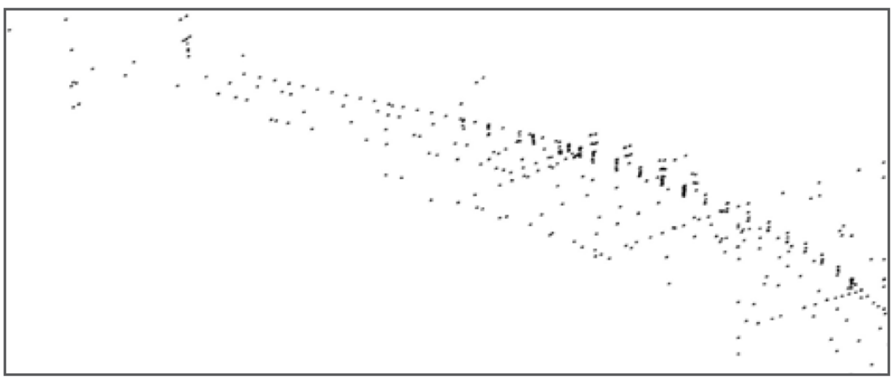


Figure 6.6 Total station point cloud of incident scene on bridge section

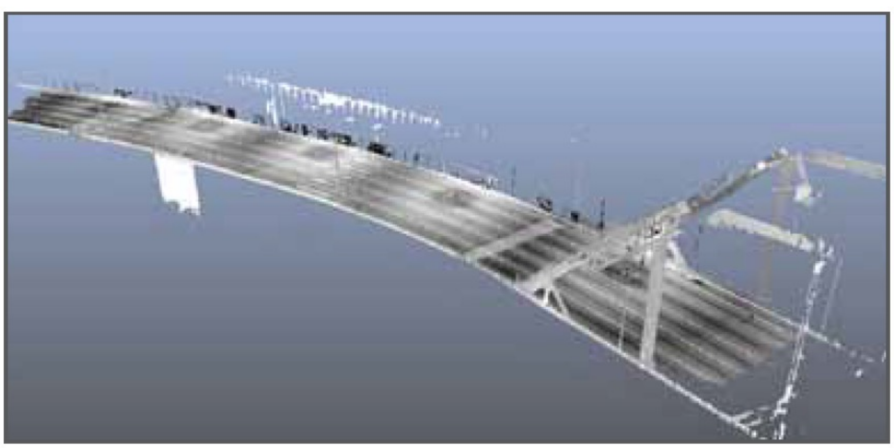


Figure 6.7 3D Laser scan point cloud of incident scene on bridge section

6.4.1 3D LIDAR SCANNING

LIDAR is a surveying method that measures distance to a target by illuminating that target with a pulsed laser light, and measuring the reflected pulses with a sensor. Differences in laser return times and wavelengths can then be used to make digital representations of the target, often referred to as point clouds. For instance, the Leica ScanStation C10 will collect 3.7 million points in under two minutes to provide a 360-degree field of view of an incident scene in low resolution. These devices are also capable of collecting at a rate of roughly 100,000 points per second in high resolution, but the capture time increases to roughly 15 minutes. Figures 6.8 and 6.9 show a typical setup of the scanning system. The LIDAR is located with a view of a courtyard with a central tree providing canopy to multiple buildings. Three targets are located around the courtyard to allow the scanner to be moved around the tree to obtain views from all angles.

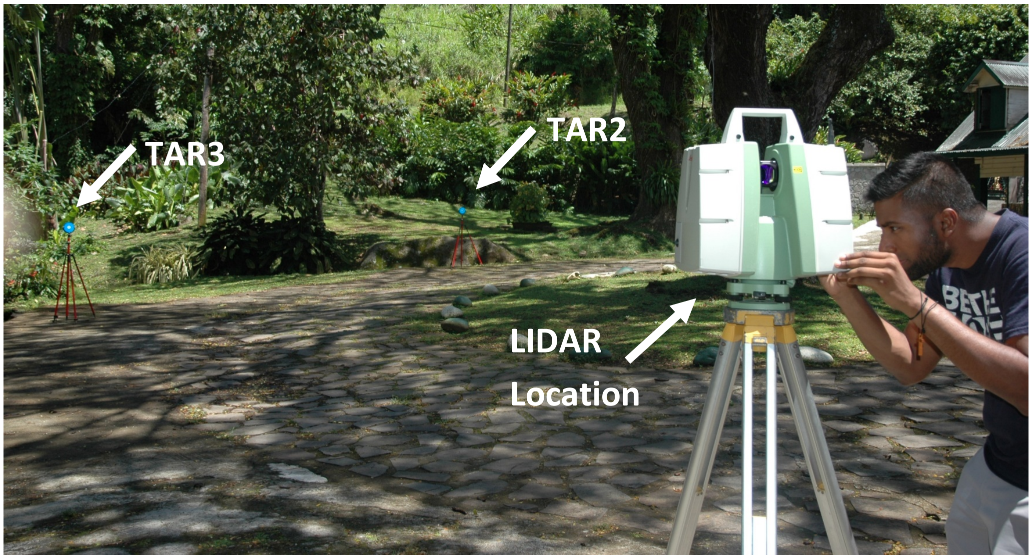


Figure 6.8 Typical Leica ScanStation C10 Setup with targets used to stitch scans together

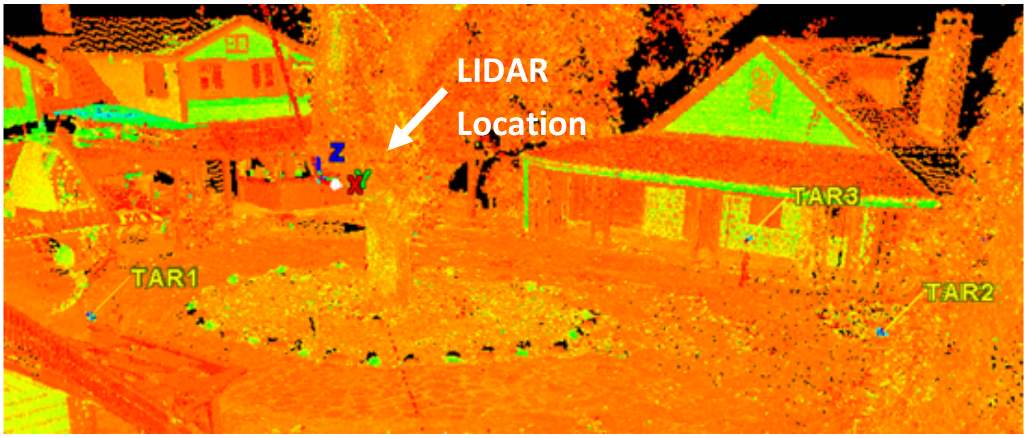


Figure 6.9 3D LIDAR Scan of Courtyard showing XYZ axis of LIDAR scanner and target locations

In addition to the sheer magnitude of data that can be collected in relatively short time periods, the 3D laser scanners have a number of other benefits. In many cases, the equipment can be set up to capture data without full lane closures, thus reducing congestion and the risk of secondary accidents. The device can be operated with a single user, which limits the number of people that must be on the scene. There is no need to touch the measured object, which in some cases is not possible or desirable. The device can collect data in darkness or direct sunlight, where photographs will be of little benefit. The data set will allow measurement of vehicle deformation and calculation of sight distance. In fact, the dataset contains the full scene, so measurements that were not initially deemed important are preserved to allow unlimited observations and measurements. The system captures all measurements and therefore typical terrestrial measurements are not required. Given that the new laser scanners are automated, once the system is set up, the MAIT investigators would be free to collect tire pressures and lamp evaluations, forensic evidence, data from the event recorder, occupant kinematics, and VIN numbers among other items.

In 2006, the Humberside Police in England tested 3D laser scanning in accident investigations. John Rusted, a collision investigator for over 26 years, indicated that the scanning technology and associated software bring a new level of clarity, detail, and accuracy to investigative reconstructions. He was quoted as stating,

> *"Using this technology it is possible to capture the whole environment of the incident as it was, in a matter of minutes… The scanner doesn't tire, doesn't feel stress and is saving time and man hours for those attending the scene… Laser scanning automatically picks up detail which is time consuming to map, such as debris, tyre marking and white lines, recording with pin point accuracy, a 360-degree environment even in adverse conditions. It captures the position of small components and the slightest marks and gouges in the surface of the road – automatically. Often the significance of the data isn't realized until the post incident software processes the data and creates a 3D representation. Areas of dampness on the road and even faintly painted road markings will be recorded. Traditional surveying methods wouldn't pick up these subtleties and it is this minute detail which gives a complete picture of the scene and the ability to view it comprehensively from any point."*

Pagounis et. al. (2006) conducted numerous crash reconstruction tasks with 3D laser scanning to showcase the power of the technology. The following categories of information were tested and resulting figures shown:

- Sight Distance – Drivers approaching or departing intersections should have unobstructed views of the intersection, including traffic control devices, and sufficient lengths of the intersecting roadway to avoid potential collisions. The 3D models allow the available sight distance triangles to be measured precisely (see Figure 6.10).
- Rapid Prototyping – Laser scanning delivers a level of surface mapping that is not practically possible with standard total station equipment. This data can be used to generate rapid prototype models of accident involved vehicles for use in finite element analysis and other software packages (see Figure 6.11).
- Scene Diagramming – Typically, using total station equipment, multiple elements in the environment must be measured to allow the development of roadway geometry, markings, and other environmental elements. With 3D laser scanning, the analyst is essentially extracting pertinent details from a complete

point cloud of the scene. Measurements of signs, locations of vehicles, roadway markings, etc. are easily deducted (see Figure 6.12).

Figure 6.10 Examples of sight distance restrictions and information extraction from 3D model

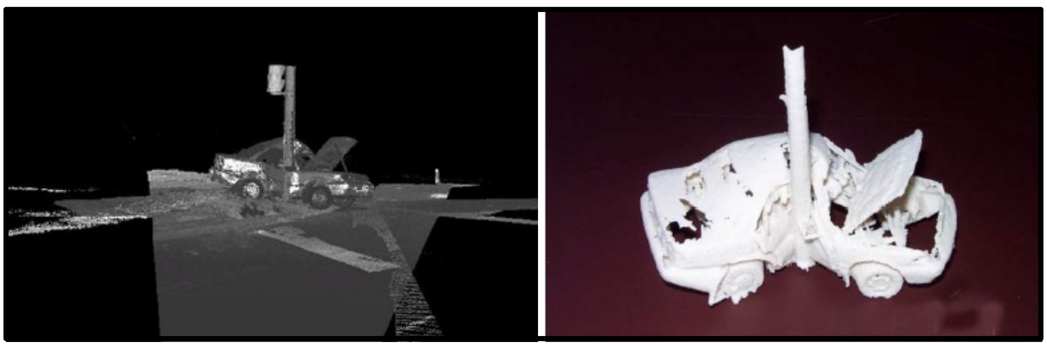


Figure 6.11 3D Laser scan (left) and resulting rapid prototype model (right)

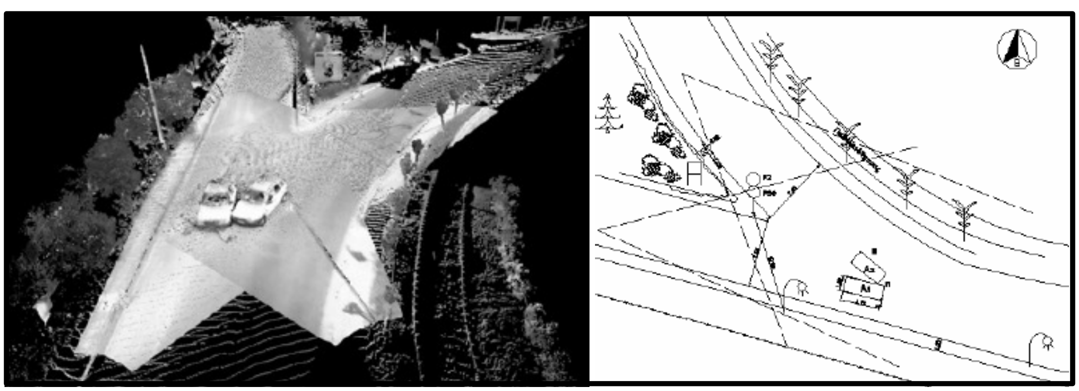


Figure 6.12 Laser scan capture of two-car scene and deducted scene diagram

Laser scanners have absolute point accuracy less than 10mm, fast (100,000 points/sec) and high density data, simple data acquisition, ranges up to 1000m, 360° field of view, and can be combined with other devices, such as GPS and cameras. 3D LIDAR scanning can be conducted with operators moving in the scene although ghost images will be created. LIDAR can be used in dark conditions, without the collection of simultaneous photography. Wind and rain do not adversely affect data collection, though the scans will depict scattered points from rain droplets which will need to be cleaned from scenes during post processing. Drawbacks to this technology are bulky equipment, moderate expense, and the technical knowledge and data processing required for operation. The FARO Focus 3D Scanner, targets, tripod, power block battery, dock, charger, and training cost about $60,000. The Focus scanner includes FARO's proprietary software called SCENE, but the scan data can also be imported in to other 3rd party software programs, including AutoCAD and Microstation. Reported reductions in time for scene measurement were found to be more than 75%.

The National Institute of Justice released an overview report, Technical Advances in the Visual Documentation of Crime Scenes, in 2013 that provided information on the relative costs, time and data storage requirements, as well as the challenges and benefits of both 2D and 3D panoramic imaging technologies available in the market. Figures Figure 6.13 Costs and array of NIJ test equipment (as of June 2013)6.12, Figure 6.15 Overview of Findings from NIJ Panoramic Imaging Evaluation (Part 2)and 6.14 document these aspects in summary form. The time and data requirements shown in the summaries are comparable, but could be more involved than necessary for a typical collision scene. Note that indoor scanning is not applicable to motor vehicles crashes. Further, the costs identified in the figure are 2013 values and the costs have dropped dramatically. In some cases, the costs are nearly half what is shown in the diagram.

The scans using the Leica ScanStation C10 were conducted in high resolution, which is not required for crash scene documentation, and increased the individual scan time from two minutes to 15 minutes. Clemson University has recently received a Leica ScanStation C10 donation, and after only a half-day training session, researchers were able to produce detailed scans of complex areas in the field. The equipment setup takes approximately 15 minutes, target scanning takes another 10 minutes, a mid-resolution 360-degree scan takes nine minutes with photo capture, and roughly ten minutes to tear down equipment. A two car scene is estimated to require 3 scans to acquire all involved sides of both vehicles, and thus the total scan time (including set up and tear down) is estimated at under one and a half hours with a single operator. During each of the nine minute scans, the operator is free to move around and collect additional data elements.

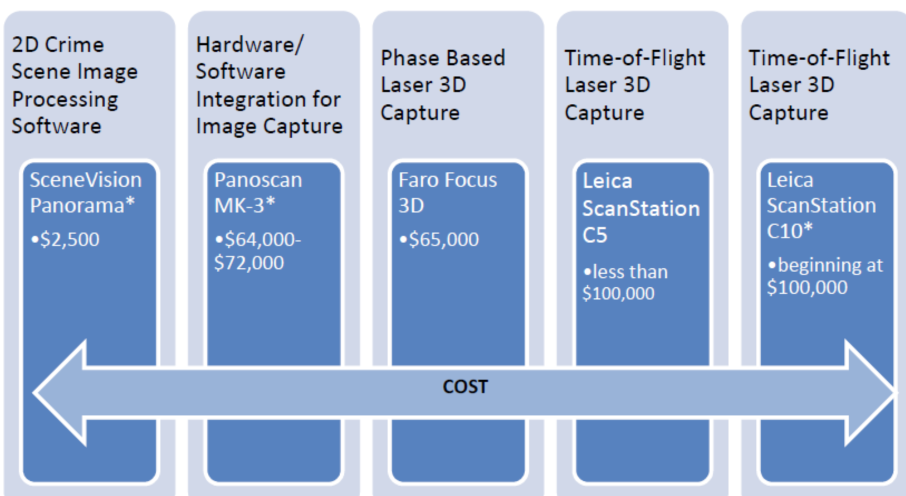


Figure note: Costs were approximated as of June 2013. Technologies listed in each category are examples of products in the category, and the (*) indicates a technology selected for FTCoE evaluation.

Figure 6.13 Costs and array of NIJ test equipment (as of June 2013)

General	SceneVision-Panorama	Panoscan	Leica ScanStation C10
Hardware/equipment	Panoramic head	Tripod, scan unit, lenses, computer, batteries, accessories	Tripod, scan unit, targets, computer, batteries, accessories
Transport	Small addition to traditional photo kit	Large hard-side case, soft carry case	Multiple large hard-side cases
Personnel requirements	1	1–2	1–3
Third-party support	Panoramic heads, stitching software	Image processing software	No
CALIBRATION/CAPTURE			
Setup time	3 minutes	10 minutes	10–15 minutes
Calibration	One-time, 10-minute setup	N/A	NIST calibration during target acquisition, approximately 5 minutes
Time on indoor site	135 minutes*	155 minutes*	225 minutes**
Time on outdoor site	90 minutes*	125 minutes*	125 minutes**
Scans (indoor)	Two scans, average of 1 minute each	Two scans, average of 6 minutes each	Nine scans, average of 25 minutes each
Scans (outdoor)	Two scans, average of 1 minute each	Two scans, average of 4 minutes each	Five scans, average of 25 minutes each
INTERFERENCES			
Weather	No known issues outside of normal camera operation	No known issues outside of normal camera operation	May need environmental case for freezing weather
Low light	Challenging to develop an evenly lit panorama	Longer scan time without lighting kit	Camera functions affected, measurement capabilities unaffected
Movement	Generates blurring	Generates blurring	Generates ghost images
Skies	Featureless skies can result in challenging stitching	Glare, hot spotting	Bright skies can result in uneven exposure
Reflections	Equipment may be in scan	Equipment may be in scan	Reflective surfaces may appear dark/blacked out
Featureless surfaces	May be necessary to include known reference point	May be necessary to include known reference point	No known issues

*includes measuring evidence with conventional tape measure; ** measurements were made by the ScanStation

Figure 6.14 Overview of Findings from NIJ Panoramic Imaging Evaluation (Part 1)

General	SceneVision-Panorama	Panoscan	Leica ScanStation C10
SOFTWARE			
Processing time	5 hours total***	5 hours total	4 hours
Preparation	Stitching images into panorama, hotlinking still photography and overall sketches	Hotlinking still photography, developing Total Station measurement diagrams	Evidence selected to show measurements, assembling virtual tour
File size (Raw + distributable)	0.638 GB	2.85 GB	6.63 GB
Final product	Panoramic images with links to still photography, animated virtual tour using panoramas and stills	Panoramic image with links to still photography	3D virtual tour capable of some interactive measurements and links to still photography

*** processing did not include developing diagrams from hand-measurements.

Figure 6.15 Overview of Findings from NIJ Panoramic Imaging Evaluation (Part 2)

	SceneVision-Panorama	Panoscan MK-3	Leica ScanStation C10
Strengths	• Cost-effective • Single agent operation possible • Crime scene units will already have most of the hardware • No special transport considerations • Easy to learn and use • Fast to deploy on scene • Third-party stitching software can be used	• Data collection is "push button" • Single agent operation possible • Images are produced quickly on scene with minimal processing • Excellent photo quality • Few transport considerations • Third-party software can be used • No stitching is required	• Measures large areas much faster than manually • Data-rich scene capture; millions of points measured • Unit can make measurements even when ambient light is too low for photography • Unit is weather resistant • Every element in the scene is measured • Removes operator bias from measurement
Weaknesses	• No automation • Operator must have strong basis of photography theory and photo composition • Scan times can take longer in low-light conditions because of photography requirements • Non-descript rooms or featureless open areas are difficult to stitch • Especially large scene files can tax older computers	• Auxiliary light sources must rotate around the camera or they will appear as a starburst • Light source is sold separately, but is needed for low-light environments • Uneven lighting at scene requires additional software processing • Panometric photogrammetry system is inaccurate outside of 25 feet (not evaluated for this report) • Training is separate from purchase • High-resolution pictures can tax older computers	• Slower than manually measuring for tight and small scenes • Comprehensive measurement times are greatly increased by clutter/debris/obstructions • Must have clear line of sight to document elements in scene • Requires training commitment • Not user friendly • Equipment is bulky and requires transport considerations • Large file size • Computer knowledge is a requirement to use and perform backend processing

Figure 6.16 Strengths and Weaknesses of Panoramic Imaging from NIJ Report

6.4.2 DRONE CAMERAS

An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without a human pilot aboard. While they originated mostly in military applications, their use has been rapidly expanding to commercial, scientific, and recreational applications, such as accident reconstruction, emergency surveillance, aerial photography, etc. Camera drones have either fixed wing or rotary wing operation (See Figure 6.15), and rotary configurations can have up to eight arms which increases the cost, stability, weight, and payload potential. Rotary wing operations are typically the choice for crash scene investigation because they are easier to fly, especially when it comes to take-off and landing, and provide a unique hover ability for taking aerial images. Less pilot skill is needed for these aircraft, especially with GPS plotted flights, which allow for autonomous photogrammetry surveys. Fixed wing drones require greater skill to fly, and very good spatial awareness. But they also have advantages, fixed wing drones allow for greater distances to be flown because the aerofoil design allows glide possibilities, thus reducing the power and weight requirements. These systems start at a $2,000-$3,000 and extend upward of $100,000 as requirements for autonomous flight, precise locationing, increased payload, and accurate digital orthophotography are added. Regardless of operation type, drones will be limited when vehicles crash into trees due to the cover of the tree canopy. While the approach path and skids may be observed from overhead, the final resting place and vehicle crush details may not be observable due to tree cover.

Figure 6.17 Fixed wing UAV (left) and Rotary wing UAV (right), both with cameras
(Sources: http://dronesarefun.com/WorldOfDrones/skywalker.jpg, and https://en.wikipedia.org/wiki/Unmanned_aerial_vehicle)

Nex and Remondino (2014) assembled a comparison table (Table 6.2) for fixed and rotary wing drones as compared to simple kite/balloon operations. Their assessment used literature reviews and personal experiences to provide ratings from low (1) to high (5) for the included criteria: payload, wind resistance, minimum speed, flying autonomy, portability, and landing distance. As shown in the table, rotary wing devices have limitations related to payload, wind resistance, and flying autonomy, but minimum speed is good for hover and aerial photography and limited space is needed for landing. Portability is average and is dependent on the design of the system.

Table 6.2 Evaluation of drone platforms for geomatic applications (1=low and 5=high, Source: Nex and Remondino (2014))

	Kite/balloon	Fixed wing		Rotary wings	
		Electric	ICE engine	Electric	ICE engine
Payload	3	3	4	2	4
Wind resistance	4	2	3	2	4
Minimum speed	4	2	2	4	4
Flying autonomy	–	3	5	2	4
Portability	3	2	2	3	3
Landing distance	4	3	2	4	4

Nex and Remondino (2014) defined the workflow for drone camera operations. A typical image-based aerial surveying drone platform requires a flight or mission planning and ground control points (GCPs) measurement for geo-referencing purposes. After the acquisitions, images can be used for stitching and mosaicing purposes, or they can be the input of the photogrammetric process. In this case, camera calibration and image triangulation must also be performed, to generate successively a DSM or digital terrain model. These products can be used to develop digital orthoimagery, 3D modeling applications, or simply for the extraction of measurements from the scene. The general workflow for drone cameras is shown in Figure 6.18. The input parameters are in green, while the single workflow steps are in yellow. Note that simple measurements may be taken from the product of image stitching/mosaic. However, detailed digital photogrammetry would be typical of information needed for court cases and requires camera calibration and the collection of ground control points.

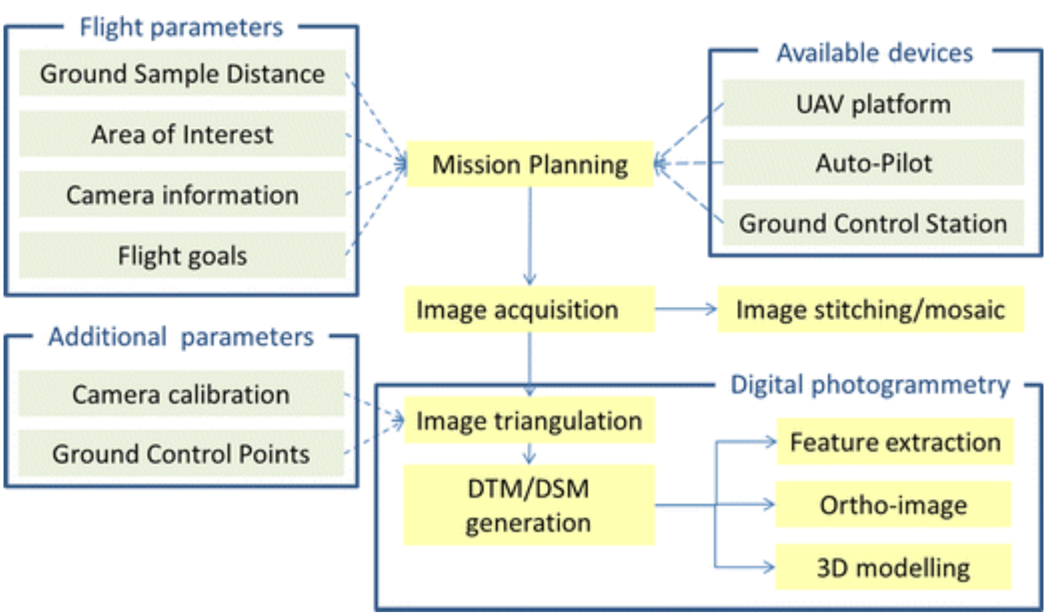


Figure 6.18 Drone camera setup and workflow

Figure 6.19 provides an example of a typical flight plan as prepared prior to image capture to determine the path of flight and required image capture locations. The green square defines the area of interest, and the white line represents the flight path. Figure 6.20 shows an example of stitched photography and measurements that can be captured from the remotely collected data. The derived high-resolution images (GSD generally in the centimeter level) can be used, beside very dense point cloud generation, for texture mapping purposes on existing 3D data, for orthophoto production, map and drawing generation, or 3D building modeling. When compared to traditional airborne platforms, UAVs decrease the operational costs and reduce the risk of access in harsh environments, still keeping high accuracy potential. But the small or medium format cameras which are generally employed, in particular on low-cost and small payload systems, enforce the acquisition of a higher number of images in order to achieve the same image coverage at a comparable resolution. In these conditions, automated and reliable orientation software are recommended to reduce the processing time.

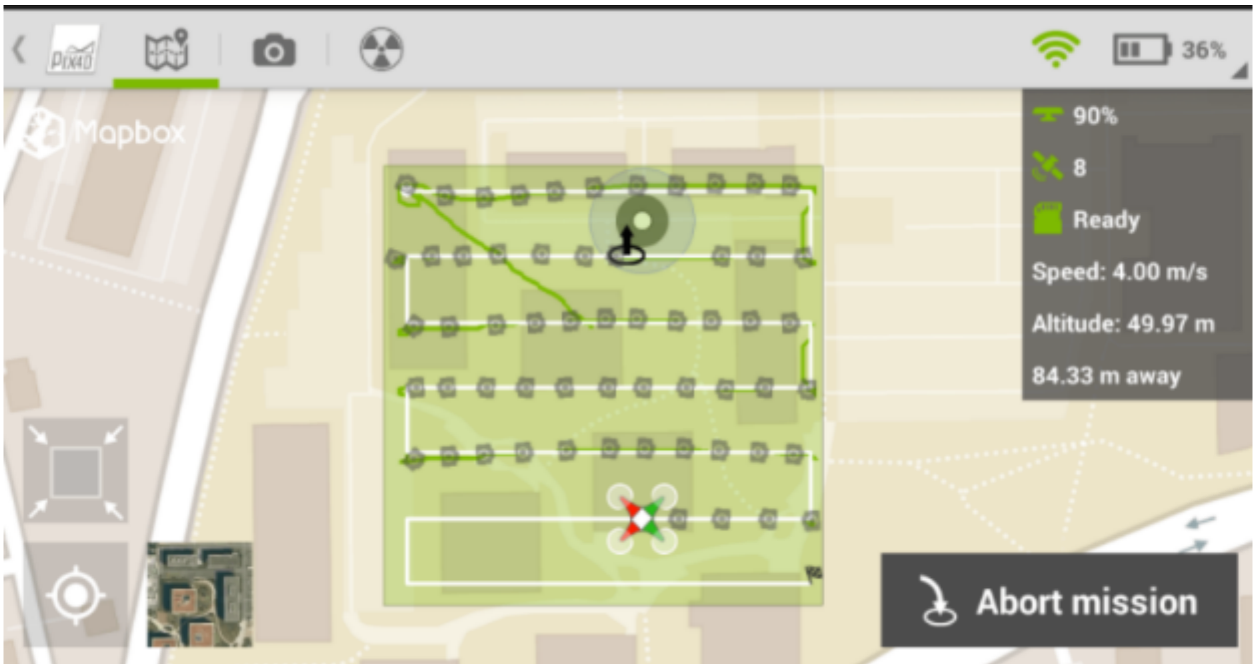


Figure 6.19 Pix4D Flight Plan App

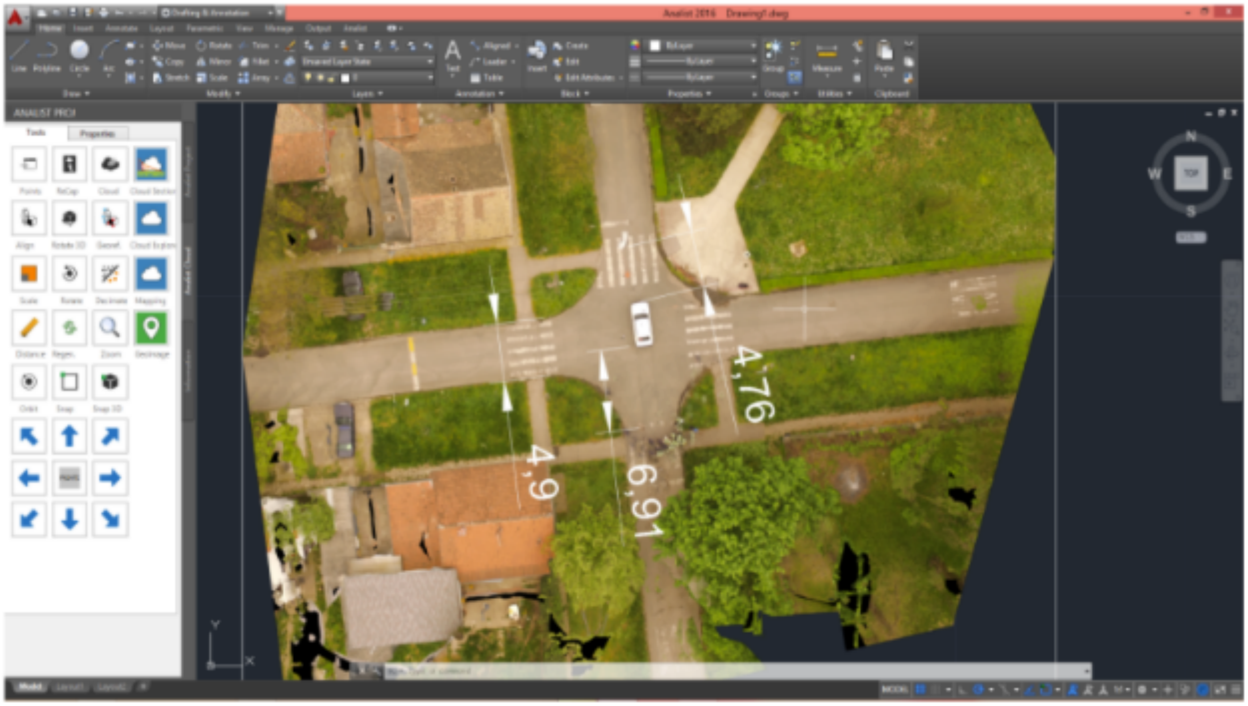


Figure 6.20 Pix4D aerial image-based measurements

There are a number of UAV regulations that have been put into place, though these have recently been brought under question. From 21 December 2015, all hobby type UAV's between 0.55 and 55 pounds needed to be registered with FAA no later than 19 February 2016. The FAA UAV registration process includes requirements for:

- Eligible owners must register their UAV's prior to flight
- If the owner is less than 13 years old, a parent or other responsible person must do the FAA registration
- UAV's must be marked with the FAA-issued registration number
- The registration fee is $5. The registration is good for 3 years and can be renewed for an additional 3 years at the $5 rate
- A single registration applies to all UAVs owned by an individual. Failure to register can result in civil penalties of up to $27,500 and criminal penalties of up to $250,000 and/or imprisonment for up to three years

On 21 June 2016, the Federal Aviation Administration announced regulations for commercial operation of small UAS craft between 0.55 and 55 pounds including payload. The rules, which exclude hobbyists, require the presence at all operations of a licensed Remote Pilot in Command. Certification of this position is obtained solely by passing a written test and then submitting an application. All licensees are required to take a review course every two years. Commercial operation is restricted to daylight, line-of-sight, under 100 mph, under 400 feet, and Class G airspace only, and may not fly over people or be operated from a moving vehicle. Waivers or Certificates of Authorization are available for commercial operations that exceed these rules. For example, waivers exist for drones modified for injury prevention to fly over people, and other waivers allow night flying with special lighting, or non-line-of-sight operations for agriculture or railroad track inspection. From a crash investigation standpoint, these regulations can impact drone use by limiting to daylight conditions (over half of fatalities occur during night time conditions) and less populated areas (a good portion of fatalities occur in dense urban areas).

6.4.3 SUMMARY OF LIDAR AND DRONES

The total station is currently the method used for crash investigation in the state of South Carolina. Advantages of this program include absolute point accuracy, inexpensive equipment, widely available scanning and image taking facilities, one-person operation, and long range capabilities. Total stations, however, have relatively slow operation (50 points/hour) and field of view resulting in an average investigation time of 60 minutes (15). The cost of a total station can range from $20,000 to $40,000, depending on the style. Through numerous stakeholder meetings, SC responders have expressed interest in moving from the use of total stations towards the use of LIDAR scanners and drone cameras.

3D LIDAR scanners have similar setup in reference to the total station, but once set up collect millions of points automatically to provide a 360-degree representation with a single operator. With a total station, the officer needs to be concerned about collecting all of the pertinent point measurements and ensuring personal safety, but with a 3D LIDAR scanner the main focus is associated with ensuring all perspective view angles have been captured. Once set up for data collection, the officer is free to collect data from the vehicle and surroundings knowing that all markings, gouges, and deformation within view will be captured by the scanner. The scanner can operate in dark conditions, during light rain, and in heavy wind. Responders and traffic operations can be resumed during operation. Equipment costs range from $40,000 to over $100,000 depending on selected capabilities, software, and storage options.

Drone cameras capture an aerial perspective of the crash site and have obvious benefits when the scene is very large (~one mile). They can also be operated by a single user, however during flight the operator must be able to take control of flight at all times. Minimal ground based measurements are required, and the operation time is relatively fast with most flights taking only a few minutes. However, the camera calibration, setup of the flight plan, and ground point controls can be as time consuming as operating the 3D LIDAR scanner. Further, the overhead perspective may necessitate crush measurements on the sides of vehicles as well as additional measurements under tree canopies. As mentioned earlier, other limitations include daylight operation and low wind conditions. Equipment costs can be as low as $2,000-$3,000 for basic imagery, and as much as $100,000 for high resolution, high accuracy digital orthophotography systems.

Adoption of these technologies can have a profound time-savings effect on scene clearance times, but one of the most important reasons for adoption can be personnel safety and improved operations. These technologies don't require personnel to enter hazardous areas of the scene during data collection, nor do they require traffic operations to be suspended during use. Despite the benefits, there are a number of considerations that must be made before an agency decides to purchase. A critical consideration is the agency's commitment to support the purchase long-term. Both technologies require special training and have steep learning curves, thus continued use of the systems is key to reducing clearance times in the field. Hardware and software maintenance contracts, and warranties are also a consideration in the costing of adoption. Once adopted, the agency will also need to devise a plan for data maintenance. Processing, sharing, and archiving will be intensive from a storage standpoint, and the data has to be treated like any other crime scene digital data. Finally, officers using these devices will need access to 'gaming' type computer resources as the size of the files and visualizations require far more computer RAM and speed than a typical computer has to offer.

7 SIMULATION FOR BENEFIT COST ANALYSIS

A travel demand model using 2013 Annual Average Daily Traffic Volumes was developed to simulate existing base conditions and proposed ICS strategies for three high-incident sections of the I-26 corridor between Columbia and Charleston. All three corridor sections were modeled using 60, 120, and 180-minute incident durations, which closely resemble the recovery time distributions for over 23,000 crash incidents of all severities on interstates in South Carolina. Based on successful results from other states where ICS strategies were adopted, implemented, and evaluated, incident duration reductions of 30, 25, and 20 percent were included in the model. However, these reductions are considered conservative in terms of potential reductions for major incidents such as those that would benefit from incentive based major incident towing, fatality certification laws, and new technologies for major accident investigation.

Results from these analytically robust simulations, using VISUM and VISSM, produced the following numerically quantifiable travel time benefits for the incident duration and corresponding ICS reduction scenarios:

Incident Duration (min)	ICS reduction Scenario	Delay (min/Veh)	% Reduction
60	Base Condition	128	
	20% incident reduction	81	37
	25% incident reduction	73	42
	30% incident reduction	60	53
120	Base Condition		
	20% incident reduction		
	25% incident reduction		
	30% incident reduction		
180	Base Condition		
	20% incident reduction		
	25% incident reduction		
	30% incident reduction		

Based on adoption of recommended ICS strategies for the I-26 corridor, considerable travel time savings would be accompanied by correlated beneficial reductions in fuel consumption and air emissions, which were also included in the model simulations.

To evaluate performance of ICS strategies, South Carolina's incident management contingency plan for the I-26 corridor, developed by the SC Emergency Management Division, was used as the basis for ICS strategy comparisons. Study site locations and alternate routes, based on South Carolina's contingency plan for hurricane evacuation, are illustrated (highlighted in yellow) in Figure 7.1. The first phase of the simulation analysis involved calibrating the simulated I-26 corridor in the traffic micro-simulation software VISSIM 5.40. In the second phase, ICS strategies were evaluated using the calibrated model, which included 91.5 miles of freeway with 19 interchanges on I-26 (as shown in Figure 7.1). The ICS strategies were then evaluated for three different incident durations (60, 120, and 180 minutes) along roadway segments 1, 2 and 3, identified in Figure 7.1. These specific roadway segments were selected based on previous records of highest incident occurrence locations for incident duration 60, 120, and 180 minutes, which were compiled from the Computer Aided Dispatch (CAD) database. Methods and procedures used to calibrate the I-26 simulated corridor are explained in detail in the following sections.

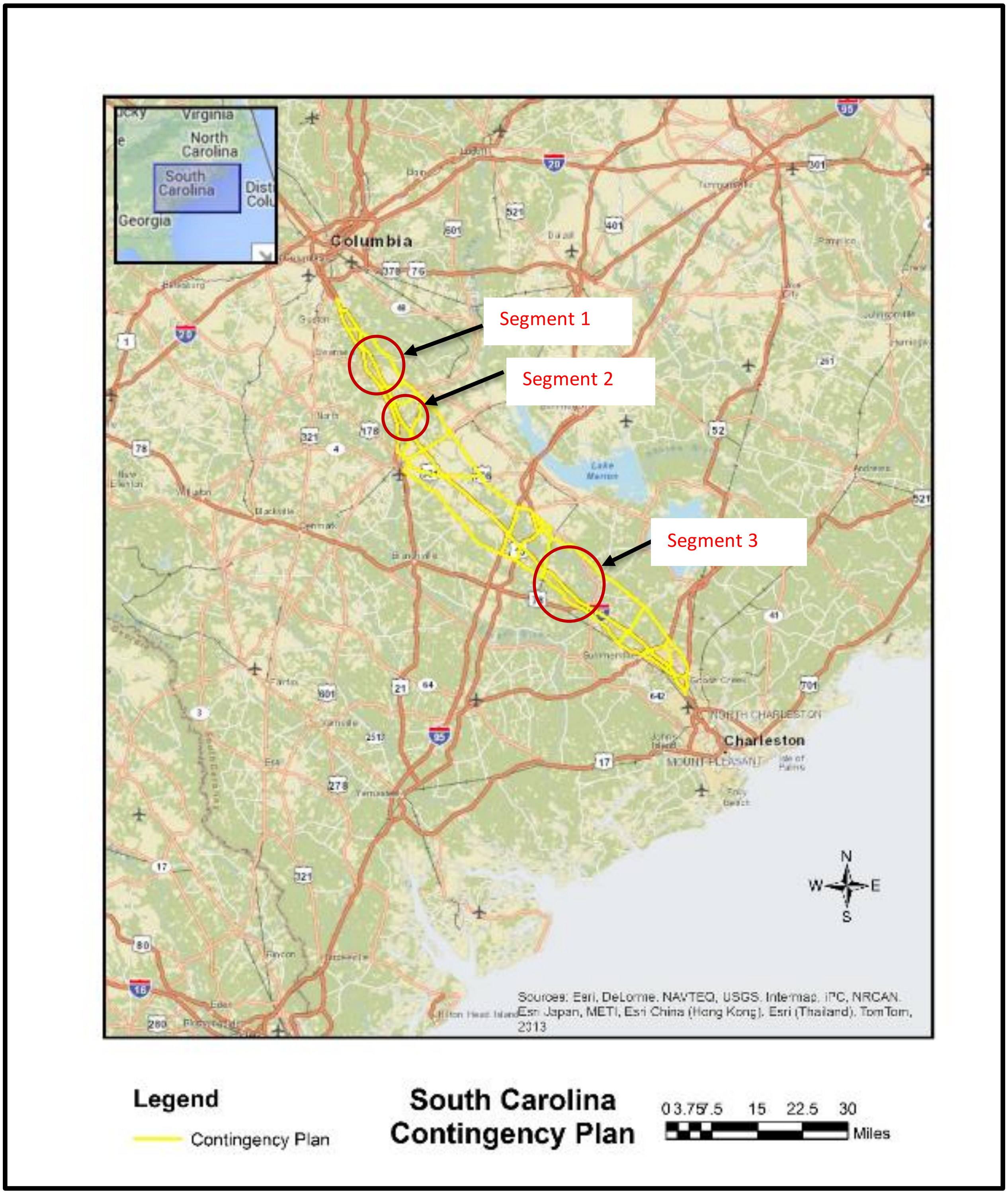


Figure 7.1 Study network: I-26 and alternate routes (highlighted in yellow)

7.1 TRAFFIC SIMULATION NETWORK DEVELOPMENT

As shown in Figure 7.2, the simulation tools VISUM (a macroscopic travel demand planning software) and VISSIM (a microscopic traffic simulator) developed by PTV (2) were used to develop a simulation model of the I-26 corridor. The GIS shape file obtained from the SCDOT GIS warehouse was imported to VISUM. Since the original shape file included all SCDOT maintained roadways, the road network was reduced to include only the I-26 corridor as shown in Figure 7.3. The satellite images of the road network and geometric data collected in the field were used to fine-tune the link attributes, and then the network was exported to VISSIM.

Traffic volume data was obtained from the SCDOT traffic count website (3). The obtained 2013 Annual Average Daily Traffic (AADT) was converted to Directional Design-Hour Volume (DDHV) for purposes of developing an origin-destination (O-D) matrix. Travel time data and volume data were collected for the I-26 corridor for calibration of the simulation models. The VISSIM network was simulated using the preliminary O-D matrix and volumes were checked against the field data at permanent traffic count stations as well as at selected locations in the network. The O-D matrix was then adjusted until the difference between the model volume and the actual volume at all locations were within ± 5%.

The next step in the simulation model development process involved using the Dynamic Traffic Assignment (DTA) feature of VISSIM to obtain turning volumes at each interchange and intersection. This approach was used because of the availability of several alternate routes for each set of origin and destination. Through this approach, the modeling process was repeated for several iterations to calibrate the simulated link counts within ±5% of the actual traffic count. The actual travel time and volume data collected for calibration was checked against the simulation output of each run.

The link cost, the speed distribution and the driver behavior parameters in VISSIM were adjusted in this iterative process to obtain a match between the model volumes and travel times and observed volumes and travel times. The roadway network was considered to be calibrated when the simulation model volumes and travel times were within the range of ±5%. The final DTA paths and cost files were then used to convert all dynamic routes into static routes. ICS strategies were then simulated at three different highest incident occurrence segments of the study routes with the static route assignment, which is discussed in Section 7.2.

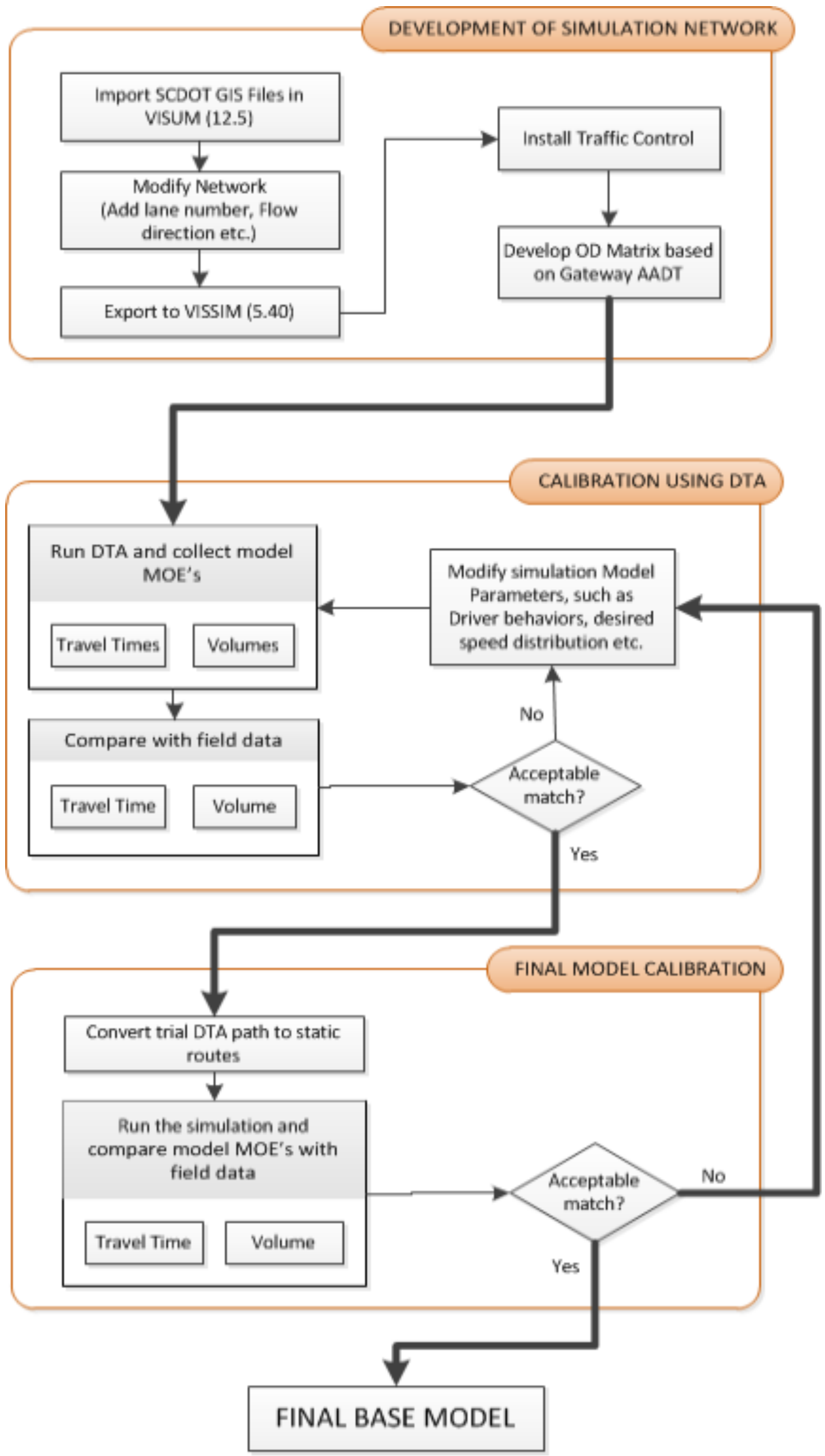


Figure 7.2 Simulation model development process

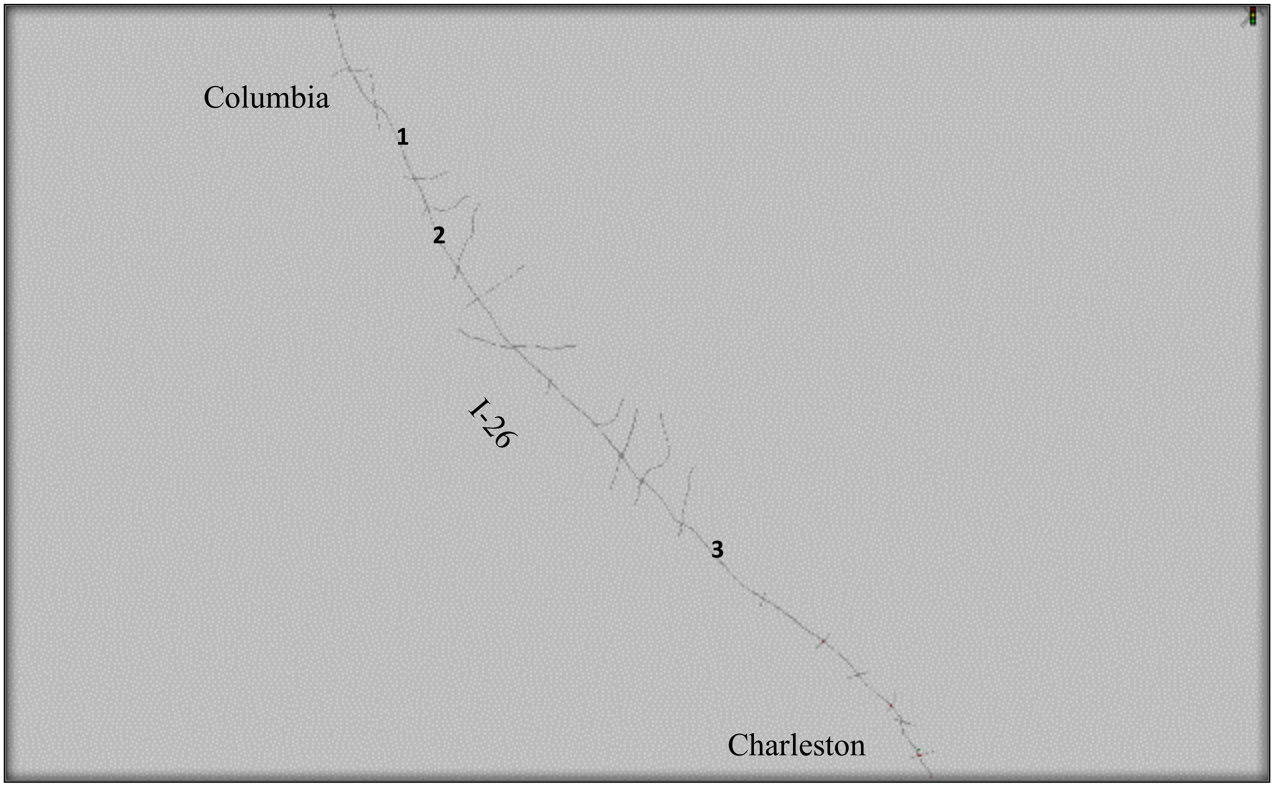


Figure 7.3 VISSIM simulated network

7.2 ICS STRATEGIES

The Federal Emergency Management Agency defines ICS as “a standardized on-scene incident management concept designed specifically to allow responders to adopt an integrated organizational structure equal to the complexity and demands of any single incident or multiple incidents without being hindered by jurisdictional boundaries” (4). A predefined Unified Command (UC) structure, which is derived from an Incident Action Plan (IAP), helps agencies achieve a set of common objectives: i) agency assignments, ii) incident priorities, assignment of agency objectives, iii) communications protocols, iv) knowledge of duties within agency responsibilities, and v) acquisition and allocation of materials and resources (5).

The Incident Commander (or the Unified Commander), who is a single individual, and leaders of multiple agencies must fulfill the five major ICS functions: i) command, ii) operations, iii) planning, iv) logistics, and v) finance and administration. Intelligence is gradually being adopted as a sixth function in response to the National Incident Management System (NIMS) guidelines for gathering, sharing, and managing an incident related information (4). The organizational functions and responsibilities are illustrated in Figure 4. These tasks can be either self-performed or delegated to others within a reasonable span of control. NIMS and ICS guidelines specify that the span of control ranges from three to seven people with an average of five people (6).

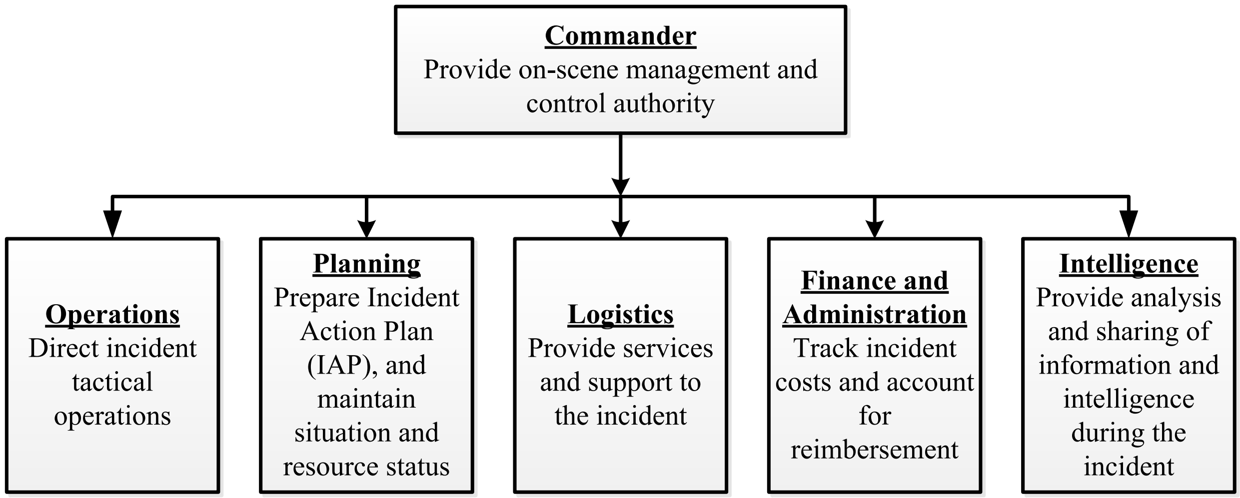


Figure 7.4 ICS organizational function and responsibilities (adopted from (7)).

In addition to a clear and defined chain of command, ICS emphasizes the necessity of common terminology to facilitate clear communication regardless of location. The NIMS outline requires the use of a common terminology when describing organizational functions, resource description and incident management facilities. Organizational functions define the major functions and functional units and standard organizational elements for consistency. The description of resources related to incident management includes: a) personnel, b) facilities, and c) major equipment and supply items. The concept of incident facilities involves the use of an integrated communication plan, interoperable communication protocols, and architecture to manage the incident during and after the occurrence. The integrated communication plan, which enhances the deployment of personnel and available resources only when they are needed at the scene, must be established prior to an incident and incorporated into the incident action plan.

To optimize resource allocation and mobilization among the different involved incident management agencies, a comprehensive resource management system is needed to support the execution of ICS strategies during any incident. The exact number of personnel, teams, equipment, supplies, and facilities and their readiness status must be maintained. Ensuring the accountability of each involved organization is an absolute necessity for ensuring the most efficient resource allocation and management in ICS. This criterion of accountability must be determined and reviewed at all stakeholder agency levels and in intra- stakeholder agency functional areas. It is then possible, upon achieving such accountability of both resources and chain of command, to properly manage both information and intelligence. This multi-step process entails collection, analysis, assessment, sharing, and management of incident-related information across agencies during and after the incident to allow benchmarking and process improvement. The ICS scenarios were developed based on total incident time reduction in national ICS programs (1, 8). The ICS strategies adopted for this study are provided in Table 1. The strategies are based on the Coordinated Highways Action Response Team (CHART) program developed in Maryland, which reported a 25% reduction in incident duration after the implementation of ICS (1, 8). Since the reduction of incidents varies from 23% to 28%, we selected the minimum and maximum expected reduction of incident durations of 20% and 30%, respectively. We assumed that the following ICS strategies, similar to the Maryland CHART strategies, will be implemented on the I-26 network.

We also assumed that the expected reduction of incident duration ranges from 20% to 30% with an average of 25% due to ICS strategies implementation.

Table 7.1 ICS strategies

ICS strategies	Expected reduction of incident duration
• Emergency Traffic Patrols to assist emergency motorists and to move disabled vehicles from the travel lanes. • Emergency Response Units to control overall traffic at the incident locations. • Freeway Incident Traffic Management Trailers (with traffic control tools) to quickly set-up alternate routes according to contingency plans if all roadway lanes are blocked because of incident. • An Information Exchange Network Clearinghouse to inform the information of incident and traveler across the responsible agencies along I-26.	*Minimum:* 20% reduction in total incident duration *Average:* 25% reduction in total incident duration *Maximum:* 30% reduction in total incident duration

7.3 INCIDENT SIMULATION

Incidents that blocked both lanes of I-26 WB were modeled in the final calibrated simulation model. The total incident times were set at 60, 120, and 180 minutes and the total simulation time was set at 240 minutes for all simulation scenarios.

7.4 ICS SIMULATION STRATEGIES

Three ICS simulation scenarios (as shown in Table 7.1) were designed to capture the impact of the ICS strategies. Figure 5 presents the considered ICS scenarios. The base scenario included existing traffic volume with 2 lanes blocked in a 60, 120, and 180-minute incidents. The left lane of the two-lane blocked incident was opened after 45, 90 and 135 minutes for the 60, 120, and 180-minute incidents, respectively. The incident duration was reduced by 20%, 25%, and 30% to represent the minimum, average and maximum reduction of the incident duration with the use of ICS strategies. The ICS simulation strategies are presented in detail in Figures 7.5(a), 7.5(b), and 7.5(c).

Base case with a 60-minute incident duration

- 2 lanes blocked for 45 minutes
- Inside lane blocked for 45 minutes
- Outside lane blocked for 60 minutes

ICS case with a 30% reduction of incident duration

- 2 lanes blocked for 31.5 minutes (30% reduction from base scenario)
- Inside lane blocked for 31.5 minutes (30% reduction from base scenario)
- Outside lane blocked for 42 minutes (30% reduction from base scenario)

ICS case with a 25% reduction of incident duration

- 2 lanes blocked for 33.75 minutes (25% reduction from base scenario)
- Inside lane blocked for 33.75 minutes (25% reduction from base scenario)
- Outside lane blocked for 45 minutes (25% reduction from base scenario)

ICS case with a 20% reduction of incident duration

- 2 lanes blocked for 36 minutes (20% reduction from base scenario)
- Inside lane blocked for 36 minutes (20% reduction from base scenario)
- Outside lane blocked for 48 minutes (20% reduction from base scenario)

(a) Incident duration of 60 minutes

Base case with a 120-minute incident duration

- 2 lanes blocked for 90 minutes
- Inside lane blocked for 90 minutes
- Outside lane blocked for 120 minutes

ICS case with a 30% reduction of incident duration

- 2 lanes blocked for 63 minutes (30% reduction from base scenario)
- Inside lane blocked for 63 minutes (30% reduction from base scenario)
- Outside lane blocked for 84 minutes (30% reduction from base scenario)

ICS case with a 25% reduction of incident duration

- 2 lanes blocked for 67.5 minutes (25% reduction from base scenario)
- Inside lane blocked for 67.5 minutes (25% reduction from base scenario)
- Outside lane blocked for 90 minutes (25% reduction from base scenario)

ICS case with a 20% reduction of incident duration

- 2 lanes blocked for 72 minutes (20% reduction from base scenario)
- Inside lane blocked for 72 minutes (20% reduction from base scenario)
- Outside lane blocked for 96 minutes (20% reduction from base scenario)

(b) Incident duration of 120 minutes

Base case with a 180-minute incident duration

- 2 lanes blocked for 135 minutes
- Inside lane blocked for 135 minutes
- Outside lane blocked for 180 minutes

ICS case with a 30% reduction of incident duration

- 2 lanes blocked for 94.5 minutes (30% reduction from base scenario)
- Inside lane blocked for 94.5 minutes (30% reduction from base scenario)
- Outside lane blocked for 126 minutes (30% reduction from base scenario)

ICS case with a 25% reduction of incident duration

- 2 lanes blocked for 104.25 minutes (25% reduction from base scenario)
- Inside lane blocked for 104.25 minutes (25% reduction from base scenario)
- Outside lane blocked for 135 minutes (25% reduction from base scenario)

ICS case with a 20% reduction of incident duration

- 2 lanes blocked for 108 minutes (20% reduction from base scenario)
- Inside lane blocked for 108 minutes (20% reduction from base scenario)
- Outside lane blocked for 144 minutes (20% reduction from base scenario)

(c) Incident duration of 180 minutes

Figure 7.5(a) ICS simulation scenarios for various incident durations

7.5 SIMULATION OUTCOMES AND DISCUSSION

The benefits were estimated based on the simulation outputs in which the base scenario (without ICS) was compared against scenarios with ICS. The cost was determined based on the implementation cost of the ICS strategies for the I-26 corridor in South Carolina. The reduction in travel time, fuel consumption, and pollution were considered as expected benefits with the implementation of ICS. The reduction in travel time, fuel consumption and emissions for roadway segment 3 are provided in Table 2(a), 2(b), and 2(c), respectively. The simulation output for roadway segment 3 of I-26 is provided as an example. The application of an ICS strategy resulted in 8%, 11%, and 12% reduction in fuel consumption, corresponding to a 20%, 25%, and 30% reduction in the total incident duration, respectively. The estimated benefits per incident (i.e., benefit for reduction in delay, fuel consumption, CO emissions, and NOx emissions) for the selected segments (i.e., 1, 2, and 3) on I-26 are presented in section 3.

Table 7.2 (a) Travel time savings per vehicle for a 60-minute incident on segment 3 of I-26

Simulation Scenarios	Delay (minutes/vehicle)	Reduction in Delay (minutes)	% of Delay Reduction
Base scenario	128	NA	NA
ICS scenario (20% Reduction)	81	47	37
ICS scenario (25% Reduction)	73	55	42
ICS scenario (30% Reduction)	60	68	53

TABLE 7.2(b) Reduction in fuel consumption for a 60-minute incident on segment 3 of I-26

Scenarios	Fuel Consumption (gallons)	Reduction in Fuel Consumption (gallons)	% Reduction in Fuel Consumption
Base scenario	208	NA	NA
ICS scenario (20% Reduction)	190	17	8
ICS scenario (25% Reduction)	184	23	11
ICS scenario (30% Reduction)	182	26	12

TABLE 7.2(c) Reduction in emissions for a 60-minute incident on segment 3 of I-26

Scenarios	CO Emission Reduction (grams)	NOx Emission Reduction (grams)
ICS scenario (20% Reduction)	1,238	240
ICS scenario (25% Reduction)	1,643	319
ICS scenario (30% Reduction)	1,832	356

8 BENEFIT-COST ANALYSIS

Benefit-cost analysis was conducted using quantified values for benefits and estimated costs, using 2014 dollars. Benefits were determined through incident simulations of 60, 120, and 180-minute durations along three high-incident sections of the I-26 corridor between Columbia and Charleston. Cost quantified benefits included travel time savings, reduction in fuel consumption, and reduction in air emissions. Annual incidents were determined from the SCDOT incident database. Estimated costs include ICS staff training and computer-aided dispatch communication facilities. Total annual costs were estimated to $221,302 per year assuming 30 representatives from each agency stakeholder participated in the training sessions. Resulting benefit-cost ratios were considerably large, ranging from 17:1 to 149:1 for combinations of three incident durations along three high incident section locations. In addition to these quantified benefits, improvements in incident verification and improved repose in tow truck arrival time would result from implementation of ICS strategies and serve to further reduce travel time delay. The following sections further explain the benefit-cost analysis for different ICS strategies in more detail by quantifying the benefits from simulation analysis and estimated costs for implementation of ICS strategies.

8.1 BENEFIT-COST ANALYSIS PROCEDURE

Three categories of benefits, delay, fuel consumption, and emissions are considered in this research. To estimate the expected savings, the research team used different simulation seed numbers to calculate the average benefits at each of the three study segments. The savings, in terms of vehicle delay, fuel consumption, and emissions from the implementation of ICS incident management strategies, were converted to the monetary savings per incident for each segment. The benefits were calculated using the selected measure of effectiveness as shown in Table 8.1. The costs of implementing ICS were divided into two categories: communication facilities procurement and ICS training cost. The cost of the ICS implementation is provided in Table 8.2. The procedure for determining the benefit to cost ratio is illustrated in Table 8.2.

Table 8.1 Measures of Effectiveness (MOE) for ICS benefits from the simulation

Category of MOE's	MOE	Simulation Output
Delay	Travel time savings	Delay for different simulation scenarios
Energy Consumption	Change in Fuel Consumption	Fuel Consumption
Air Pollution	CO	CO
	NO_x	NO_x

Table 8.2 ICS costs

Category of costs	ICS implementation costs
ICS training	Training on other agencies roles and responsibilities
	Training on concurrent execution of actions by several agencies
	Training on resource management
Communications facilities	Cost of communications facilities for incident area

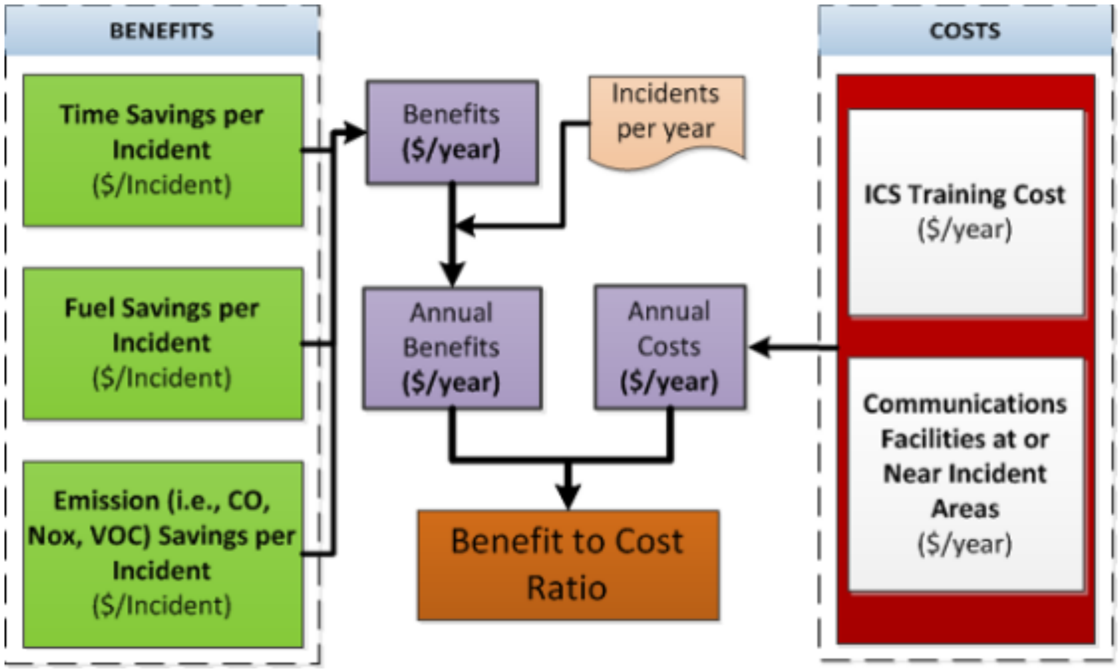


Figure 8.1 Benefit-cost estimation procedure

8.2 BENEFIT-COST ANALYSIS

The research team performed a benefit-cost analysis to evaluate the benefits of different ICS strategies over the implementation costs. The primary expenditures considered were the cost for the ICS training for the various stakeholder agency personnel, and the communication facilities required to support incident response through a computer-aided dispatch (CAD) system. The training costs were estimated by considering three days of training for 10, 20, or 30 attendees from each stakeholder agency, including one coordinator and three trainers (9). The research team considered five agencies to take part in ICS strategies implementation: Fire Department, Traffic Management Center, Towing Company, Emergency Management Division, and Fire and Rescue Management organization. It was assumed that two training sessions per year would be provided with a total annual cost of $50,000, $100,000, and $150,000 for 10, 20, or 30 attendees from each stakeholder agency, respectively (Table 5(a), 5(b), and 5(c)). The cost of communication facilities for a medium size area to support incident response for computer-aided dispatch was estimated to be $820,000 using data from the ITS cost database (10), and the equivalent annual cost for communication facilities in 2014 dollars was $71,302 (Table 5(a), 5(b), and 5(c)).

Table 8.3(a-c) Estimated annual cost for all roadway segments per number of attendees per stakeholder agency

(a) Estimated annual cost for all roadway segments for 10 attendees per stakeholder agency

Cost Categories	Cost /Attendees/year ($)	Number of Attendees/ Stakeholder Agency	Number of Stakeholder Agency	Number of Training/year	Total Cost/year ($)
ICS Training cost ($)	500	10	5	2	50,000
Communications logistics ($)	71,302	NA	NA	NA	71,302
Total Cost ($)					121,302

(b) Estimated annual cost for all roadway segments for 20 attendees per stakeholder agency

Cost Categories	Cost /Attendees/year ($)	Number of Attendees/ Stakeholder Agency	Number of Stakeholder Agency	Number of Training/year	Total Cost/year ($)
ICS Training cost	500	20	5	2	100,000
Communications logistics	71,302	NA	NA	NA	71,302
Total Cost ($)					171,302

(c) Estimated cost for all roadway segments for 30 attendees per stakeholder agency

Cost Categories	Cost /Attendees/year ($)	Number of Attendees/ Stakeholder Agency	Number of Stakeholder Agency	Number of Training/year	Total Cost/year ($)
ICS Training cost ($)	500	30	5	2	150,000
Communications logistics	71,302	NA	NA	NA	71,302
Total Cost ($)					221,302

Travel time savings, fuel savings, and reduction of CO and NOx emissions were the primary benefits of ICS strategies. Since all of the benefits are in terms of dollar/incident, the research team analyzed a CAD database for collisions to identify the total number of incidents per year on each segment of the I-26 study corridor. Given that incidents were simulated for three different durations, a total number of annual incidents for these three incident durations were determined from the CAD database. The number of incidents occurring in a year with an average of 60-minute duration, 120-minute duration, and 180-minute duration are shown in Column 6 in Table 8.4(a), 8.4(b), and 8.4(c).

To estimate total travel time savings, an hourly travel time savings of $24 per passenger vehicle was adopted (11). After determining the total emissions, and fuel consumption, the dollar values of total emissions and fuel consumptions were calculated using the IDAS (ITS Deployment Analysis System) database (12) and the average fuel costs for South Carolina (13). A 2.38% inflation rate was applied to convert all costs to 2014 dollars (14). The annual benefits from savings in travel time, emissions and fuel consumption yielded the total annual benefits of ICS strategy in 2014 dollars. To capture the stochastic behavior under actual traffic conditions, three different seed numbers were used in simulation. The benefit-cost analyses for three different incident durations (i.e., 60, 120, and 180 minutes) for roadway segments 1, 2, and 3 are presented in Table 8.4(a), 8.4(b), and 8.4(c), respectively.

The benefit-cost ratios (as shown in Table 6(a)) for different ICS scenarios indicate that the fuel consumption and travel time savings yield the largest benefits. Note that the benefits of ICS strategy for a different roadway segment were not identical. The benefit-cost ratio ranged from 17:1 to 149:1 for the roadway segment 1 for different ICS scenarios and incident durations as shown in Table 8.4(a).

Table 8.4(a) Estimated average benefit-cost ratio for roadway segment 1 for different incident durations

For 60 minute incident:

ICS Scenarios	Benefit for reduction in travel time ($/Incident)	Benefit for reduction in fuel consumption ($/Incident)	Benefit for reduction in CO emission ($/Incident)	Benefit for reduction in NOx emission ($/Incident)	Number of incident/year	Total benefit/year ($)	Total cost/year ($)	Benefit/Cost
ICS scenario (20% Reduction)	16,463	56	8	2	172	2,842,993	171,302	**17**
ICS scenario (25% Reduction)	21,846	65	9	2	172	3,770,572	171,302	**22**
ICS scenario (30% Reduction)	30,321	72	11	2	172	5,229,788	171,302	**31**

For 120 minute incident:

ICS Scenarios	Benefit for reduction in travel time ($/Incident)	Benefit for reduction in fuel consumption ($/Incident)	Benefit for reduction in CO emission ($/Incident)	Benefit for reduction in NOx emission ($/Incident)	Number of incident/year	Total benefit/year ($)	Total cost/year ($)	Benefit/Cost
ICS scenario (20% Reduction)	268,066	299	44	8	43	11,541,946	171,302	**67**
ICS scenario (25% Reduction)	323,100	361	53	10	43	13,911,503	171,302	**81**
ICS scenario (30% Reduction)	353,179	418	61	11	43	15,207,766	171,302	**89**

For 180 minute incident:

ICS Scenarios	Benefit for reduction in travel time ($/Incident)	Benefit for reduction in fuel consumption ($/Incident)	Benefit for reduction in CO Emission ($/Incident)	Benefit for reduction in NOx emission ($/Incident)	Number of incident/year	Total benefit/year ($)	Total cost/year ($)	Benefit/Cost
ICS scenario (20% Reduction)	958,938	206	30	6	18	17,265,222	171,302	**101**
ICS scenario (25% Reduction)	1,250,736	390	57	11	18	22,521,477	171,302	**131**
ICS scenario (30% Reduction)	1,413,745	502	73	14	18	25,458,002	171,302	**149**

TABLE 8.4(b) Estimated average benefit-cost ratio for roadway segment 2 for different incident durations

For 60 minute incident:

ICS Scenarios	Benefit for reduction in travel time ($/Incident)	Benefit for reduction in fuel consumption ($/Incident)	Benefit for reduction in CO emission ($/Incident)	Benefit for reduction in NOx emission ($/Incident)	Number of incident/year	Total benefit/year ($)	Total cost/year ($)	Benefit/Cost
ICS scenario (20% Reduction)	23,482	32	5	3	77	1,811,179	171,302	**11**
ICS scenario (25% Reduction)	30,230	36	5	4	77	2,331,154	171,302	**14**
ICS scenario (30% Reduction)	35,603	40	6	5	77	2,745,346	171,302	**16**

For 120 minute incident:

ICS Scenarios	Benefit for reduction in travel time ($/Incident)	Benefit for reduction in fuel consumption ($/Incident)	Benefit for reduction in CO emission ($/Incident)	Benefit for reduction in NOx emission ($/Incident)	Number of incident/year	Total benefit/year ($)	Total cost/year ($)	Benefit/Cost
ICS scenario (20% Reduction)	189,557	198	29	5	32	6,073,251	171,302	**35**
ICS scenario (25% Reduction)	213,362	243	35	7	32	6,836,699	171,302	**40**
ICS scenario (30% Reduction)	253,657	274	40	7	32	8,127,343	171,302	**47**

For 180 minute incident:

ICS Scenarios	Benefit for reduction in travel time ($/Incident)	Benefit for reduction in fuel consumption ($/Incident)	Benefit for reduction in CO emission ($/Incident)	Benefit for reduction in NOx emission ($/Incident)	Number of incident/year	Total benefit/year ($)	Total cost/year ($)	Benefit/Cost
ICS scenario (20% Reduction)	833,875	468	68	13	26	21,695,034	171,302	**127**
ICS scenario (25% Reduction)	1,065,480	587	86	16	26	27,720,394	171,302	**162**
ICS scenario (30% Reduction)	1,134,287	661	97	18	26	29,511,645	171,302	**172**

TABLE 8.4(c) Estimated average benefit-cost ratio for roadway segment 3 for different incident durations

For 60 minute incident:

ICS Scenarios	Benefit for reduction in travel time ($/Incident)	Benefit for reduction in fuel consumption ($/Incident)	Benefit for reduction in CO emission ($/Incident)	Benefit for reduction in NOx emission ($/Incident)	Number of incident/year	Total benefit/year ($)	Total cost/year ($)	Benefit/Cost
ICS scenario (20% Reduction)	30,291	57	8	3	98	2,975,184	171,302	**17**
ICS scenario (25% Reduction)	35,008	76	11	4	98	3,439,733	171,302	**20**
ICS scenario (30% Reduction)	43,435	85	12	5	98	4,266,707	171,302	**25**

For 120 minute incident:

ICS Scenarios	Benefit for reduction in travel time ($/Incident)	Benefit for reduction in fuel consumption ($/Incident)	Benefit for reduction in CO emission ($/Incident)	Benefit for reduction in NOx emission ($/Incident)	Number of incident/year	Total benefit/year ($)	Total cost/year ($)	Benefit/Cost
ICS scenario (20% Reduction)	225,193	190	28	5	22	4,959,166	171,302	**29**
ICS scenario (25% Reduction)	271,669	246	36	7	22	5,983,067	171,302	**35**
ICS scenario (30% Reduction)	310,956	282	41	8	22	6,848,332	171,302	**40**

For 180 minute incident:

ICS Scenarios	Benefit for reduction in travel time ($/Incident)	Benefit for reduction in fuel consumption ($/Incident)	Benefit for reduction in CO emission ($/Incident)	Benefit for reduction in NOx emission ($/Incident)	Number of incident/year	Total benefit/year ($)	Total cost/year ($)	Benefit/Cost
ICS scenario (20% Reduction)	544,360	82	12	2	16	8,711,292	171,302	**51**
ICS scenario (25% Reduction)	760,881	198	29	5	16	12,177,816	171,302	**71**
ICS scenario (30% Reduction)	1,126,043	310	45	8	16	18,022,512	171,302	**105**

8.3 BENEFIT-COST ANALYSIS WITH VARYING BENEFITS BY SEGMENT

The mean, maximum, and minimum benefit-cost ratio for the three different roadway segments that were estimated using an average costs with varying benefits are provided in Table 8.5. The benefit-cost ratio ranges from 11:1 to 31:1, 29:1 to 89:1, and 51:1 to 172:1 when ICS strategies are applied to the 60, 120, and 180-minute incident duration, respectively.

Table 8.5 Mean, maximum, minimum benefit-cost ratio for three different roadway segments with varying benefits

Incident Duration	Category of B/C ratio	Number of Roadway Segment on I-26 (Varying benefits)		
		B/C for segment 1	B/C for segment 2	B/C for segment 3
60 minute	Mean	23	14	21
	High	31	16	25
	Low	17	11	17
120 minute	Mean	79	41	35
	High	89	47	40
	Low	67	35	29
180 minute	Mean	127	154	76
	High	149	172	105
	Low	101	127	51

8.4 BENEFIT-COST ANALYSIS WITH VARYING COSTS

The cost scenarios include 10, 20, and 30 attendees from each of the five agencies participating in the ICS training as shown in Table 8.3(a), 8.3(b), and 8.3(c). The mean, maximum, and minimum benefit-cost ratios for the three roadway segments, which were estimated with varying costs, are provided in Table 8.6. The benefit-cost ratio for this analysis ranges from 11:1 to 33:1, 27:1 to 112:1, and 59:1 to 217:1 when ICS strategies are applied to the 60, 120, and 180-minute incident, respectively.

Table 8.6 Mean, maximum, minimum benefit-cost ratio for three different roadway segments with varying costs

Incident Duration	Category of B/C ratio	Number of Roadway Segment on I-26 (Varying costs)		
		B/C for segment 1	B/C for segment 2	B/C for segment 3
60 minute	Mean	25	15	22
	High	33	19	29
	Low	18	11	16
120 minute	Mean	84	43	37
	High	112	57	49
	Low	61	31	27
180 minute	Mean	135	163	80
	High	179	217	107
	Low	98	119	59

8.5 AVERAGE BENEFIT-COST RATIO CONSIDERING ALL THREE STUDY SEGMENTS

The average benefit-cost ratios of all three segments with varying benefits are provided in Table 8.7 and Table 8.8 shows the average benefit-cost ratios of all three segments with varying costs. As shown in Table 8.7 and Table 8.8, the benefit to cost ratios vary from 15:1 to 142:1 with varying benefits for different ICS strategies, and the benefit to cost ratios vary from 15:1 to 168:1 with varying training costs.

Table 8.7 Mean, maximum, minimum benefit-cost ratio considering all three segments

Incident Duration	Category of B/C ratio	Average B/C (Varying Benefits)
60 minute	Mean	19
	High	24
	Low	15
120 minute	Mean	51
	High	59
	Low	44
180 minute	Mean	119
	High	142
	Low	93

Table 8.8 Mean, maximum, minimum benefit-cost ratio considering all three segments

Incident Duration	Category of B/C ratio	Average B/C (Varying Costs)
60 minute	Mean	20
	High	27
	Low	15
120 minute	Mean	55
	High	73
	Low	40
180 minute	Mean	126
	High	168
	Low	92

8.6 TRAFFIC DIVERSION STRATEGIES USING CONTINGENCY PLAN OF SCDOT

Through detection and verification, traveler information, response (tow truck arrival), scene management and traffic control, and quick clearance and recovery activities, the impact of congestion due to incidents can be eased with the implementation of a TIM plan (see Figure 8.2 Incident Management Timeline **(adopted from (17))**). Traffic diversion strategies not only relieve congestion, but also lead to travel time savings, energy conservation, environmental benefits, and improved health and safety (8). Routing vehicles to alternate routes in the event of a major incident is one of the strategies to increase driver safety, ease congestion, improve traffic operations, and reduce negative environmental impacts (15). The methods to route vehicles include relaying messages via Variable Message Signs (VMS), Highway Advisory Radio (HAR) services, etc. However, diverting vehicles to an alternate route is not always a feasible solution (16). Furthermore, due to the influx of diverted traffic, the alternate routes may face heavy congestion. The two key events for a traffic incident management plan are verification time and response time (arrival time of a tow truck). Higher verification time or a late arrival of a tow truck results in an increased queue length and potential for secondary incidents on the main route. In this research, the impact of a traffic diversion strategy was evaluated in a traffic micro simulation environment by developing different scenarios based on different verification times and arrival times of a tow truck.

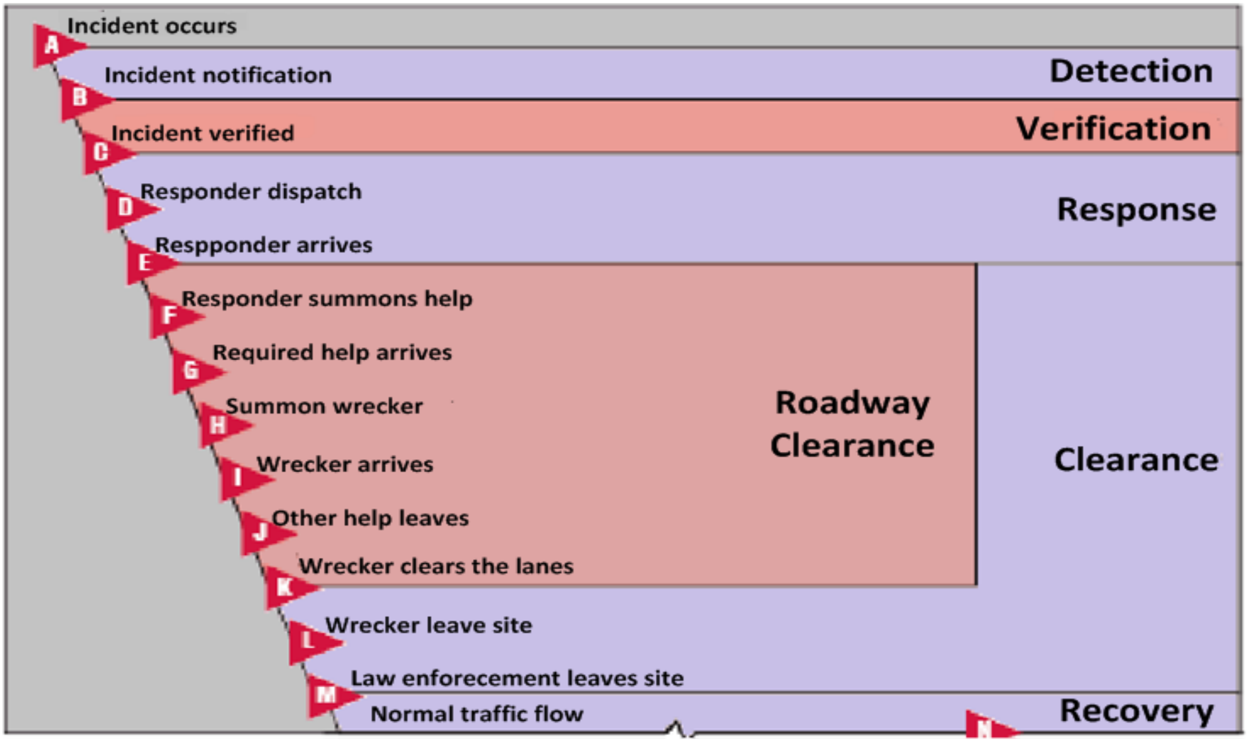


Figure 8.2 Incident Management Timeline (*adopted from (17)*)

8.7 SIMULATION OF TRAFFIC DIVERSION

Traffic diversion was evaluated in a traffic micro simulation environment by developing different scenarios based on different verification times and arrival times of a tow truck at the incident scene. Traffic diversion scenarios were modeled using the Vehicle Actuated Programming (VAP) feature in the traffic micro simulation software VISSIM 5.40. As shown in Figure 8, segment 3 of the I-26 corridor includes 17.6 miles of freeway with three interchanges and two alternate routes that are 40 miles and 30 miles long. The scenarios were then evaluated for an incident. VAP logic for traffic diversion scenarios was developed for the section (i.e., segment 3) of I-26 in Berkeley, Orangeburg and Dorchester County with two alternate routes that are recommended for the section according to the SCDOT contingency plan for traffic incidents (Figure 8).

Since the incident management authority in South Carolina only considers route diversion for the most severe incidents, incidents that blocked both lanes of I-26 WB were modeled in the final calibrated simulation model. The total incident clearance time was set at 46 minutes and total simulation time was set at 120 minutes. The incident duration was selected based on the average duration estimated for incidents that fell in the 30 to 60 minutes range from the 2012 CAD database. First, the base model was simulated without an incident. For the incident scenario, the VAP logic was executed at every simulation second and it checked when the incident will start in the simulation model. Based on the VAP logic, the vehicles whose final destination is beyond the I-26 northwest end (towards Columbia, refer to Figure 8) are rerouted to alternate routes.

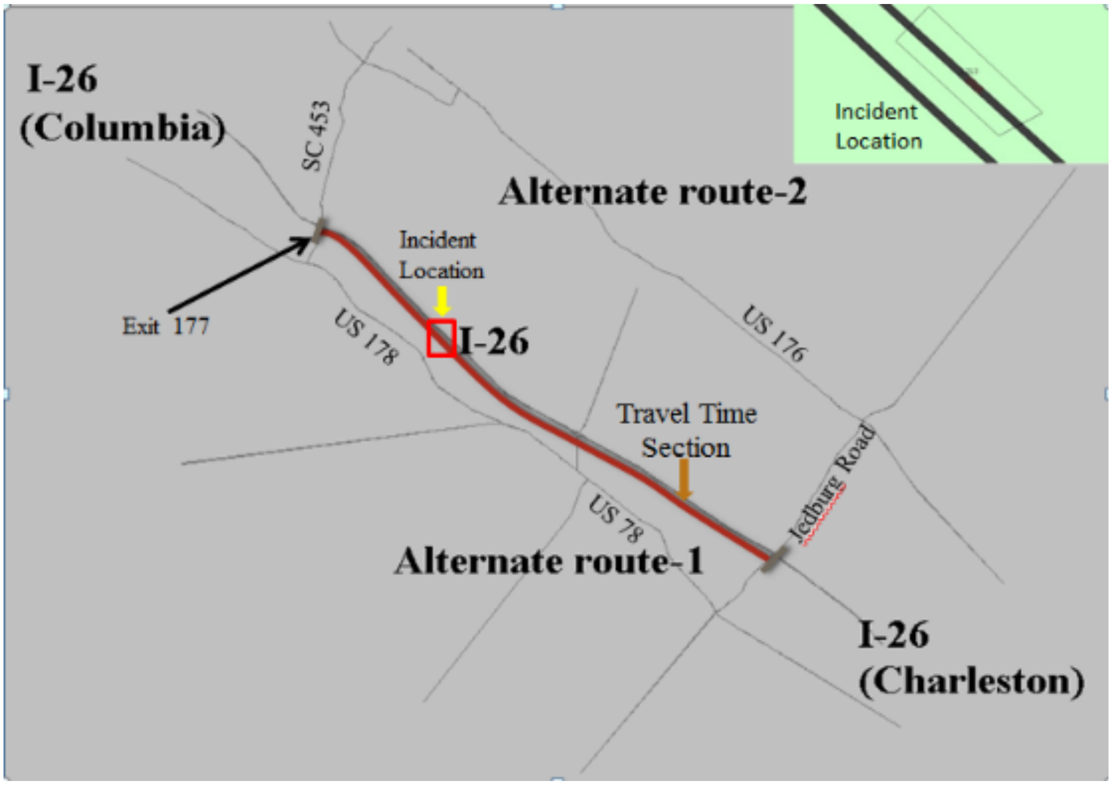


Figure 8.3 Segment 3 of I-26 with two alternate routes

8.8 SIMULATION SCENARIOS

The simulation scenarios were designed to capture the impact of the traffic diversion strategy. The scenarios were developed based on the two key time parameters of a traffic incident management plan: (1) verification time (see Table 8.9) and (2) response time (tow truck arrival time) (see Table 8.10). The base scenario includes existing traffic volume without incident and routing to alternate routes.

Table 8.9 Simulation scenarios based on verification time

Simulation scenarios	Verification Time
Base scenario with incident	5 minutes
Base scenario with incident and traffic diversion	5 minutes
Base scenario with incident and traffic diversion	4 minutes
Base scenario with incident and traffic diversion	3 minutes
Base scenario with incident and traffic diversion	2 minutes

Base scenario with incident and traffic diversion	1 minute
Base scenario with incident and traffic diversion	0 minute

Table 8.10 Simulation scenarios based on tow truck arrival time at incident scene

Simulation scenario	Towing truck arrival time at incident scene
Base scenario with incident	12 minutes
Base scenario with incident	11 minutes
Base scenario with incident	10 minutes
Base scenario with incident and traffic diversion	12 minutes
Base scenario with incident and traffic diversion	11 minutes
Base scenario with incident and traffic diversion	10 minutes

8.9 SIMULATION OUTCOMES AND DISCUSSION

The simulation results obtained for the different traffic diversion scenarios are summarized in Tables 8.9 and 8.10 for different verification time and tow truck arrival time at the incident scene. The traffic diversion scenarios were compared against the base scenario without traffic diversion. Traffic diversion scenarios were also evaluated for a range of verification times and response times (tow truck arrival time at incident scene) to investigate the effect of these strategies.

8.9.1 EFFECT OF INCIDENT ON VERIFICATION TIME

Figure 8.4 illustrates the effect of verification time on incident recovery time for both incidents without traffic diversion and incidents with traffic diversion. The total duration of incident clearance time was 46 minutes, including a 5-minute verification time for the base incident scenario. Figure 8.4 shows that the density profile with incident and traffic diversion of the I-26 corridor reduces from the density of base scenario in simulation time from 6600 seconds to 7200 seconds, as traffic is rerouting to alternate roads when it reaches maximum base density. It was found that the recovery time was reduced by 52.26 % with the traffic diversion strategy for all 0 to 5-minute verification time scenarios. Recovery time was reduced by a 4.56% for every minute reduction of verification time with the traffic diversion strategy.

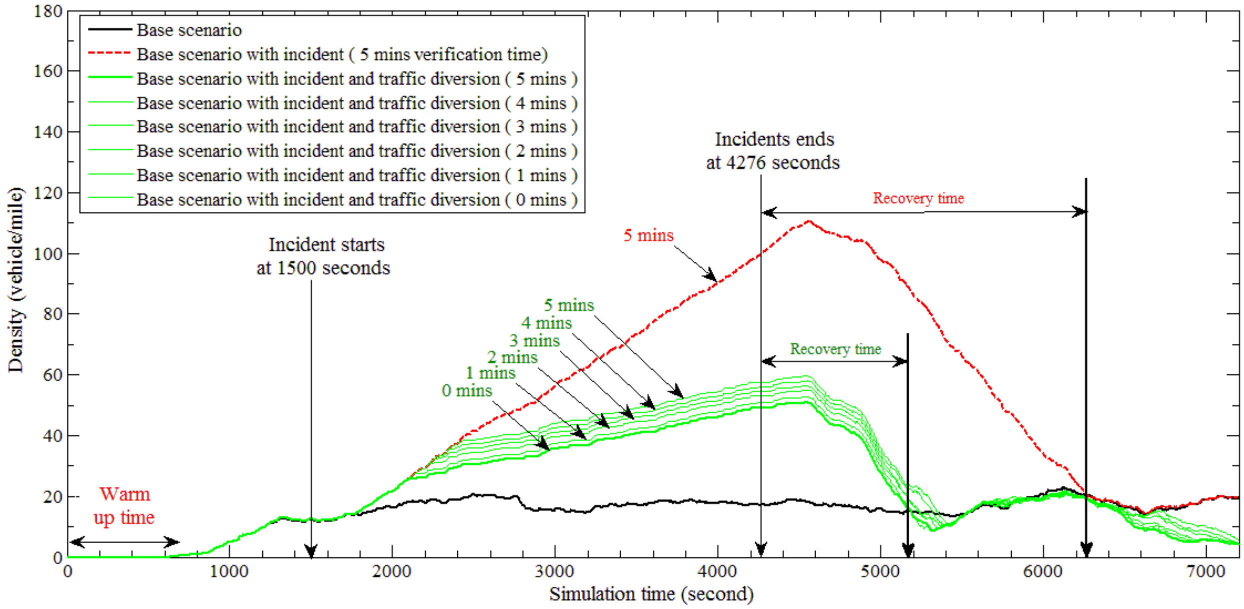


Figure 8.4 Effect of traffic diversion strategies on incident verification time

8.9.2 EFFECT OF RESPONSE TIME (TOW TRUCK ARRIVAL TIME AT INCIDENT SCENE)

Figure 8.5 represents the density profile for 10, 11, and 12 minute arrival times of tow trucks with and without traffic diversion strategies. Tow truck arrival times of 10 to 12 minutes were adopted from (15). Tow truck arrival time can be defined as the duration between incident notification time and incident response time. The total incident clearance time for the base scenario with incident was the same as the verification time scenario. For the base case, the arrival time was 10, 11, and 12 minutes. From Figure 8.5, it is clear that the recovery time was significantly reduced. The recovery time was reduced by 59.83%, 61.18%, and 61.27% for a tow truck arriving after 12, 11, and 10 minutes of incident notification, respectively.

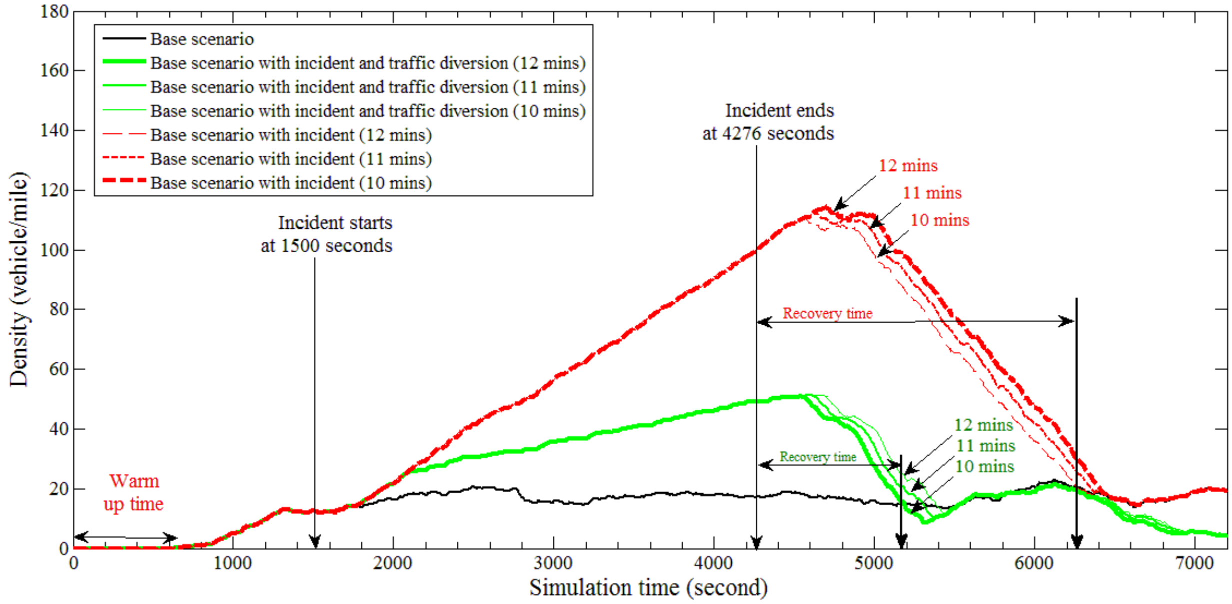


Figure 8.5 Effect of traffic diversion strategies on arrival time at incident scene

8.10 BENEFIT COST SUMMARY

The impact of different ICS strategies for incident management on the I-26 freeway corridor in South Carolina, a 91.5 mile length of interstate with 19 interchanges, was evaluated using traffic micro-simulation tool. Limited coordination among all agencies involved in incident response increased the incident clearance time substantially. The research team found that the use of ICS strategies enables an effective and timely communication between multiple agencies by educating them about their respective roles and expertise in incident clearance activities. The effectiveness of ICS depends upon the well-timed communication, timely dispatching of resources, and most importantly, well-trained professionals who can manage the various challenges inherent in any road incident. It also depends upon the procurement of dependable and inexpensive equipment, and the creation of reliable communication protocols to ensure the effective coordination among the various responders. An effective ICS strategy was also deemed necessary in eliminating the redundancies among the various responding agencies. Several ICS implementation scenarios were modeled using a traffic micro-simulation tool to quantify benefits in terms of reductions in travel time, fuel consumption, and emissions. Simulation experiments were conducted to evaluate the impact of ICS strategies through the simulation of traffic and incidents (incident data include locations, start times, and incident durations). To evaluate the effectiveness of ICS strategies, a benefit-cost analysis was conducted. Benefits were determined by comparing the simulation outputs between a base scenario and ICS scenarios. The cost was estimated based on the implementation cost of the ICS scenarios. It was found that the ICS strategies could provide a return of $15 with $1 invested to a maximum return of $ 168 with $1 invested. The return on invested is due to savings in terms of travel time, fuel, and emissions. The B/C analysis suggests that there is a significant benefit derived from the implementation of ICS with very little investment. A well-coordinated ICS improve traffic operations and the reliability of transportation services for businesses, while fostering an increased level of economic prosperity and quality of life.

The analysis of impact of traffic diversion strategies demonstrated that the traffic diversion strategy could reduce incident recovery time by 52 % with a reduced verification time and an average 61% reduction in incident recovery time due to earlier arrival time of a tow truck at the incident scene. Thus, timely verification of an incident and quick response to the incident scene results in reduced recovery time and early restoration of normal traffic conditions.

9 CONCLUSIONS AND RECOMMENDATIONS

Surface transportation has been described as "the thread that knits the country together, providing the mobility that is such a significant part of America's quality of life and is deeply embedded in our culture, psyche, and history of events… Highways (also transit and rail) provide unprecedented access to work, education, health care, recreation, and the many other activities that constitute the American way of life." Additionally, America's surface transportation system serves as the backbone of our country's economy. According to research conducted by the United States Department of Transportation (USDOT), in 2002, transportation-related goods and services, or freight, accounted for more than 10%—over $1 trillion—of the U.S. Gross Domestic Product (GDP).

In South Carolina, the highway system is heavily traveled. In 2006, South Carolina's population was 4.3 million, a 24% increase over 1990 figures. Yet, for the same 15-year period, vehicle miles of travel in South Carolina grew by 44%, that is, from 34 billion vehicle miles of travel to 49 billion. As such, currently, South Carolina's highway system is one of the most traveled per capita in the nation. A consequence of this over congested condition is traffic accidents. According to the SCDOT, South Carolina has the eighth highest fatality rate for highways in the nation, and an average of three people die each day on South Carolina roadways.

Given the significant importance of the state's interstate system, incidents must be cleared as soon as possible to prevent secondary incidents, and reduce delay to motorists and freight activities. The clearance of incidents involves multiple stakeholders, including SCDOT, SC Highway Patrol (SCHP), Coroners, other public agencies (both state and local), as well as private entities (such as towing and hazardous spill cleanup services). In order to respond effectively to each incident, it is essential that all of these partners work collaboratively and efficiently to clear the roadway as soon as possible. To accomplish this, there needs to be an organized management response.

After analyzing the current best practices, the potential areas for improvement could be identified. Based on the implementation tables, the TIM areas most in need of improvement were response and clearance strategies. The major gaps existed in towing, coroner, HAZMAT, and crash investigation procedures. The research team reviewed current SC policies in each of these areas, and presented alternatives used in other states with proven success. The summary of these recommendations are as follows:

- Towing - In South Carolina, towing operations are conducted on a rotation dispatch system. Currently there are 3 wrecker lists, divided by class, and assigned to each zone. Once the SCHP calls one of the wrecker companies on the wrecker list, the company has 45 minutes to arrive at the scene of the accident and is paid by the hour to clear the wrecked vehicles. The rotation arrangement is similar to prior programs in Washington, Georgia, Florida, North Carolina, and Virginia before they implemented incentive based towing programs. With the current system in South Carolina, there is no motivation for the towing companies to get the job done quickly, because the longer they work the crash scene the more money they earn. In 2008 Georgia implemented the Towing and Recovery Incentive Program (TRIP) which compensates certified, inspected heavy-duty recovery companies to expedite clearance at major incident scenes. Over the seven years that the program has been in operation, there have been 515 activations and clearance times have dropped from 216 to under 40 minutes (38 min in 2014). An independent evaluation of the program in 2011 indicated a cost savings per incident of $456,396 (or 71% savings). The financial benefit of TRIP for 2008 and 2009 was over $9 million providing a cost benefit ratio of 11:1. based on a median fatal crash recovery time of 355 minutes in South Carolina, and a 66% improvement in incident duration resulting from the implementation of the TRIP program in Georgia, an estimated 234 minutes could be saved for a single fatal incident. This is a significant improvement which would greatly reduce time that personnel are in harm's way, the chances of secondary crashes, and congestion resulting from lane closures.

- Hazmat – Jason Krusen, a Special Operation Chief for the Columbia Fire Department in Columbia, SC, indicates that more often than not, the amount of fuel spilled is overestimated by on-scene response potentially resulting in unnecessary response. Accurately identifying that an incident does not require a hazmat team response means quicker clearance of the incident. It is important for first responders to understand and be able to recognize the reportable amounts for fuel spills. Regulations for fuel spill response varies from state to state to state, and sometimes even county to county which can complicate response because local governments may have a more stringent reporting quantity based on local codes. A statewide policy helps to provide consistency and formal protocols for dealing with fuel spills. Delays in HAZMAT response and clean-up may occur when DHEC resources are requested unnecessarily to incident sites which should be notification only events. By explicitly defining and developing standard statewide operating procedures and interactive spill training, hazardous material spills could be handled more quickly and efficiently by the closest resources.
- Coroner - Currently in South Carolina, state legislation allows removal of a deceased body from a fatal crash scene only after a formal investigation and authorization by a coroner, deputy coroner, medical examiner, or deputy medical examiner. In South Carolina, incident responders are not allowed to disturb the victim's body in any way, either by moving the body or the vehicle containing the body. This type of legislation can significantly delay incident clearance and increase congestion as numerous responders may sit idle with vehicles blocking the travel way while awaiting the arrival of the coroner. To exasperate the effect, there are typically a limited number of qualified individuals that may investigate and authorize the removal of deceased from a traffic incident scene. Other states including Texas, Tennessee, and Louisiana have implemented traffic fatality certification laws. These laws are a combination of quick clearance and hold harmless acts to address the removal of deceased victims from the crash scene where the location obstructs or presents a hazard to adjacent traffic flow. While the coroner is concerned with establishing the manner and cause of death in all unknown-cause deaths, the precipitating events leading to most motor vehicle crash fatalities can easily be documented. Quick clearance objectives can be handled by allowing temporary removal of the deceased from the highway, and/or certification of the fatality by someone other than the coroner. The implementation of traffic fatality certification laws in South Carolina is another response mechanism that could provide significant reductions in clearance time.
- Crash Investigation – In South Carolina, the Multidisciplinary Accident Investigation Team (MAIT) conducts in-depth investigations of traffic collisions involving complex circumstances such as fatalities, felony cases, etc. MAIT investigations are associated with the lengthiest incident durations. While much of the investigation is likely conducted in the field at the time of the incident, some parts may be conducted after the fact. Much of the data collected at the scene is required to reconstruct the crash through speed calculations; determination of pre-impact, post-impact and at-impact locations; vehicle crush measurement and energy calculation; time, distance, and acceleration calculations, as well as crash simulation and scale drawings. Much like the 70% reduction in data collection time with the transition from using measuring tapes to total stations, using 3D laser scanning technology, crash scene measurements can be completed in a fraction of the time with exponentially more data collected. Reductions in data collection time in the literature range from 50% to 90% with this technology. In addition to the sheer magnitude of data that can be collected in relatively short time periods, the 3D laser scanners have a number of other benefits. In

many cases, the equipment can be set up to capture data without full lane closures, thus reducing congestion and the risk of secondary accidents. The device can be operated with a single user which limits the number of people that must be on the scene. There is no need to touch the measured object, which in some cases is not possible or desirable. The device can collect data in darkness or direct sunlight, where photographs will be of little benefit. The data set will allow measurement of vehicle deformation and calculation of sight distance. In fact, the dataset contains the full scene, so measurements that were not initially deemed important are preserved to allow unlimited observations and measurements.

Based on evaluations of other ICS/TIM enhancements, it is expected that implementing the results of this research will produce better communication, cooperation, and control between SCDOT, SCHP and its partners when handling incidents on our highways. Based on results in other states, SC can expect shorter incident duration times, less cost and better efficiency for each stakeholder agency and better cooperation with local responders. The motoring public will be better served by experiencing fewer secondary collisions, reduced time in congestion, lower vehicular operating costs, and lower maintenance costs resulting from reduced braking operations by heavy vehicle. Also, there will be fewer emissions from idling vehicles since incident times are reduced and less fuel wasted. A more favorable opinion by the public of our agencies will result from this implementation. Additionally, highway capacities will be enhanced under any conditions as congestion is reduced. To evaluate the effectiveness of ICS strategies, a benefit-cost analysis was conducted. Benefits were determined by comparing the simulation outputs between a base scenario and ICS scenarios. The cost was estimated based on the implementation cost of the ICS scenarios. It was found that the ICS strategies could provide a return of $15 with $1 invested to a maximum return of $ 168 with $1 invested. The return on invested is due to savings in terms of travel time, fuel, and emissions. With the recent adoption of the SHRP-II Training across the state, these benefits are already accruing. Add to this, the potentially significant reductions in response to major events and the benefits continue to grow.

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