2017

Incident Traffic Management Respone

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This is to certify that the doctoral dissertation by

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has been found to be complete and satisfactory in all respects,
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2017

Abstract

Incident Traffic Management Response

by

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MPA, Master of Public Adminstration, East Carolina University, 1991

BA, Bachelor of Arts, North Carolina State University, 1981

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Public Policy and Administration

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Abstract

The North Carolina State Highway Patrol (NCSHP) and the North Carolina Department of Transportation (NCDOT) are often called upon to assist in traffic incidents. Yet little systematic research has examined the extent to which these two agencies collaborate. This gap in understanding is problematic, as a lack of collaboration may result in significant delays in the clearing of traffic incidents. The purpose of this correlational study was to investigate circumstances when the two agencies collaborated in clearing major traffic incidents, and the efficiency of the clearance of the incidents, through the measurement of normal traffic flow. The theory of the convergence of resources from divergent organizations framed the study. The research questions addressed the extent of collaboration between the NCSHP and the NCDOT, the conditions under which this collaboration took place, and the efficiency of the clearance of these incidents. Data were obtained from the NCSHP and the NCDOT on characteristics of 1,580 traffic incidents that occurred on the North Carolina portion of Interstate 95 during the year 2014. The data were analyzed using chi-square tests, analyses of variance, and *Z*-tests for proportions. Collaboration between the two agencies occurred in 7.2% of all of the incidents and in 21.6% of incidents of major severity ($p < .001$), which indicated a low level of interagency collaboration. The mean clearance time for incidents in which collaboration took place was 115.92 minutes compared to a national goal of 90 minutes. It is hoped that these results can contribute to policy dialogue relevant to the state's Strategic Plan, leading to safer highways and less financial loss due to congestion caused by traffic incidents.

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Dedication

This dissertation is dedicated to my family. Mom and Dad, along with my sister, Cheryl, and brother, Frank, have been on this journey with me from the beginning. There have been many challenges along the way, but my family has never doubted my ability to complete this journey.

Thank you to my friends and colleagues within the emergency management field; every day you face challenges with each and every call for service. These are the men and women whom we count on every day, every hour, and every minute to make things better. I hope that my research draws to light issues, and by working together, to make them better. Thank you for all that you do.

Acknowledgments

My thanks and appreciation goes to Dr. Elaine Spaulding, my advisor and committee chair. Her assistance and encouragement have been my foundation through this doctorate journey. I also want to thank Dr. Patricia Ripoll, my dissertation committee member, for her assistance in keeping me on track during the dissertation process. To all the Walden staff, for being there for my many phone calls and questions, and to Ms. Jeanne Ainslie for all her advice and guidance.

In addition, I am especially thankful to Professor Emeritus of Psychology, Dr. David West, and Holly Whistler, my editor, for all their support, advice, and guidance through this long process.

To all my friends and colleagues who remained true to my journey; knowing this process would be a complete success. I thank you.

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Chapter 1: Introduction

The United States' Strategic Plan cites traffic congestion as one of the nation's single largest threats to economic prosperity (Texas Transportation Institute [TTI], 2012). Traffic incidents and associated congestion accounted for 5.5 billion hours of wasted time, 2.9 billion wasted gallons of fuel, and approximately 121 billion dollars in lost revenue as of 2011 (TTI, 2012, p. 48). As defined in the *Traffic Management Data Dictionary* (Institute of Transportation Engineers, 2000), a *traffic incident* is an unplanned and randomly occurring event adversely affecting normal traffic. Traffic incident responses require partnerships orchestrated between public agencies and the private sector (Bergner, 2010; Carson, 2008, 2010; Delcan, 2010). The existence of these partnerships does not imply that all incidents demand an extensive response from various agencies; most traffic incidents do not (Carson, 2010). Coordination entails clarification of responder roles and responsibilities to ensure consistent, effective, and appropriate responses. Implementation of interorganizational communication and efficient use of resources are critical for effective service delivery. The Federal Highway Administration's *Best Practices in Traffic Management* recognizes inefficient communication as the leading challenge in incident response (Federal Highway Administration [FHWA], 2010). Efficient and quick communications between dispatchers and parties on scene are vital for overall scene management.

Various federal, state, and local public safety agencies manage traffic incidents and maintaining efficient traffic flows. In North Carolina, two such agencies are the North Carolina Department of Transportation (NCDOT) and the North Carolina State Highway Patrol (NCDPS, 2014). The NCDOT's mission, according to its website, is connecting people, products, and places safely and efficiently with customer focus, accountability, and environmental sensitivity to enhance the economy and vitality of North Carolina (NCDOT, 2014). Similarly, according to its website, the NCSHP’s primary mission is to reduce collisions and make the highways of North Carolina as safe as possible (NCDPS, 2014). The two agencies vary in emphasis. The NCSHP is more oriented toward law enforcement and criminal and incident investigation; whereas, the NCDOT is more oriented toward maintaining infrastructure, restoring traffic flow and affecting the economic movement of motorists and goods on state highways. The overlap in missions of the two agencies lies in the management of traffic incidents to maintain the safety of the roadways’ traffic flow. Traffic control was of such concern that in 1929 the General Assembly passed an act authorizing the establishment of the State Highway Patrol. The new organization was given statutory responsibility to patrol the highways of the state, enforce the motor vehicle laws, and assist the motoring public.

Thus, differential emphasis in missions was similar to that found by Balke et al. (2002) in other states between the specific state's department of transportation and its statewide law enforcement agency. Balke et al. concluded, in this situation of overlapping missions, lack of collaboration between transportation and law enforcement agencies could develop, which can, in turn, reduce the efficiency of traffic incident clearance. In a similar vein, Carson (2010) concluded that the norm of operations for most agencies is to follow their particular protocols independently of other agencies responding to the same traffic incident. State agencies with overlapping missions such as the NCSHP and the NCDOT are especially vulnerable to the limitations expressed by Balke et al. (2002) and Carson (2010).

As implied in the description of incident responses discussed above, the efficacy of governmental agencies in task completion has involved the collating, processing, and communicating of information gathered. No longer are duties simply the processes of gathering information, but duties have included the agency's ability to share and exchange that information to promote effective interagency communications (Helmam, 2004). A major research study by the California Department of Transportation (CALTRANS) concluded with recommendations for data integration and data transfer efficiency among agencies (Balke, Seeherman, & Skabardonis, 2014).

A second key concept in the public policy aspect of traffic incident management has been the efficiency of task completion. Traffic incidents have included not just crashes, but also vehicle breakdowns, cargo spills, lane blockages, and severe weather conditions, and have produced substantial human and financial costs (Ma, Chowdury, Fries, & Ozbay, 2009; Ma, Zhang, Lu, & Yuan, 2014; Taylor, 2008; Vasconez, 2013). With respect to each incident category listed above, a number of tasks must be completed. Bunn and Savage (2003) defined the term *incidence clearance* as the process of the removal of a traffic incident (i.e., disabled vehicle, debris, or any other material that blocks the flow of traffic) and the restoration of the roadway to its preincident condition. The major CALTRANS study cited above also examined incident clearance time as a measure of organizational efficiency and developed a framework to monitor incident clearance performance and ensure continuous improvement in Traffic Incident Management operations.

Accounting for 25% of all congestion in the United States, clearing traffic incidents has been listed as a top priority in North Carolina’s Strategic Plan. Research has shown North Carolina's congestion rate for nonrecurring traffic incidents and accidents as between 30% and 40% (Hartgan, 2007). Therefore, increased efficiency concerning unimpeded travel time has been an important economic and safety goal clearly associated with the nature and degree of collaboration among the responsible agencies involved.

The Problem Statement and Purpose sections describe the problem to be investigated and the purpose of the study. The Research Questions and Hypotheses sections specify empirical and operational measurements of interagency communication, collaboration, and efficiency as they related to traffic incident clearance in the state of North Carolina, and specific research questions and hypotheses related to these measures. Subsequent sections address the Theoretical Framework of the study, the Nature of the Study, and Definitions, Assumptions, and Limitations of the study. The chapter concludes with a discussion of the significance of the findings of the study.

Problem Statement

The problem addressed by this study is the lack of collaboration between the NCSHP and the NCDOT, two state agencies with overlapping responsibilities in emergency management of traffic incidents. The National Research Council (2006) has defined dysfunctional responses to critical incidents as problems in interagency collaboration, including such areas as “failure to recognize the magnitude and seriousness of an event" and "failures in intergovernmental coordination" (as cited in Jensen & Waugh, 2014, p. 6). As explained in the *Traffic Incident Management Handbook*, although each responder agency has had a narrow role to play in incident clearance, a shared understanding of the roles and responsibilities of the other agencies has been essential for the effectiveness of incident response (Dongald, Goodall, &

Venkatanarayana, 2016). The development of a memorandum of understanding (MOU) has been one way to define those roles and responsibilities for establishing a working relationship (Dongald et al., 2016). According to NCSHP's and NCDOT's Memorandum of Understanding (2011), which facilitates initiation of interagency collaboration in the clearance of incidents, "all major lane blocking or traffic disruption related to incidents, such as overturned tractor trailers, hazardous material spills, fatal investigation or multi-vehicle wrecks contact should be made with the NCDOT State Transportation Operations Center (NCDOT STOC)."

An additional concern related to a potential lack of interagency collaboration has been the presence and implementation of policies, regulations, and guidelines, which might suggest an instance of public policy failure (e.g., McConnell, 2010). Relevant aspects of McConnell's theory of policy failure concern the misunderstanding and partial or total lack of implementation of program objectives, the failure to measure the accomplishment of program objectives, and the subsequent failure to modify policy based upon this program evaluation. As discussed below, implementation of the Memorandum of Understanding between the NCSHP and NCDOT may have reflected a number of aspects within McConnell's (2010) theory, such as the failure to evaluate and implement program objectives regarding collaboration and the failed documentation of the collaboration between the two agencies.

The differential emphasis in missions between the NCSHP and the NCDOT was similar to that found in other states by Balke et al. (2002) regarding the particular state's department of transportation and its statewide law enforcement agency. Their research concluded that in this situation of overlapping missions, communication problems between transportation and law enforcement agencies could develop, which in turn could result in a reduction in the efficiency of traffic incident clearance.

Traffic incident clearance has been influential in the following respects:

- The safety of the drivers on the roadway blocked by the traffic accident ("incident"),
- The safety of emergency personnel responding to the incident,
- The economic costs of traffic delays due to the incident, and
- The environmental costs of traffic delays caused by the incident.

The CALTRANS study by Balke et al. (2014) emphasized the utility of collecting data on incident times and the potentially differing operational definitions of this measure by different agencies. This situation has existed in North Carolina. The NCSHP has defined *clearance time* as the time elapsed between the report of the incident and the time that the state trooper leaves the incident site. This definition has been reasonable in light of the specific mission of the NCSHP to initially organize the cleanup of the site, investigate the circumstances of the incident, investigate potential criminal liability, and complete the collision report. The NCDOT, on the other hand, has been tasked with the cleanup to restore normal traffic flow. Therefore, the NCDOT's activity at the incident site could have continued after the departure of the state trooper from the site of the incident. Consequently, the NCDOT has defined incident clearance time as the elapsed time between initial notification of the incident and the time that traffic resumes its normal flow.

The important quantitative aspect of the communication between the two agencies has been the frequency of notification of the NCDOT by the NCSHP and the circumstances under which such communication takes place in the care of incidents of major severity (those longer than 120 minutes in duration).

Purpose of the Study

The purpose of this nonexperimental, quantitative, archival study was to investigate the extent and circumstances of collaboration between NCSHP and NCDOT in the management and resolution of traffic incidents and the evaluation of these practices within the policies specified by the Memorandum of Understanding.

Research Questions

Policy governing the collaborative response to incident clearance as specified in the Memorandum of Understanding indicates that the NCSHP shall contact the NCDOT when *major* collisions or incidents occur. The standard definition of a *major incident* is one for which incident clearance is over 120 minutes in duration (*Manual on Uniform Traffic Control Devices*, 2009). The review of the literature has also revealed the type of incident (Balke, Fermo, & Ullman, 2002; Basu & Maitra, 2010; Manoj & Baker, 2007; Schroeder & Demetsky, 2011) and the number of lanes blocked (Balke et al., 2002; Feyen & Eseonu, 2009) as important and frequently used measures of incident severity.

The research questions that were investigated in the study were as follows:

- What is the current extent of collaboration between NCSHP and the NCDOT in the management and resolution of traffic incidents?
- Under what circumstances did this collaboration between the two agencies take place?

- As suggested by the CALTRANS study (Balke et al., 2014), what characteristics of the incident were associated with the efficiency of incident clearance?
- In what ways did the actual collaboration between the two agencies fulfill the public policy objectives of the Memorandum of Understanding, or did the policy represent an example of policy failure?

Research Hypotheses

From these research questions, the following general research hypotheses were derived.

- There will be a direct association between the factors of incident severity, type of incident, and number of lanes blocked, on the one hand, and the collaboration between NCSHP and NCDOT in the clearance of the incident, on the other.
- The proportion of traffic incidents of major severity (as classified in the *Manual on Uniform Traffic Control Devices*, 2009) in which collaboration occurs between the NCSHP and the NCDOT in incident clearance will be greater than zero.
- There will be a direct association between the factors of incident severity, type of incident, and number of lanes blocked, and the efficiency of incident clearance as measured by incident clearance time.

Null and research hypotheses for each of the specific traffic incident characteristic/ attribute variables are enumerated in Chapter 3: Research Methodology**.**

Theoretical/Conceptual Framework

The theoretical framework of this study was oriented within the fields of emergency management theories and McConnell's (2010) theory of policy failure. Drabek (2004) identified several normative theories of emergency management, which, he pointed out, can and should be useful to the emergency manager if employed in real situations. Tactical management models, the theory of convergence, and program evaluation related to policy success or failure have explained the multifaceted nature of emergency management.

The definition of *emergency management* varies depending upon which agency or entity is involved. Drabek (2004) argued that emergency management is not one idea, but is instead a set of functions that will strengthen an agency's effectiveness; the National Governor's Association has housed these functions under the term "Comprehensive Emergency Management." Various agencies have successfully governed themselves using this umbrella of strategies: "Through a series of common managerial functions, i.e., mitigation, preparedness, response, and recovery, emergency managers can organize their programs for an all-hazard approach through the implementation of a series of broad strategies and specific tactics" (Drabek, 2004, p. 3). Agencies involved in emergency management could be local, state, regional, national, or international agencies.

Tactical management models have provided a more structured system for agency-specific needs. Such models have been the incident command system (ICS; Drabek, 2004) and the National Incident Management System (NIMS). Traffic incident management (TIM), as defined by Delcan (2010), is an additional theoretical model not identified by Drabek (2004) but similar to two of his theoretical models. TIM refers to the “coordinated detection, response to and removal of traffic incidents and the restoration of traffic capacity as quickly and safely as possible” (Delcan, 2010, p. 5). The benefits of TIM include, but are not limited to, reducing traffic congestion and reducing economic cost (NTIMC, 2006; Neudorff et al., 2006). The object of implementing TIM has been to reduce the duration and impact of incidents on traffic flow.

The TIM conceptual paradigm has addressed some aspects of interagency collaboration. The TIM model has been built on coordination among multiple public agencies and private sector partners (Bergner, 2010; Carson, 2008, 2010; Delcan, 2010; Neudorff et al., 2006; Ouyang, 2013). TIM performance measures have included the collaboration and communication among incident responders, safety and traffic operations professionals, agency officials, and researchers working to together to improve the quality of coordinated incident management (Bergner, 2010; Delcan, 2010; Feyen & Eseonu, 2009; Sullivan, 2009). Relevant to incident clearance as discussed in the Introduction, the TIM paradigm has been concerned with the "coordinated detection, response to and removal of traffic incidents and the restoration of traffic capacity as quickly and safely as possible" (Delcan, 2010, p. 5). Coordination and communication between agencies have entailed clarification of roles and responsibilities to ensure the most appropriate and effective incident response (Feyen & Eseonu, 2009).

Incident Command System (ICS), beginning in the 1970s, was implemented as an approach for managing rapidly-spreading wildfires in California (Birenbaum, 2009; Jensen & Waugh, 2014). In the 1980s, ICS became part of the National Incident Management System (NIMS), which is the basis for response to highway incidents (Birenbaum, 2009). ICS has five key functional areas: command, operations, planning, logistics, and finance and administration, which are divided into specialized subunits (Birenbaum, 2009). Its adaptable, standardized, on-scene approach to managing traffic incidents allows responders to operate under an integrated organizational structure without being impeded by jurisdictional boundaries. McEntire (2004), within the context of Homeland Security, also identified what he termed the existence of “permeable borders" between responding agencies that may have different organizational structures. Balke et al. (2002), Carson (2010), and Kreps et al. (1994) additionally discussed the importance of the emergency response’s role when multiple agencies with possible role conflicts collaborate in responding to an emergency.

The modernization of intelligent transportation systems (ITS) and traffic incident management systems (TIMS) immensely influenced the field of emergency management in 2004. ITS have integrated sophisticated information and communication technologies (ICTs) into all operations with the aim of improving traffic conditions, minimizing delays, and enhancing safety (NCDOT, 2014). Incident Command System (ICS) is designed to integrate facilities, equipment, personnel, and communications systems to accomplish efficient, domestic incident management (Dague & Hirami, 2015). ITS have been common practice in the traffic management systems of all 50 states.

Inherent in traffic management is event assessment. According to Jensen (2010), Samuel Henry Prince, a pioneer in disaster research in Canada, first suggested the relationship between event characteristics and emergency response, an important theoretical tenet of emergency management theory referred to as *convergenc*e. The theory of convergence is concerned with the type and severity of the event, “who participates and what they attempt to do, and what strategies and tactics are employed to manage convergence" (Jensen, 2010, p. 16). Jensen has commented that several of these types of propositions "have the potential to be powerful explanatory and predictive tools" but have not been tested (p. 16). Assessing the scene for event characteristics is an essential skill for appropriate incident response.

Planning incident response has meant a close analysis of processes for interagency collaboration. This important aspect inherent in Drabek's (2004) theory emphasizes planning (to enhance preparation). Drabek stressed the necessity for continuous planning, including continual evaluation of changing circumstances (Jensen, 2010). This attitude toward planning and evaluation has intersected with the necessity of continual evaluation of program objectives, and program modifications motivated by this information, to avoid incomplete policy success or policy failure.

Relevant aspects of McConnell's theory of policy failure concern the misunderstanding and partial or total lack of implementation of program objectives, the failure to measure the accomplishment of program objectives, and the subsequent failure to modify policy based upon this program evaluation. Policy failure theory has referred to a taxonomy developed by McConnell (2010). Policy success or failure ranges have included "success, resilient success, conflicted success, precarious success, and failure" (McConnell, 2010, p. 345). An additional concern related to a potential lack of interagency collaboration has been the presence and implementation of policies, regulations, and guidelines, which might suggest an instance of public policy failure (e.g., McConnell, 2010). For example, the Memorandum of Understanding between the NCSHP and NCDOT may reflect a number of aspects within the theory of policy failure effects, such as the evaluation and implementation process of meeting program objectives in regard to collaboration between the two agencies.

Nature of the Study

The aim of this study was to quantitatively investigate some of the parameters alluded to by the emergency management theorists above as those theories apply to the management of traffic incidents. These parameters included the severity of the incident, the nature of the incident, the degree and circumstances of the collaboration between multiple responders, and the effectiveness of the performance of the responders. The study also investigated the degree to which the behavior of multiple responders is congruent with the policy regarding emergency incidence response dictated by interagency agreements.

This was a nonexperimental, quantitative, archival study designed to investigate the extent and circumstances of collaboration, the efficiency of incident clearance carried out by these agencies, and the potential lack of implementation of public policy as expressed in the Memorandum of Understanding regulating the collaboration between the NCSHP and the NCDOT, which are both tasked with incident clearance on North Carolina Highways.

The data for the study were obtained from data sources maintained by the NCDOT and the NCSHP.

The operational measurement of the extent of collaboration between the two agencies was (a) the proportion of traffic incidents in which collaboration occurred and (b) the proportion of traffic incidents of major severity (as defined by the *Manual on*

Uniform Traffic Control Devices, U.S. Department of Transportation, 2009) in which collaboration occurred.

While a number of factors have been hypothesized to be directly related to collaboration and efficiency in incident clearance, the empirical evidence of actual collaboration was the request from the NCSHP for NCDOT participation in the clearance of the incident. As an NCDOT employee who is "on the receiving end" of these requests, I have noticed that more forms and channels of communication would exceedingly improve collaboration between the two agencies. Investigation of this phenomenon could demystify what happens under this currently limited state of communication and collaboration and under what circumstances it has occurred.

The operational measurements of the efficiency of task completion were the incident clearance times reported and recorded by both agencies in their respective databases. These were the following:

- The NCDOT reported clearance time for the incident, which was the elapsed time between the initial notification to the NCDOT of the incident and the time that traffic at the incident site began to flow at the authorized speed limit, and
- The NCSHP reported clearance time for the incident, which was the elapsed time between the initial notification to the NCSHP of the incident and the time that the state trooper left the scene of the incident.

The factors hypothesized to be directly associated with collaboration between the two agencies, the severity of the incident (Balke et al., 2002; Feyen & Eseonu, 2009; Jensen & Waugh, 2014; Kiattikomol et al., 2008); the type of incident that occurred

(Balke et al., 2002; Basu & Maitra, 2010; Manoj & Baker, 2007; Schroeder & Demetsky, 2011) , and the number of lanes that were blocked (Balke et al., 2002; Feyen & Eseonu, 2009), were included in the study.

Independent variables hypothesized to be associated with both the NCDOT and NCSHP reported clearance times. The efficiency of incident clearance, included

- The severity of the traffic incident as defined by the *Manual on Uniform Traffic Control Devices* (USDOT, 2009),
- The type of incident that occurred, and
- The number of lanes that were blocked.

Because the investigation has dealt with the degree of association between incident factors and collaboration in incident responses, and the efficiency of incident responses as measured by incident clearance times, a quantitative study was deemed the most appropriate method to be used in this investigation. The data were analyzed by using chi-square tests, one-sample tests for proportions, and one-way analyses of variance.

Definitions of Selected Terms

The definitions of key terms are outlined below as they pertain to the study.

Clearance is defined as the process of removing the traffic incident (i.e., disabled vehicle, debris, or any other material that blocks the flow of traffic) and restoring the roadway to its preincident condition (Bunn & Savage, 2003).

Collisions are defined as unpredictable, unusual, and unintended external actions that occur in particular times and places, with no apparent and deliberate cause, but with marked effects.

Disabled vehicle is defined as a vehicle that is no longer operable along or in the travel partition of the highway (NCDOT, 2010)

Emergency personnel include firefighters, rescue personnel, law enforcement, tow truck drivers, and the North Carolina Department of Transportation. Emergency service workers can be any personnel called to the scene of a collision or incident to clear it from the travel roadway. This category can include personnel responsible for mitigation activities in a medical emergency, fire emergency, hazardous material emergency, or natural disaster (15 U.S. Code § 2223e, 1974).

Incident Motorists Assistance Program in North Carolina is defined as a service that is provided by NCDOT to warn motorists of impending hazards, aid stranded drivers, and to have the ability to clear travel lanes of disabled or stranded vehicles (NCDOT, 2015).

Incidents are defined as motor vehicle crashes, vehicle breakdowns, flat tires, and work zone or traffic delays resulting in backups along the roadways. They can also be defined as occurrences or events of natural or human origin that require an emergency response to protect life or property (Haddow et al., 2013).

Intermediate traffic incidents are incidents lasting from 30 minutes to 2 hours (US Department of Transportation, 2009).

Lane miles are defined as the number of miles multiplied by the number of lanes on a particular highway (FHWA, 2004).

Major traffic incidents are defined as incidents lasting more than 2 hours with multiagency response and significant impacts to the flow of traffic (i.e., closed lanes; US Department of Transportation, 2009).

Minor traffic incidents are defined as incidents lasting fewer than 30 minutes (US Department of Transportation, 2009).

Manual on Uniform Traffic Control Devices (MUTCD) is a dynamic and constantly changing document established in 1935 to standardize the use and design of traffic control devices across the nation (US Department of Transportation, 2009).

NCDOT clearance time is the time between the initial traffic incident report and the time that traffic begins to flow normally.

NCSHP clearance time is the time of the initial traffic incident report and the time the trooper leaves the scene and "clears" the traffic incident (NCSHP, 2014). As emphasized in the discussion in the previous sections of this chapter, this definition of incident clearance is quite different from that of the NCDOT.

Response is defined as the overall process of dispatching the appropriate personnel and equipment, and implementing the personnel and equipment.

Secondary incidents are defined as subsequent incidents that are directly caused by the initial incident. The initial incident causes an unanticipated stop or slow down in traffic for which the motoring public is not prepared, resulting in additional incidents (Chan, Gan, & Hedi, 2009).

Site management is defined as the practice of coordinating and managing the traffic incident on scene. This is the coordinated effort to expedite the clearing of the scene, protect on-scene responders, assist the direct victims of the traffic incident, and reduce the effect on motorists (Raub & Schofer, 1998).

Traffic incident management is defined as planned and coordinated efforts to remove traffic incidents from the roadway as soon as possible (Carson, 2010).

Traffic management is defined as the use of traffic control measures to assist with traffic in and around a traffic incident scene. This process includes the traffic control devices at the scene of an incident and the availability of equipment, materials, workforce, knowledge, preplanning for response, and alternate route planning (Bunn & Savage, 2003).

Assumptions

The assumptions on which the study was based are outlined below.

- The times logged on the two databases containing the extracted data were verified as accurate. I assumed that the operators at both the North Carolina State Highway Patrol Communications Center and the North Carolina Department of Transportation State Operations Center had accurately logged the traffic incident data recorded in these databases.
- Data were accurately extracted by me from the two databases. A range check on variable values was performed as part of the SPSS *Descriptive* procedure. Patently incorrect data values were tracked down and corrected before statistical analyses were performed.
- Observations on the quantitative dependent variables were normally and independently distributed (Cohen & Cohen, 1975). Because the entire population of observations was included in the sample, the assumption of normality can be relaxed. As the traffic incidents occurred independently of each other—that is, no incident influenced the occurrence of another incident appearing in the sample—the assumption of the statistical independence of the observations was met.

Scope and Delimitations

The study variables were chosen to provide stakeholders and decision makers with actionable data, accurate estimates of incident clearance times, and better knowledge of the level and type of collaboration between state departments of transportation and state-level law enforcement agencies (in the case of the State of North Carolina, the NCDOT and the NCSHP). The data on the variables were recorded by emergency operators located in the North Carolina Department of Transportation State Operations Center, the North Carolina State Highway Patrol Communications Center, North Carolina state troopers, and NCDOT workers and investigators working at the scene of the incident.

As this was an archival study involving extraction of these secondary data from a publically available data source, the study did not have to meet the requirements of internal validity of an experimental or quasi-experimental study.

The target population for the study consisted of 1,580 traffic incidents that occurred on the North Carolina portion of Interstate 95 between January 2014 and December 2014 and that involved collisions, hit-and-run incidents, property damage, fire, direction of traffic at the incident site, and vehicle fires. The principal issue of the external validity of the results of an archival study employing secondary data concerns the generalization of the results to new populations or contexts (Bracht & Glass, 1968). The results of the study could be logically generalized to future incidents occurring on Interstate 95 and other interstate highways with similar traffic patterns and characteristics located in other states. To better facilitate these potential generalizations, statistics describing traffic patterns and characteristics about the portion of Interstate 95 located in

North Carolina are discussed in later chapters. Findings pertaining to the clearance times and factors correlated with clearance times of interstate highway incidents could likely be generalized to states with organizations that function in a manner similar to that of the NCDOT and the NCSHP in their roles of clearing traffic incident sites. In addition, findings related to the collaboration between statewide law enforcement agencies and departments of transportation could be generalized to states with similar administrative structures and roles in highway traffic safety and incident clearance.

Limitations

Internal Validity

As discussed above, this was a nonexperimental study, and threats to internal validity were not applicable.

External Validity

As discussed above, the principal threat to external validity was the inappropriate generalization of the results to another population or context that differs from which the original research was conducted. Under the assumptions that traffic patterns on the North Carolina portion of Interstate 95 and the latency of response to traffic incidents on the part of the NCSHP and NCDOT have not significantly changed during the past 2 years, it is logical to posit that the results from this study of traffic incidents on Interstate 95 occurring between January 2014 and December 2014 could be appropriately generalized to future traffic incidents and traffic incidents occurring on interstate highways in other states that have similar traffic patterns. If, on the other hand, traffic patterns and/or response times on the part of the NCSHP and NCDOT have changed from those present at the time of the study, such generalizations to incidents occurring in future years, or incidents occurring on other interstate highways, would be inappropriate and potentially invalid.

Threats to Construct Validity

The dependent and independent variables in this study were directly measured and are not indicators of latent constructs or variables. Moreover, there were no hypothetical constructs or intervening variables in the data analytic model. Therefore, threats to construct validity were not relevant.

Potential Biases

As mentioned above, the dependent and independent variables in this study were directly measured and therefore could not be influenced by biases inherent in “biased questions” present in questionnaires, or in the scaling or other interpretations or transformations of the raw data performed myself. The most complex data transformation to be initiated by me was the calculation of the difference between the two times logged in the database (i.e. the difference between the time of initial notification of the NCDOT of the traffic incident and the time that traffic was again flowing normally at the incident site). Based on the assumption that the times were accurately logged in the database, it was not thought that these calculations were subject to any biases.

Significance

In this research, I sought to investigate the extent of, and factors associated with, communication between NCSHP and NCDOT in the efficient clearance of traffic incidents. Potential social and organizational changes that may result from the findings of the study include the following:

- According to McConnell (2010), evaluation of the extent of accomplishment of a program's objectives is critical in reformulating or redefining the objectives so that they can realistically be accomplished in practice. If the results of the study have demonstrated a low level of interagency communication and collaboration, it is believed that this finding might motivate senior state-level policy makers in Raleigh to formulate policies designed to increase the level of collaboration, coordination, and collaboration between the two agencies, possibly through increased emphasis on training in traffic incident management.
- Accurate knowledge regarding the time to task completion could provide empirical data to aid in the formation of more effective policies related to traffic incident clearance as well as a more rational allocation of human and fiscal resources.
- The reduction of clearance times could lead to the immediate social and economic benefit accruing from shorter blockages of traffic flow on state and interstate roads and highways.

Summary

The North Carolina State Highway Patrol (NCSHP) and the North Carolina Department of Transportation (NCDOT) have had overlapping missions with respect to traffic incident clearance and, therefore, must have been able to communicate well with each other to provide efficient roadway clearance to reduce the duration of roadway blockages. The extent of communication and collaboration between the two agencies had not been empirically investigated at the time of this study. Additionally, the degree of efficiency in incident clearance displayed by both of these agencies had not been well explored. In order to investigate these issues, the entire population of the 1,580 traffic incidents that occurred on the North Carolina portion of Interstate 95 between January 2014 and December 2014, which consisted of collisions, hit-and-run incidents, property damage, fire, direction of traffic at the incident site, and vehicle fires, was examined.

The proportion of incidents of major severity in which NCDOT was requested to participate in incident clearance and factors hypothesized to be associated with this interagency collaboration were investigated. The extent to which this collaboration achieved the policy objectives outlined in the Memorandum of Understanding between the two agencies was studied. Factors associated with efficiency in incident clearance by both agencies were also investigated.

The next chapter contains a review of the literature related to incident clearance, interagency collaboration, effectiveness in task completion, and policy failure. The nonexperimental archival methodology of the study is discussed in Chapter 3. The descriptive and inferential findings of the study are discussed in Chapter 4. Chapter 5 contains recommendations for public policy relevant to the results of these analyses.

Chapter 2: Literature Review

Introduction

NCDOT and NCSHP have been two of the primary agencies responsible for clearing traffic incidents along North Carolina highways. The North Carolina Department of Transportation (NCDOT) has been tasked with the maintenance of approximately 79,328 miles of highway, the largest network system of roads maintained by a state (NCDOT, 2012). NCDOT has also been entrusted with keeping those same roads free of obstructions that cause travel time delays, congestion, fuel waste and pollution, and secondary crashes. As these tasks are beyond the scope of a single agency, NCDOT has worked closely with other emergency management agencies to mitigate the impact of traffic incidents.

Interagency collaboration is not a novel phenomenon. The extent of collaborations in public policy and practice, including cross-sector collaborations (public, private, and nonprofit organizations) as well as collaborations between government agencies, has grown exponentially over the last few decades (Kapucu & Hu, 2014). Indeed, interagency collaboration has been described as a hallmark feature of modern governance structures (Shepherd & Meehan, 2012). In the case of emergency management, collaborative relationships based on mutual understanding of the roles and resources of all involved parties are deemed critical to an effective response (McGuire & Silvia, 2010). Conversely, weaknesses in collaborative networks are at least partly to blame for adverse outcomes.

Responding to traffic incidents typically has required the work of multiple agencies. However, effective coordination has been complicated by differences in agency objectives and protocols. Each agency has had its own set of objectives on which they have built a specific response protocol (Feyen & Eseonu, 2009). Conflicts often have arisen from these differences, presenting a substantial challenge to those involved in coordinating cohesive multiagency incident management. Collaboration between and even within agencies has posed the greatest challenge in emergency response work (Manoj & Baker, 2007). Obstacles to communication have ranged from radio interoperability between agencies, to the lack of a common vocabulary, and issues (notably trust) related to willingness to share information.

The purpose of this nonexperimental, quantitative, archival study was to investigate the circumstances under which the NCSHP and NCDOT communicate with each other to coordinate the efficient clearance of traffic incidents. Collaboration and efficiency, two important and interrelated conceptual themes, were applied to the problems addressed by this study. The different perspectives of the NCSHP and NCDOT were similar to the differences in objectives and hence in performance measures found in other states between transportation agencies and law enforcement and emergency service providers (Balke et al., 2002). These disparities have often given rise to collaboration problems that impede the efficiency of traffic incident clearance. In a similar vein, Carson (2010) observed that most agencies typically follow their own protocols independent of other agencies responding to the same traffic incident. King (2015) noted that the evolution of traffic incident management (TIP) revealed numerous variations in the priorities and strategies of the various disciplines involved, referencing law enforcement, transportation and public works departments, fire, emergency medical services (EMS), safety and service patrols, and towing companies as the major parties involved. State agencies with overlapping missions such as the NCSHP and the NCDOT have been especially vulnerable to challenges posed by different protocols.

As a result of their disparate orientations toward the task of incident clearance, the NCSHP and the NCDOT have had different definitions and different measurements of traffic incident clearance times and, therefore, of task efficiency. The NCSHP has defined *clearance time* as the time elapsed between the report of the incident and the state trooper's exit from the incident site. This has been a reasonable definition given the specific mission of the State Highway Patrol to organize the cleanup of the site, investigate the circumstances of the incident, investigate potential criminal liability, and complete the collision report.

Furthermore, law enforcement officials have witnessed the greatest number and the most diverse types of traffic incidents. Indeed, King argued that of all the disciplines involved in TIM, law enforcement has the capacity to provide the most comprehensive set of performance data. King's statement was based on Federal Highway Administration (FHWA) recommendations that agencies go beyond the three basic performance measures (roadway clearance time, incident clearance time, and secondary crashes) by including measures related to secondary crashes or other primary incidents. At the same time, King reported that each discipline defined the given performance measures. In most jurisdictions, the documentation of secondary crashes has generally been completed by law enforcement officials.

The NCDOT has been tasked with the clean-up effort so that traffic can begin to flow normally. Therefore, NCDOT activity at the incident site could continue after the state troopers have departed from the incident site. Consequently, the NCDOT has defined the incident clearance time as the elapsed time between the initial notification of the incident and the return of normal traffic flow. In an internal study, the NCDOT reported an average clearance time of 67 minutes for traffic incidents across the state (NCDOT, 2015).

Clearance time efficiency has been crucial, particularly for highways. Traffic delays due to freeway congestion have been highly detrimental to the efficiency and mobility of highway systems (Liu et al., 2013). Accidents have represented one of the key causes of traffic congestion on roads throughout the United States, combined with escalating numbers of vehicles (Lee & Wei, 2010). Traffic incidents including vehicle breakdowns, cargo spills, lane blockages, and severe weather conditions as well as crashes have produced substantial human and financial costs (Ma, Chowdury, Fries, & Ozbay, 2009; Ma, Zhang, Lu, & Yuan, 2014; Taylor, 2008; Vasconez, 2013). Between 2008 and 2012, the number of annual deaths from car crashes in North Carolina, the site of this study, averaged 1,317 and totaled 6,585 fatalities for the 5-year period (TRIP, 2014). As such, travel on the nation's highways requires constant surveillance.

Emergency response agencies have played a pivotal role in ensuring that "lifeline infrastructures and essential services" are immediately restored. Dickey and Santos (2011) declared that "effective critical infrastructure management is essential for guarding a region's economic and social well-being against the consequences of extreme events," given that such events can damage infrastructure and disrupt, if not end, people's lives (p. 1859). The transportation system has embodied the concept of a lifeline infrastructure in a networked society.

A dysfunctional transportation system can have a negative impact on healthy economies. Drivers in the Asheville and Wilmington areas have lost 18 hours each year due to traffic congestion; those in Raleigh-Durham have lost 23 hours to traffic congestion, and Charlotte area drivers are on average stuck in traffic for 40 hours annually. The financial expense of additional travel time and fuel consumption due to traffic congestion, whether due to routine or aberrant incidents, is roughly $37.5 billion per year for 50 large urban areas (Lee & Wei, 2010). Estimates of the national economic burden have ranged from $83 billion to $124 billion (Levy, Buonocore, & von Stackelberg, 2010). For North Carolina residents, the annual cost for extra vehicle operation, lost time, and wasted fuel as a result of traffic congestion and traffic collisions is roughly $6.5 billion (TRIP, 2014). The combination of overwhelming traffic volume and incidents with extended duration is implicated in up to 60% of travel delays (Liu et al., 2013). The cost becomes even greater when considering medical bills of those injured while traveling these highways.

The damage caused by road incidents has been declared a global public health problem. The United Nations General Assembly proclaimed 2011 to 2020 the "Decade for Road Safety" and requested that the World Health Organization (WHO) develop interventions to address the increasing problem (Kondro, 2010). According to WHO's (2013) *Global Status Report on Road Safety 2013: Supporting a Decade of Action*, road traffic injuries are the eighth major cause of death globally and the leading cause of death for young people under age 30. The UN General Assembly (2014) followed up its initial report reaffirming the importance of addressing road safety and developing strategies to mitigate the social and economic consequences of traffic incidents. The UN General

Assembly and the WHO deemed the prevalence of road accidents an impediment to growth and development. The hours lost while drivers are stuck in traffic highlight the detriment to economic productivity and growth presented by traffic congestion. The poor quality of many highways and roads has increased the risk of road accidents.

While the risk of accidents on many highways is high, travelers have not typically avoided these roads. North Carolina's extensive transportation system has provided access to roadways that allow drivers to move freely throughout the state (TRIP, 2014). Indeed, the complex system of roads, highways, bridges, airports, and railways has been described as "the backbone that supports the state's economy," according to the North Carolina Chamber Foundation (p. 2). Attracting new businesses and keeping existing businesses from moving to other states have entailed improving the condition of the transportation network and its capacity for providing individuals and businesses with reliable, efficient transportation.

In the remainder of this chapter, I discuss the literature search strategy, describe the conceptual/theoretical foundation of the study, provide a review of literature related to key variables, and offer a summary of material covered in the chapter.

Literature Search Strategy

The literature presented in this review was drawn mainly from the following EBSCO databases: Academic Search Premier, MasterFILE Premier, and Business Source Premier. Due to the nature of this study, the searches included the websites of state, federal, and international databases related to transportation, traffic incident management, highway safety, highway maintenance, and emergency response. The initial searches focused on the following keywords used individually and in conjunction: *traffic*, *traffic* *incidents*, *traffic accidents*, *traffic congestion*, *road incidents*, *traffic incident management*, *incident response*, *response time*, *emergency management*, and *clearance*. Keywords added to later searches included *efficiency*, *collaboration*, and *communication between organizations tasked with traffic incident management*.

Most searches were limited to the year 2004 onward to coincide with the adoption of Intelligent Transportation Systems (ITS) and Traffic Incident Management Systems (TIMS). ITS have integrated sophisticated information and communication technologies (ICTs) into all operations with the aim of improving traffic conditions, minimizing delays, and enhancing safety (NCDOT, 2014). ITS have been incorporated into the traffic management systems of all 50 states, as has the use of the Incident Command System (ICS). Thus, studies examining traffic incident management prior to the use of ITS and ICS were likely to be outdated. The ICS was designed to integrate facilities, equipment, personnel, and communication systems to accomplish efficient domestic incident management (Dague & Hirami, 2015). The searches were further limited to 2008 to the present to obtain the most up-to-date practical, theoretical, and empirical information about traffic incident management.

Theoretical/Conceptual Framework

This study was driven by aspects of emergency management theory and public policy theory as they relate to interagency collaboration. Working from the broader perspective of emergency management and disaster response, a review of the literature highlights the pivotal role of communication in coordinating an effective response (Comfort, 2007; Kozuch, Sienkiewicz-Matyjurek, & Kozuch, 2014, 2015; Manoj & Baker, 2007). Breakdowns in communication that impeded responses to the World Trade

Center attack and Hurricane Katrina are routinely cited as compelling evidence for improving communication between government agencies as well as between government, nongovernment sectors, and the general public (Canestraro et al., 2009; Comfort, 2007; Jensen & Waugh, 2014; Manoj & Baker, 2007). Negotiation of the path of emergency management via interagency communication and collaboration has provided a suitable conceptual framework for investigating how NCSHP and NCDOT communicate with each other to coordinate the efficient clearance of traffic incidents.

Administrative efficiency has been directly linked with collaboration within and between organizations and individuals. Administrative efficiency has been interpreted as "the efficiency of the gathering, processing, and communicating of information" (Spenkelink, 2012, p. 3). In examining administrative efficiency in the Indonesian medical equipment manufacturing firm PT. Sarandi, Spenkelink (2012) drew on the dimensions of organizational structure as defined by Pugh and colleagues in 1963: standardization, formalization, specialization, centralization, configuration, and flexibility. Research using this model has shown that specialization and standardization/formalization (often combined due to substantial overlap) have been positively connected with administrative efficiency, whereas centralization has detracted from administrative efficiency.

This observed pattern has been especially pertinent in an environment where classic hierarchical and compartmentalized bureaucratic structures are being replaced by flatter organizations, interorganizational networks, and shared governance structures (Curnin & Owen, 2013; Duggan et al., 2015; Kapucu, Arslan, & Collins, 2010; Kapucu & Garayev, 2012; Kapucu & Hu, 2014; McGuire & Silvia, 2010; Neshkova & Guo, 2012; Shepherd & Meehan, 2012). Indeed, McGuire and Silvia (2010) have considered emergency management an "ideal context" for exploring "the general forces of intergovernmental collaboration" (p. 280). Its evolution to a more collaborative model from a management model has been based primarily on hierarchical command and control.

Collaboration, efficiency of task completion, and administrative efficiency have been implicit if not explicit aspects of TIM. Thus, TIM has offered a viable conceptual framework for this study. TIM is a descendent of the Incident Command System, which all organizations involved in emergency management at the federal, state, and local levels were mandated to adopt in the aftermath of the terrorist attacks of September 11, 2001 (Jensen & Waugh, 2014). The following section addresses interagency collaboration in emergency management with a brief background on ICS, followed by a discussion of TIM.

Emergency Management Public Policy

The theoretical framework of this study has been derived from emergency management theories and the theory of policy failure. Drabek (2004) identified several normative theories of emergency management, which, he pointed out, can and should be useful to the emergency manager if employed in real situations. These theories included the idea that "through a series of common managerial functions, i.e., mitigation, preparedness, response, and recovery, emergency managers can organize their programs for an all-hazard approach through implementing a series of broad strategies and specific tactics (Moralista et al., 2014)." As such, management becomes a priority for many large, comprehensive government agencies.

Tactical management models have included the incident command system (ICS) (National Wildfire Coordinating Group, 1994) and the National Incident Management System (NIMS). An additional theoretical model of this type, which was not identified by Drabek (2004), is similar to two theoretical models that he identified, and is more applicable to traffic incident management is the Traffic Incident Management (TIM) model. As defined by Delcan (2010), Traffic Incident Management (TIM) refers to the "coordinated detection, response to and removal of traffic incidents and the restoration of traffic capacity as quickly and safely as possible" (Delcan, 2010, p. 5). The benefits of TIMS include, but not are not limited to, reducing traffic congestion and reducing economic cost (NTIMC, 2006; Neudorff et al., 2006). The object of implementing TIM has been to reduce the duration and impact of incidents on traffic flow.

The Traffic Incident Management (TIM) conceptual paradigm has addressed some aspects of interagency collaboration relevant to incident clearance. Traffic incident management (TIM) is built on coordination among multiple public agencies and private sector partners (Bergner, 2010; Carson, 2008, 2010; Delcan, 2010; Neudorff et al., 2006; Ouyang, 2013). TIM performance has included collaboration and communication among incident responders, safety and traffic operations professionals, agency officials, and researchers working to together to improve the quality of coordinated incident management (Bergner, 2010; Delcan, 2010; Sullivan, 2009). As discussed in the Introduction, the TIM paradigm has been concerned with the "coordinated detection, response to and removal of traffic incidents and the restoration of traffic capacity as quickly and safely as possible" (Delcan, 2010, p. 5). This coordination and communication between agencies has entailed clarification of roles and responsibilities to ensure the most appropriate and effective incident response.

ICS is a standardized, on-scene approach to managing traffic incidents that allows responders to operate under an integrated organizational structure without being impeded by jurisdictional boundaries. Incident Command System (ICS) began in the 1970s when it was implemented as an approach for managing rapidly spreading wildfires in California (Birenbaum, 2009; Jensen & Waugh, 2014). In the 1980s, ICS became part of the National Incident Management System (NIMS), the basis for response to highway incidents (Birenbaum, 2009). ICS has five key functional areas: command, operations, planning, logistics, finance and administration, which are divided into specialized subunits (Birenbaum, 2009). Moreover, ICS is adaptable so that the response matches the level of the incident.

The modernization of Intelligent Transportation Systems (ITS) and Traffic Incident Management Systems (TIMS) has greatly influenced the field of emergency management in 2004. ITS integrate sophisticated information and communication technologies (ICT) into all operations with the aim of improving traffic conditions, minimizing delays, and enhancing safety (NCDOT, 2014). ITS has been the generally accepted practice of state-run traffic management systems, as has been the use of the Incident Command System (ICS) as designed to integrate facilities, equipment, personnel, and communications systems to accomplish efficient, domestic incident management (Dague & Hirami, 2015). As such, the integration of these factors requires strong management.

Effective management requires the application of research-based theories. Drabek's (2004) research has confirmed that "all of these 'normative' theories are relevant to emergency management and provide emergency managers with important theoretical foundations." Balke et al. (2002), Carson (2010), and Kreps et al. (1994) have discussed the importance of the emergency response's role, especially when multiple agencies with possible role conflicts collaborate in responding to an emergency. This concern was echoed by McEntire (2004) within the context of Homeland Security who identified what he termed "permeable borders" between responding agencies. Overlap of duties as related to individual agencies is inevitable during an emergency.

Agencies recognize that planning is necessary to prepare for the unexpected. Drabek (2004) has stressed the necessity for continuous planning including continual evaluation of changing circumstances (Jensen, 2010). This attitude toward planning and evaluation intersects with the necessity of continual evaluation of program objectives, and program modifications motivated by this information, in order to avoid incomplete policy success or policy failure.

A review of the history of policymaking has revealed that policies, which are generally developed by organizations, are more greatly impacted by individuals because individuals are providing the research that shapes the policy. Individuals are confronted with anecdotal evidence from stakeholders, and can view policy changes over time; the development of this policy, therefore, might not reflect organizational needs and values. Weible, Heikkila, deLeon, and Sabatier (2012), and McConnell (2010) emphasized the pressure upon the policy process for data collection and information extraction. As many of these individuals more extensively delve into the policy, the more extensive the knowledge is they obtain toward changing policy, particularly if the policy is deemed successful or unsuccessful.

Management via Interagency Coordination

Historically, response to disasters has been plagued by myriad problems related to difficulties in, but not limited to, interorganizational collaboration, coordination, collaboration, and leadership. Jensen and Waugh (2014) declared that "The United States has a chronic response problem," citing the National Research Council, which reported dysfunctional responses to critical incidents resulting in problems such as failure to grasp the magnitude and severity of an event; delayed and inadequate responses; confusion over jurisdiction and responsibilities (often causing "turf battles"); resource shortages and misallocation; poor collaboration at the organizational, interorganizational, and public level; lack of coordination among government agencies; poor leadership, and inequities in providing disaster assistance (Jensen & Waugh, 2014, pp. 6, 16). The United States has witnessed the effects of this chaos firsthand as the government responded to natural disasters, school shootings, and terrorist attacks.

Disaster responses with such dysfunction can be prevented, asserts many researchers. Comfort's (2007) has critiqued the three critical elements, or "three Cs" of emergency management: *communication, coordination,* and *control.* Comfort later adds a fourth element: *cognition.* Defining cognition as "the triggering insight of emerging risk," Comfort declared that cognition substantially changes the collaboration among communication, coordination, and control and described cognition as a process of ongoing inquiry, building on previous knowledge of the at-risk site, and integrating changing conditions and systems performance into assessment of the current situation (p. 189). This change could improve the outcomes of incident response.

In the context of TIM, models designed for incident detection and prediction would fall under the heading of cognition. Automatic incident detection algorithms (AIDs) have represented the predominate technique for detecting traffic incidents (Li et al., 2013). To accomplish this, the algorithms employ mathematical models based on traffic data obtained from sensors that far surpassed other detection methods in speed, efficiency, and overall utility. Predicting traffic incidents, however, has been far more challenging. According to Qi, Smith, and Guo (2007), the development of accident probability forecasting models has been difficult given that accidents are random occurrences affected by a complex collaboration of factors. For predictive purposes, these factors can be classified into two types: local specific and time varying. Local specific factors are specific to that particular area, and can be roadway configuration, pavement surface conditions, and driver characteristics. Time varying factors, like weather conditions and traffic flow rate, affect all roadways with time variations. The problem has been in the complexity of attempting to integrate all the potentially relevant factors into a model.

Qi et al. (2007) devised a prediction model using panel data, which enables researchers to examine all relevant factors over time. Collecting accident data from the Hampton Roads area of Virginia, Qi et al. based their forecasting model on weather conditions, traffic flow characteristics, and geometric characteristics. Analysis revealed that all three factors were significantly connected with traffic accidents. The findings confirmed the utility of the model as a forecasting tool. According to Qi et al. (2007), integrating the model into a traffic monitoring and management system should enable traffic management centers to devote resources to areas with high accident probability and thus induce a faster response.

Predictive models have become the future of incident management. Kiattikomol, Chatterjee, Hummer, and Younger (2008) conducted their research with the aim of developing models for predicting crashes on urban freeways. Separate models would be devised for crashes of varying severity, ranging from property damage only, injury, to fatality and injury. Data were taken from the archives of the NCDOT and the Tennessee Department of Transportation (TDOT) covering freeway inventory records and crash records. Six North Carolina counties and four Tennessee counties were selected for analysis.

The analyses showed that crashes were much more prevalent on freeway segments influenced by interchanges than freeway segments distant from interchanges (Kiattikomol et al., 2008). Differences, which emerged in the models for North Carolina and Tennessee, were also observed between two-lane and four-lane freeway sections. For example, in North Carolina, crash rates for four-lane segments increased with growing traffic volume. In Tennessee, higher traffic volume produced higher crash rates on sections with more than four lanes. The researchers emphasized that each state should create its own prediction models to effectively capture the unique conditions that influence crash rates. They concluded that their models would be useful for long-range planning in North Carolina and Tennessee.

Prediction models could aid recognition of the magnitude of traffic incidents, promote a more rapid and targeted response, and lead to more efficient allocation of resources. The use of prediction models such as those developed by Qi et al. (2007) and Kiattikomol et al. (2008) would address some of these problems in emergency management response described by the National Research Council (Jensen & Waugh, 2014). However, predictive models have not yet addressed the human elements involved in interagency coordination and collaboration.

Incident Command System

ICS has its roots in the 1970s when it was implemented as an approach for managing rapidly spreading wildfires in California (Birenbaum, 2009; Jensen & Waugh, 2014). In the 1980s, ICS became part of the National Incident Management System (NIMS), which is the basis for response to highway incidents (Birenbaum, 2009). ICS is a standardized, on-scene approach to managing traffic incidents that allows responders to operate under an integrated organizational structure without being impeded by jurisdictional boundaries.

ICS delineates roles and responsibilities for incident responders, while at the same time providing a flexible leadership structure. ICS has five key functional areas: command, operations, planning, logistics, finance and administration, which are divided into specialized subunits (Birenbaum, 2009). These features, specifically high formalization and standardization combined with decentralized governance, are associated with superior administrative efficiency (Spenkelink, 2012). Moreover, ICS is adaptable so that the response matches the level of the incident and its surrounding conditions (Birenbaum, 2009). Thus, the federal government quickly adopted the model.

Unified Command

Another area is need of organizational theory is leadership during incidents. Unified Command (UC) provides a structure for managing incidents that require a response from multiple agencies within a single incident jurisdiction or for incidents that cross multiple jurisdictions (Birenbaum, 2009). UC enables agencies to work collaboratively within an accepted set of common objectives and strategies, which 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 (Birenbaum, 2009, p. 6). This has provided clear areas in which each agency can provide leadership.

Effectively deployed, UC resolves the challenges to interagency communication and collaboration. However, despite the federal mandate to utilize ICS, studies have revealed that it is used inconsistently (Jensen & Waugh, 2014). ICS has been used most consistently by firefighters, most likely due to its origins in fighting fires. Birenbaum (2009) emphasizes that the ICS promotes interagency communication and collaboration, which results in more efficient responses when “applied effectively” (p. 6) but it has not always been the case. According to Jensen and Waugh (2014), ICS has had a sound theoretical foundation but, in practical application, however, myriad factors have influenced its effective implementation of ICS, thus undermining its ability to facilitate communication and collaboration among organizations.

Traffic Incident Management

Decreasing the duration and impact of incidents on traffic flow, which in turn also improves the safety of drivers, crash victims, and incident responders, has been a major goal of the TIM model. Traffic Incident Management (TIM) refers to the “coordinated detection, response to and removal of traffic incidents and the restoration of traffic capacity as quickly and safely as possible” (Delcan, 2010, p. 5). Documented benefits of TIM have included reduced traffic congestion, reduced economic costs, energy conversation and benefits to the environment, reductions in crashes and secondary crashes, fewer roadway fatalities, fewer hospital deaths due to faster emergency medical service (EMS) response, more efficient deployment of public safety personnel, improved responder safety, and increased consumer satisfaction (NTIMC, 2006; Neudorff, et al., 2006). Safety and swiftness of response have been at the core of agencies who implement TIM.

TIM has required extensive collaboration between agencies before, during, and even after incidents. Traffic incident management (TIM) is built on coordination among multiple public agencies and private sector partners (Bergner, 2010; Carson, 2008, 2010; Delcan, 2010; Neudorff et al., 2006; Ouyang, 2013). This does not imply that all incidents demand an extensive response from multiple agencies; most traffic incidents do not (Carson, 2010). Coordination entails clarification of roles and responsibilities to ensure the most appropriate and effective responses (Birenbaum, 2009; Abdel-Aty et al., 2007). In fact, incident responders, safety and traffic operations professionals, agency officials, and researchers are all working to improve TIM performance. TIM Teams are groups of representatives who meet on an ongoing basis to improve the quality of coordinated incident management (Bergner, 2010; Delcan, 2010; Sullivan, 2009). TIM Teams are typically organized by region, but otherwise they can vary substantially in size, composition, organization, and activity level. An ideal team has members from each of the core agencies that respond to traffic incidents including law enforcement, fire and rescue, EMS, transportation, towing and recovery, hazmat teams, public safety dispatch, and communications and the media.

The importance of having a political champion should not be downplayed. The impetus to create a team is actually often driven by a single champion or a dedicated cadre (Delcan, 2010). A proposed plan to relieve Edinburgh's high levels of traffic congestion failed to pass a referendum due to two critical reasons, one of which was the lack of a political champion, which ultimately led to a "no vote" (Rye, Gaunt, & Ison, 2008). Notably, members of the media are often invited to join the TIM teams (Delcan, 2010). Even communication via social networks is also an important strategy for coordinated emergency response (Hossein & Kuti, 2008, 2010). As the Edinburgh study showed, failure to disseminate information about the traffic management plan and secure support among critical stakeholders can doom a plan (Rye et al., 2008). Beyond the use of communication to secure stakeholders, a strong telecommunications infrastructure has been essential for an effective, coordinated response, especially in response to disaster (Canestraro et al., 2009; Patricelli et al., 2009). Disasters have become situations in which the TIM model could be truly tested to handle emergencies.

Communication in Emergency Management

Research has concluded that communication is the key to any effective management model. Communication in emergency management has sought to clarify the nature of events and facilitate the acquisition of information on critical operations needed for an effective response (Kozuch et al., 2015). Citing communication as the main challenge to effective emergency management, Manoj and Baker (2007) delineated three types of communication challenges: technological, sociological, and organizational. According to Manoj and Baker (2007), these three areas are pivotal to “developing and maintaining healthy and effective disaster communication systems” (p. 5). These categories were derived from primary research, practical observations of first responders’ exercises and drills, and workshop discussions.

The first technological challenge following a critical incident has been the quick deployment of communication systems for first responders and other emergency management workers (Manoj & Baker, 2007). While a typical traffic incident is unlikely to disrupt communication networks, major incidents could be caused by powerful weather conditions, like storms and flooding, or even criminal activity. More pertinent to the response to traffic incidents has been the issue of multi-organizational radio interoperability because radio offers the most effective channel for communication across multiple agencies (Manoj & Baker, 2007; Ouyang, 2013). To overcome problems with interoperability, a single frequency can be established for all responders to talk directly with one another; however, the adoption of new technologies is often met by resistance (Manoj & Baker, 2007). Although targeted training is a critical factor in TIMS and effective interorganizational communication and coordination, the process of transferring to single shared frequency entails specialized training and protocols that ensure security, particularly for sharing sensitive information (Bergner, 2010; Bergner & Vasconez, 2015; Curnin & Owen, 2013; Delcan, 2010; King, 2015; Ouyang, 2013; Birenbaum, 2009). These situations illuminate the ways in which training and agencies policies can affect incident response.

Social and organizational challenges may be more difficult to surmount than technological issues. In relation to social challenges, Manoj and Baker (2007) asserted the "understanding of human activity and communication behavior should be incorporated into communication system design" (p. 52). Information sharing has been simultaneously essential and problematic; trust is routinely cited as a critical issue in information sharing between agencies (Canestraro et al., 2009; Kozuch et al., 2014, 2015; Manoj & Baker, 2007; Ouyang, 2013). Natural disasters are only one of many incidents which may bring together responders from starkly different regions who must quickly be able to trust each other's judgment.

Messages can easily get lost or misinterpreted during incident management. One major complication during communication can be the lack of a common vocabulary between response agencies and between agencies and the general public (Manoj & Baker, 2007). In a study of methods and metrics for evaluating interagency coordination in TIM in the Minneapolis-St. Paul area, Feyen and Eseonu (2009) noted that definitions for incidents and severity classifications are specific to each agency and vary according to organizational goals. Indeed, these same variations underlie this study of agencies in North Carolina. In the Minnesota study, Feyen and Eseonu observed that incident severity was contingent on its relationship to the mission of each organization; for example, police departments were concerned with public safety, while Departments of Transportation (DOTs) focused on traffic flow and EMS responders on the presence and extent of injuries. Agencies responding to an incident may have very different goals and must quickly learn to reconcile their missions.

An effective response to incidents can be achieved through the development of an interagency identity. The purpose of Feyen and Eseonu's (2009) research was to identify a common goal across multiple agencies. Based on a comprehensive review of literature and competitive benchmarking involving several major North American cities, the researchers discerned a prevalent interagency goal: *Without compromising safety, minimize the time spent dealing with a traffic-related incident*. From this goal, a set of time-based metrics that could effectively evaluate TIM performance for all the agencies involved was derived. The researchers recognized that their methods are a long way from being adopted universally, but their study demonstrated that the objectives of disparate agencies could be synthesized into a model designed to accomplish a common goal in traffic incident management, despite the many differences that seem to emerge.

Problems often arise in groups where members of organizations marked by hierarchical, centralized decision making finding themselves in a dynamic, less structured environment. Organizational differences have presented the third challenge in emergency management communication (Manoj & Baker, 2007). Manoj and Baker see advantages and disadvantages in both types of structures; hierarchical structures are more prone to information gaps, but flat organizations lack scalability. For optimum effectiveness, the authors have envisioned a hybrid organizational model that employs features of both types of organization. This hybrid model would seem to have the potential for excellent administrative efficiency (Spenkelink, 2012). Manoj and Baker concluded that a reliable and effective communication system for emergency management entails the adoption of a comprehensive approach that resolves each of the three major communication challenges: technological, sociological, and organizational.

Communication and Collaboration

Developing a clear definition of coordination has been key to the field of incident response. Coordination denotes "aligning one's actions with those of other relevant actors and organizations to achieve a shared goal" (Comfort, 2007, p. 194). Comfort emphasizes that the capacity for coordinated effort is contingent on effective collaboration. Curnin and Owen (2013) sought to develop a typology of factors essential to multiagency coordination with the aim of facilitating multiagency coordination in emergency management. An analysis of the research literature revealed four key areas: systems enablers, capabilities, organizational linkages, and mechanisms of collaboration. The findings from the literature review were combined with empirical evidence from a large research project on emergency management in southeast Australia. Much of the data originated with emergency personnel from three areas: emergency services, critical infrastructure, and other organizations (including military and land management). Interview data was combined with field observations of multiagency coordination.

Preliminary conceptualizations were derived from the two-pronged approach (Curnin & Owen, 2013). *Systems enablers* encompass systems used to promote effective information exchange. To accomplish this, the system must have certain features: *technology* that enables stakeholders to be aware of the situation in a timely and relevant manner, which requires *accessibility* to the systems, unimpeded by *guarding* of the information by security barriers. Moreover, the systems must have the facility to *gauge* the event via feed forward and feedback modeling. In case of critical infrastructure failures and systems disruptions, *redundancy* systems must be created.

Capabilities refer to the capabilities of the constituents of the various agencies (Curnin & Owen, 2013). These individuals need the ability to form rapid situational *awareness* to aid collective decision-making, which in turn helps discern *resourcing* requirements. Additionally, constituents must have *clarification* of their respective agencies and their requirements and objectives, which demands *diplomacy* skills to effectively negotiate with internal and external stakeholders. An essential condition for these negotiations is familiarity with other organizations' roles and responsibility, derived from multiagency exercises and *training*.

Organizational linkages refer to the ability of organizations to connect with other organizations (Curnin & Owen, 2013). *Interoperability* of ICT systems and *dissemination* of information are key issues in this endeavor as are boundary spanners. Assuming the role of a boundary spanner entails the presence of a facility for efficient *networking, legitimacy* within the supra organization, and *arrangements* with other organizations.

Mechanisms of communication constitute the fourth and final dimension. These mechanisms depend on the *suitability* of the communications in the midst of heightened demand, *acknowledgement* of receipt of the information, and the incorporation of adequate timeline structures into communication and information systems in response to the *temporality* of emergency situations. According to Curnin & Owen (2013), the boundary spanner should assume a *reticulist* role in acquiring, deploying, and managing information, addressing any gaps and asymmetries in communication and information. This person will stand out in the crowd, bring new ideals and learning opportunities, have vast knowledge of the system in which s/he works, and avoids atrophy (Williams, 2012).

Curnin and Owen (2013) cautioned that the typology is still in the development stage and has not been validated empirically. Nevertheless, it seems promising as a framework for promoting multiagency coordination as the authors intend.

Emergency management presents a curious paradox in that it demands meticulous organization and planning, but at the same time it involves spontaneous actions in response to developing situations. This paradox influenced Kozuch et al. (2014) to explore communication and collaboration in emergency management networks with an extensive review of the literature. They emphasize what lies at the core of interagency coordination in emergency management: “In a complex and dynamic environment, no organization is capable of immediately satisfying all requirements” (Kozuch et al., 2014, p. 28). Coordinated actions must be undertaken in the shortest time possible and then adapted to the specific nature of the situation in accordance with the organizations’ joint capabilities.

Networking as related to communication and collaboration marks a dramatic departure from the traditional command and control model. Kozuch et al. (2014, 2015) approached communication and collaboration from a network perspective, which is increasingly common in emergency management (Kapucu et al., 2010; Kapacu & Garayev, 2012; Kapacu & Hu, 2014). Networking is built on horizontal relationships with far more range, flexibility, and dynamism than the rigid classic bureaucracy (Kapucu et al., 2010). Indeed, Kozuch et al. (2014) argue that a network approach is best suited to emergency management where response must be both comprehensive and matched to each unique situation. Their research was designed to discern the determinants of effective collaboration in emergency management, in particular in relation to close coordination among agencies.

In the context of local emergency networks, collaboration is integral to modeling organizational behavior and coordinating actions. Based on research review and analyses, Kozuch et al. (2015) reached several important conclusions about effective interagency relationships. First, collaboration is a key process underlying the functioning of all organizations and relationships. Second, in emergency management, vertical and horizontal communication each plays a pivotal role. Vertical collaboration creates norms and guidelines for operations and goals, while horizontal collaboration facilitates organizational flexibility and relationship building needed to function under unpredictable conditions. Third, collaboration processes evolve differently between actors. The strongest relationships are found in alliances between police, fire departments, and EMS rescue because collaboration among these entities is ongoing (Kozuch et al., 2015). Fourth, interorganizational relationships in emergency management are contingent on both legal and organizational regulations, as well as formal and informal linkages that develop from working together. Fifth, effective communication enhances relationships within emergency networks, although this relationship is intuitive. As described by Kozuch et al. (2015), “These processes are closely intertwined and complementary and they establish frameworks for emergency management” (p. 101). These conclusions have been supported by evidence documenting the role of communication processes and operations from planning and preparation onward in effective coordination.

The importance of collaboration increases with the magnitude of the situation. The sixth conclusion Kozuch et al. (2015) observed is that communication conditions differ at each stage of the emergency response. Seventh, and finally, collaboration influences the effectiveness of actions performed in emergency management both directly and indirectly. The collaboration of information needed to coordinate efforts has a direct impact on outcomes. The indirect impact comes from the influence of collaboration on shaping informal interorganizational relationships, which in turn impacts the degree of efficiency of collective action in emergency management.

Teamwork and Collaboration

The presence of representatives from the core responder groups on TIM Teams has helped to ensure the establishment of strong, coordinated collaboration networks. Another top priority of TIM Teams is establishing a strategic plan with clearly stated objectives (Bergner, 2010; Delcan, 2010; Sullivan, 2009). Failure to disseminate information about the traffic management plan in order to secure support from critical stakeholders and a lack of clear objectives both contributed to the demise of the Edinburgh traffic management plan (Rye et al., 2008). In addition, the Delcan (2010) report outlined several objectives that are characteristic of successful TIM Teams. At a minimum, successful teams should accomplish the following goals:

- Create a dialogue for better interagency execution of the “4-Cs” of TIM: communication, collaboration, coordination, and consensus;
- Create opportunities for interagency training and exercises, which fosters teamwork;

- Create a tool, or preferably a formal plan for developing common operational strategies;
- Cultivate better understanding of other agencies and their responsibilities; and
- Build practices that help the entire regional area rather than focusing only on the local jurisdiction.

Strategies for improving team performance have included periodically reviewing goals, objectives, and metrics used for evaluation, reviewing the effectiveness of current programs and initiatives, envisioning future improvements, and exploring new opportunities. Teams evolve through several stages; however, high performing teams strive for ongoing improvement (Delcan, 2010). In the case of TIM, continuous development is not only important for improvement in teamwork, but is essential for keeping up with advances in incident response and responder training (Bergner, 2010). Team member input and feedback ensures that the team develops and further advances the successful execution of the 4-Cs, communication, collaboration, coordination, and consensus (Delcan, 2010). A major advantage of teamwork involving the various responder groups is that each group has unique knowledge and strengths they can share with other team members to strive for peak performance.

Some TIM Teams do functional well as a cohesive unit. As an example of how TIM Teams have sought to continually upgrade and improve incident management, members of Maryland's Coordinated Highways Action Response Team (CHART) endeavored to more effectively streamline traffic management actions in response to major accidents that require activation of a Freeway Incident Traffic Management (FITM) plan. Notably, CHART has been hailed as one of the most efficient incident response programs but is still committed to continuous quality improvement (Kim, Franz, & Chang, 2012). Teams should strive for continual improvements, particularly as agencies change leadership.

Detouring entails effective coordination among multiple agencies entrusted with various responsibilities, including estimating the incident duration and its impact boundaries, identifying the available alternate travel routes, deciding where and what to display on dynamic message signs (DMS), and deciding how to accommodate the detoured traffic with responsive signal settings. Efficiently detouring vehicles during responses to major accidents in order to minimize the formation of traffic queues has been a complicated endeavor (Kim et al., 2012). The impact of DMS messages and signaling on drivers' actions cannot be underestimated (Lin, Tung, & Ku, 2010; Schroeder & Demetsky, 2011). Technology has continued to be an integral part of incident management.

A detailed research plan was undertaken to determine how the integration of technology could most effectively be accomplished. An important concern was maximizing cost efficiency due to the substantial financial and energy costs of detouring vehicles. The research project had two key objectives: illuminating the nature of incidents that triggered the activation of the FITM plan over the past five years and developing a decision-making tool that enables traffic engineers to decide whether a detour operation is justified. According to Kim et al. (2012), while the complexity of activating FITM plans is challenging, this same complexity implies that optimizing planning and execution should substantially benefit the network drivers and society as a whole. The decision support system can also serve as an evaluation measure for personnel reviewing past performances of FITM operations as well as aid in redesign or revision required due to changes in the available material and human resources.

Detour operations is a field which receives little consideration when managing an incident. Traditional indicators for initiating detour operations, namely incident duration and number of lanes blocked, have not been adequate for maximizing the benefits of the operation in relation to resource limitations (Kim et al., 2012). Feyen and Eseonu (2009) have advocated adding data beyond the requisite factors for more comprehensive understanding and evaluation of TIM. In view of the restraints on resources and the priorities of each stakeholder agency, Kim et al. (2012) have recommended examining multiple factors in determining the need to detour traffic such as the aforementioned cost-benefit ratio, safety and reliability, accessibility, and acceptability. Kim et al. (2012) reaffirmed the importance of successful coordination between freeway and local traffic agencies, particularly for establishing the duration of the detour. Their recommendations are consistent with the universal objective of minimizing the time spent dealing with a traffic-related incident without compromising safety (Feyen & Eseonu, 2009). Time pressures can be effectively curbed through shared goals and purposeful collaboration.

Responders must be capable of communicating and working collaboratively under intense time pressures toward a common set of goals, while at the same time reporting to different agencies with diverse priorities. King (2015) has emphasized that successful TIM operations entail collaboration and coordination from a diverse group of responders in an extremely stressful and dynamic environment. According to King, carrying out a successful TIM program, which includes gathering performance indicators for evaluation purposes, can potentially improve on-scene activities with the ultimate goal of increasing the safety of all stakeholders. These are important considerations for leaders in the field of incident managers.

Information Sharing in Traffic Incident Management

Despite the proliferation of new technologies, face-to-face collaboration between incident responders has remained the most popular medium for information exchange. Personal exchanges have been most successful when individuals can communicate openly and share information directly. Information exchange is an essential component of TIM (Birenbaum, 2009; Ouyang, 2013). Birenbaum (2009) has noted that most highway incidents do not involve the formal implementation of ICS, but in cases where major, complex incidents demand a multiagency response, all personnel at the scene must be aware of how ICS defines operational task responsibilities, chains of command, and scene management practices. Incident responders are increasingly being trained in ICS and UC, which smooths communication and collaboration when multiple agencies are summoned to the site of a major traffic incident. These exchanges have taken place in shared facilities as well as on the scene and include collaboration at all stages of operations, from planning and preparation, through the incident response and subsequent debriefing sessions.

Traffic operations and management centers (TOC/TMC) have allowed transportation, public safety, and other stakeholders to share communications and information systems. Thus, the facility becomes a center for sharing incident status information. Shared facilities encompass an array of locations in which multiple agencies work collaboratively in planning and debriefing sessions as well as in response to an incident (Birenbaum, 2009). Other examples of shared facilities have included

911/dispatch centers and mobile command posts. Beyond the practical benefit of having a central location for information sharing, shared facilities have allowed partners to work together and bolster relationships between partners as a result of ongoing interpersonal collaborations.

Regular team meetings have offered a neutral environment in which team members can freely discuss unresolved issues as well as share what they have learned. Meetings are often conducted by multidisciplinary TIM teams and task forces that debrief major incidents with the goal of improving TIM response. Incident-related, non-emergency meetings between responders have also provided a venue for information exchange (Birenbaum, 2009). A comprehensive debriefing session includes incident re-creation, input on more and less successful aspects of the response effort, discussion of potential improvements, development of consensus for future events, and documentation of findings and updates of response plans if needed.

Advanced Technologies

Intelligent Transportation Systems (ITS) have represented the most sophisticated technology system for information exchange between transportation and public safety agencies (Birenbaum, 2009). Agent technology and dynamic message signs have been two advanced technologies for conveying information related to traffic flow and traffic incidents.

Agent technology. Agents are highly adaptable to the various tasks inherent in a complex ITS. Agent technology is distinguished by having some human attributes such as reasoning, autonomy, learning, and knowledge communication (Cheng, Lee, & Liu, 2008). Due to these unique properties, agent software is a common component of ITS in applications such as real-time coordination of buses, spatial-temporal traffic data analysis, and advanced traveler information systems. Chen and Cheng (2010) described agent technology as "one of the powerful technologies for the development of distributed complex systems" (p. 485). According to the researchers, agents are often held to be the most important new model for software development since object-oriented software design.

Agent technology can be further enhanced through the effective use of a multi-agent system. Cheng et al. (2008) presented a multi-agent system for the purpose of traffic delay compensation. Their traffic delay compensation mechanism involved three types of agents: Travel Center Agent (TCA), Vehicle Agent (VA), and Road Side Agent (RSA). TCA obtains travel information from VA and it offers VA a global plan suggestion. VA serves the motorist and contacts TCA to help the motorist get to a destination with fair red light waiting time. RSA accepts vehicle information from VA, provides VA with local route suggestions, and on the basis of the vehicle information, controls the traffic lights so each vehicle has a fair and reasonable red light waiting time. Each VA is equipped with the capacity to store a red light waiting record, and based on these records, RSA can give a green light to VAs with long red light waiting time. An optimum system for controlling traffic lights has the capacity to "let *all* [original emphasis] vehicles and pedestrians pass through the intersections smoothly and avoid traffic congestion and accidents" (Chen & Cheng, 2010, p. 16).

In conjunction with the agent system, Cheng et al. (2008) developed a Driver Compliance Model to maximize the compliance value via collaboration of the TCA, RSAs, and VAs. The researchers proposed two different approaches to accomplish this task and conducted experimental tests with the proposed model. The results demonstrated that the agent-based system for traffic light control would provide drivers with fairer and more limited red light waiting time than the traditional fixed traffic light mechanism. Optimal timing of signals has been described as the most effective and cost-efficient strategy for reducing traffic congestion in urban areas (Lin et al., 2010). This system would seem to have the potential to reduce crashes by inducing driver compliance.

A multi-agent system has been used as a mechanism for managing inclement weather conditions on road networks. The model of Marti et al. (2010) has three components: Road Traffic Monitoring, Information Systems, and Management. Road Traffic Monitoring is composed of the Meteorological Station (MS) for collecting data from weather sensors, and the Data Collection Station (DCS) for gathering traffic data. Information Systems is comprised of a Variable Message Signal (VMS), which displays messages to road users, and the RDS-TMC module, a technology for conveying traffic and travel information to motorists through radio signals. Management consists of the Remote Station (RS), which controls MS and VMS. The RS can also be equipped with a RDC-RMC module. In areas with available communications between local systems and the TCC, the local systems provide information to the TCC about weather issues in their designated locale. The proposed traffic management system contains a Traffic Control Center (TCC) with several local systems (Marti et al., 2010). That enables the TCC to make decisions about warning users of prospective problems due to the incident, and TCC will convey the information to local systems, which can display that information to users. The local systems are able to operate independently of the TCC, which is valuable in case of a breakdown in communications between the systems.

Communication between technologies has been found to be just as effective as human communication. Marti et al. (2010) used the A-3 motorway in Spain as a case study for evaluating the proposed multi-agent system. The A-3 contains all the features needed to test the system. The researchers noted that a human operator warning drivers about rain would have produced the same results, thus demonstrating that the multi-agent system was operating properly. Both agent-based traffic management systems, the one developed by Marti et al. (2010) and by Cheng et al. (2008) were still in the prototype stage at the time of their study. However, the results illustrated how the agent system acted to avoid road incidents due to rain.

As agent technology became more advanced, it rapidly became popular in a wide variety of applications ranging from transportation and information management and healthcare to entertainment and online commerce. Chen and Cheng (2010) presented a review of the various applications of agent technology in traffic and transportation systems. According to Chen and Cheng, agent technology has the power to greatly enhance the design and analysis of problem domains under three key conditions: the domain is geographically dispersed, the subsystems exist in a dynamic environment, and the subsystems need to interact more flexibly. These three conditions are exemplified in traffic and transportation systems.

Traffic simulation and driver behavior modeling, and in one case, pedestrian behavior modeling, were the most common applications of multi-agent systems (MAS) to traffic management in the studies reviewed (Chen & Cheng, 2010). One study focused on cooperative traffic management and route guidance, and another on solving urban traffic congestion through traffic scheduling and controlling urban traffic problems. Chen and

Cheng noted that most applications made use of the stationary MAS, which they criticize for its limited capacity for handling uncertainty in a dynamic environment, envisioning greater use of mobile agents in traffic control and management. Given that a traffic information system is generally distributed, “If a mobile agent can migrate to detection stations near the incident scene and process data locally, then it will significantly reduce the delay of incident response” (p. 493). Contrary to initial theories, mobile agents are actually useful for reducing delays in incident response.

In addition, mobile agents have the capacity to facilitate collaboration between distributed roadway electronics and moving vehicles, which is major goal of the ITS systems in the United States. For the most part, communication with moving vehicles by the roadside information infrastructure has depended on expensive and vulnerable wireless network connections. Mobile agents can go on with tasks even if their communication with the main system breaks down. Reiterating the point that mobile agents are best suited for dealing with uncertainty in a dynamic environment, Chen and Cheng (2010) have noted that because “mobile agents can be generated dynamically, new services, operations, or control algorithms can be implemented as mobile agents” (p. 494). Chen and Cheng’s main criticism with the state of agent technology in traffic and transportation management has been the predominance of simulation and modeling. The actual use of agent technology in real-world applications has been rare, though it seems to hold tremendous promise for helping resolve persistent problems that continue to elude the current generation of ITS.

Dynamic Message Signs

Agent systems can be used as an advantage in designing dynamic message signs (DMS), which are used with other media to communicate traffic conditions, weather conditions, diversion tactics, and general information (Birenbaum, 2009; Chen & Cheng, 2010; Marti et al., 2010; Ouyang, 2013). Schroeder and Demetsky (2011) used loop detector data from Richmond, Virginia, to estimate diversion rates that could be ascribed to DMS advisories on I-95 where I-295 is available as an alternate route. DMS are used at the northern and southern junctions of the two highways to alert drivers to blockages attributable to incidents on I-95 and to recommend diversion strategies for maintaining traffic flow and minimizing delays. I-295 slightly extends the distance for motorists driving through Richmond but has a higher speed limit so the times are comparable for both routes. Both routes are comparable in time, and drivers diverting to I-295 are not inconvenienced, which offers an opportunity for investigating the effects of DMS on traffic diversion.

DMS messages can provide insight into driver behavior during an incident. Schroeder and Demetsky (2011) used archived data on DMS messages and traffic flows for incidents and routine traffic on I-95 for their research. All messages fell into three types: warning drivers of delays due to accident on I-95 but with no further guidance, accident alert with recommendation to use an alternate route, and an alert with a specific recommendation to divert to I-295. The messages were then sorted and classified with values assigned according to the following:

- whether or not there was an accident,
- type of message displayed,

- seasonal variations,
- time of day,
- number of lanes closed,
- the type of incident displayed on the sign,
- whether the message displayed the magnitude of an accident,
- the number of phrases contained in the message,
- the mile marker (or no mile marker) displayed,
- whether messages cited the number of lanes closed or open or neither and whether the message read only “LEFT” of “RIGHT” lane closed, and
- only displayed a number, no number, or whether no message was displayed.

The DMS were more likely to increase traffic diversion when displaying a specific message such as alerting motorists to an accident or highway closure ahead or when increasing the number of lanes closed. Schroeder and Demetsky (2011) also observed that the wording affected the drivers’ actions. Spelling out “ALTERNATE” rather than using “ALT” made a marked difference as did citing an incident as ‘MAJOR.” Encouraging drivers to change to a specific route was the most effective strategy for diverting traffic. These findings are very useful because they show that even a simple change in how messages are projected to drivers can increase diversion and therefore reduce delays and congestion.

Analyses conducted of actual and hypothetical traffic scenarios could show that traffic information delivered via DMS could be an excellent mechanism for spatial and temporal management of traffic congestion. Basu and Maitra (2010) examined two types of DMS (TI-I and TI-II) in light of a case study of traffic in the Kolkata Metro City along two urban corridors where there were no DMS installed. TI-I is more primitive and closer to traditional traffic signals. A comparison of the two DMS models revealed only a marginal benefit for the more sophisticated model.

Organizational Efficiency

State agencies have different primary missions that guide responses to traffic incidents. The mission of state DOTs, such as NCDOT, has been restoring traffic to its normal flow, while the mission for law enforcement agencies such as NCSHP has been focused on investigating the incident and collecting potential evidence. While these are both vital and important missions, effective and efficient accomplishment of the common goal of clearing the roadway at the site of an incident has required better understanding between the two agencies. Communication among emergency response agencies and systems is critical for making rapid and clear decisions at traffic incident sites (Kim et al., 2012).

Barriers to interagency communication have interfered with efficient task completion, a key concept in the public policy aspect of traffic incident management. Traffic incidents including vehicle breakdowns, cargo spills, lane blockages, and severe weather conditions as well as crashes, have produced substantial human and financial costs (Ma et al., 2009; Ma et al., 2014; Taylor, 2008; Vasconez, 2013). With respect to each category of incident listed above, a number of tasks must be completed. This process is referred to by the term *incidence clearance*, defined as the process of removing the traffic incident (i.e., disabled vehicle, debris or any other material that blocks the flow of traffic), and restoring the roadway to its preincident condition (Bunn & Savage, 2003).

A review of the literature highlights the dearth of research on the incident clearance process.

Empirical research has demonstrated the superior efficacy of decentralization through several theories. Spenkelink (2012) noted that most theories of organizational efficiency were developed during the 1960s and 1970s, when classic bureaucracies dominate and organizations operated under much more stable and less dynamic or unpredictable conditions than they do today. Formalization and standardization may be even more important in coordinated efforts where clearly demarcated roles, responsibilities, and objectives can be critical for a successful response to a complex emergency situation (Birenbaum, 2009). This can mean major changes for administrative norms in an organization or agency.

In a networked environment, administrative efficiency must be redefined to encompass new structures of governance (Kapucu et al., 2010; Kapucu & Garayev, 2012; Shephard & Meehan, 2012). Kapucu and Garayev (2012) raise the issue of *network sustainability*. In their study involving respondents from four Florida counties, the overarching conclusion was that "emergency management networks are effective to the extent that inter-actor relationships are enhanced for more sustainable relationships" (p. 325). Kapucu and Garayev (2012) advised emergency management networks to be prudent regarding the nature of relationships, in particular to avoid complexity that would be detrimental (as opposed to enhancing) to the overall emergency preparedness and response operations. Notably, the researchers also advised emergency management collaborative networks to invest in ICT for increasing network sustainability. Thusly, a vast array of devices can be deployed in coordinated emergency management efforts

(Birenbaum, 2009). However, formal techniques like protocols or frameworks can decrease the dysfunction of interagency collaboration.

Shepherd and Meehan (2012) developed a multilevel framework for interagency collaboration. While the framework arose in response to the challenge of interagency collaboration in the provision of mental health services in Queensland, Australia, it can be adapted to the operations of any public service agency. In fact, Shepherd and Meehan (2012) consider the framework relevant to policymaking across public sector organizations. The framework consists of four levels (Shepherd & Meehan, 2012). The *strategic level* is the collaborative level composed of planning, developing models of service delivery, sharing goals and common purpose, and mechanisms for understanding. Federal and state government regulations play a prominent role at this level. The *agency level* is marked by policies and procedures, clear role descriptions, guidelines for information sharing, and a database of relevant information. The *service provider level* involves building frontline staff's awareness of interagency programs, keeping information systems up to date, and engaging in regular meetings with other providers (or responders) to discuss shared activities. The *client level* involves the direct provision of service; assuming an active role in service provision and being aware of the roles of the various agencies take place at this level. Information sharing is at the heart of this framework; however, understanding the limits of the agencies is also significant for collaboration.

A notable feature of the framework is the presence of an *Integration Coordinator,* or boundary spanner (Shepherd & Meehan, 2012). Curnin and Owen (2013) described the role of the boundary spanner as one who engages in networking and coordinates with other organizations. McGuire and Silvia (2010) noted that organizations involved in intergovernmental collaboration often have boundary spanners functioning as program specialists whose work largely centers on their collaboration with others outside the organization. The Integration Coordinator, as described by Shepherd and Meehan (2012), facilitates collaboration across levels, organizes meetings and forums, is familiar with policies and protocols of the various agencies and service providers, and is familiar with interagency programs and their stakeholders. The Integration Coordinator plays a critical role in the efficiency and effectiveness of interagency collaboration.

Traffic Incident Management Measures

The adoption of administrative evidence-based practices (A-EBPs) has been increasing in the field of public health; A-EBPs refer to agency level structures and activities that are positively linked with performance measures (Duggan et al., 2015). A-EBPs have five broad dimensions: leadership, workforce development, partnerships, financial processes, and organizational culture and climate. While there appears to be no direct parallel in traffic incident management, there is an escalating trend toward the use of performance metrics for evaluating and improving TIM (Balke et al., 2002; Caltrans, 2010; Feyen & Eseonu, 2009). These measures can help begin the discussion about effective incident management from the perspective of all involved agencies.

Agencies involved in an incident response may use various criteria to define the incident. Balke et al., (2002) conducted an early study, soliciting the perspectives of individuals from transportation, law enforcement, fire, and EMS/rescue agencies working in 15 states. While there was no precise definition of what an “incident” was, most respondents defined an incident as “any event to which they are dispatched or requires a ‘response’ or action by them” (p. 3). The respondents tended to classify incidents according to the tenets of their respective disciplines. That is, transportation agency personnel classified incidents based on their impact on traffic, while law enforcement and emergency response personnel classified incidents based on the number and severity of potential injuries and the amount of equipment required for an effective response. Their study identified the following variables as being related to interagency collaboration and efficient performance in traffic incident responses:

- The type of incident,
- The severity of the incident, and
- The number of traffic lanes that were blocked.

Research further defines incident response through the time it takes to clear the incident. The California Department of Transportation (Caltrans, 2010) led the recognition of the importance of the quick clearance during traffic incidents. One of the strategies identified in the Caltrans Strategic Plan 2007-2012 was to improve incident management. Caltrans Division of Research and Innovation (2010) surveyed thirteen departments of transportation to inquire about their particular measurements of the efficiency of incident clearance. Five of the responding agencies measured the efficiency of their response against a set criterion of a number of minutes to incident clearance (e.g. 90 minutes). Three of the agencies reported using “graduated” response criteria, which depended upon categories of incident severity and types of incidents. For example, Idaho assessed incident clearance in terms of the following incident severities and incident types:

- Response A: Responses up to 30 minutes; stalled vehicles; minor accident;

- Response B: Responses of 30 to 120 minutes; severe accidents requiring investigation and clean-up; and
- Response C: Responses of greater than 120 minutes; catastrophic accidents.

Major incidents are defined as occurring when the California Highway Patrol (CHP) and Caltrans both respond to the incident. While there have been improvements made since reporting on this performance measure began in 2005, the average clearance time for major incidents has still been longer than the target clearance time of less than 90 minutes.

Failure to meet the target clearance time has stimulated research into the relationship between interagency collaboration and clearance. The Balke et al., (2002) and Caltrans (2010) surveys found that the key variables associated with both interagency collaboration and efficiency of incident clearance were type of incident and incident severity (including number of traffic lanes blocked). Due to the varied scaling of incident severity described above (i.e. some scales with “4” designating maximum severity, and other scales with “1” designating maximum of severity), it was decided to use a well-recognized standard scale of incident severity published in the *Manual of Uniform Traffic Control Devices* (USDOT, 2009). The metrics employed on this scale are discussed in Chapter 3.

Not surprisingly, these different conceptions of incidents translated into the use of different performance measures (Balke et al., 2002). *Response time* was a key indicator for both transportation agencies and emergency service providers, but with significant distinctions in how it was operationalized. To transportation agencies, response time typically denoted the time differential between the report of an incident to the TMC and the time the first responder from *any* agency arrived at the scene. For emergency responders, response time referred to the time differential between the time the call came through to *their* dispatcher and the time *their* first response vehicle arrived at the scene. *Clearance time* and *incident duration* (total time) were also defined differently by transportation and emergency services.

Interagency Collaboration

Several years later, Feyen and Eseonu (2009) observed similar disparities in operational definitions employed by the different agencies involved in TIM, which in turn, resulted in the application of different performance measures. Feyen and Eseonu (2009) approached the issue from the perspective of interagency collaboration. The aim of their research was to identify metrics that could be utilized for performance evaluation across agencies. From this goal, they derived a set of time-based metrics that could effectively evaluate TIM performance for all the agencies involved. As demarcated by Feyen and Eseonu (2009), these metrics are:

- *Verification time:* Detection to dispatch,
- *Agency dispatch time:* Dispatch to arrival time,
- *Lane clearance time:* Arrival time to lane clearance time,
- *Queue dissipation:* Lane clearance time to complete incident clearance time,
- *Removal time:* Arrival time to “all clear” time,
- *Overall incident response time:* Dispatch time to all clear time, and
- *Overall incident time:* Detection to all clear time (p. 32).

Employing a process-centered approach, Feyen and Eseonu (2009) found that these metrics were conducive to performance evaluation of incident response based on internal benchmarking data. Variables that tended to have the greatest impact on the duration of incident response included location, time of day, direction of travel, type of incident, weather conditions, number and type of vehicles involved, number and location of lanes involved, number and type of responders needed on scene, and traffic queues (delay). The set of metrics derived from the research could be effectively applied for performance evaluation when aligned with the overarching goal on which there was consensus among agencies.

The work of Feyen and Eseonu (2009) was cited by the Caltrans Division of Research and Innovation as an example of Best Practices in Data Management and Performance Measurement (Caltrans, 2010). The focus of the Caltrans (2010) research was improving clearance time; the investigators found that some state DOTs and regional transportation authorities were actively engaged in assessing TIM performance and striving to improve incident clearance times, with few innovative programs even available. Despite the growing number of studies in this line of research, studies on accident duration forecasting have been scarce (Lee & Wei, 2010). Traffic incident clearance has rarely been the main focus of research, despite recognition of the importance of clearance in reducing congestion and increasing safety (Carson, 2008, 2010; Federal Highway Administration, 2014).

National Unified Goal

Professionals in the field of emergency management concluded that collecting more research from outside the United States, and integrating that research with current practices, would provide insight into development of a common goal. In 2005, representatives from the National Traffic Incident Management Coalition (NTIMC), the FHWA, the Transportation Research Board (TRB), and the American Association of State Highway and Transportation Officials (AASHTO) gathered best practices in Traffic Incident Management (TIM) from several European countries (Vasconez, 2013). Based on 25 recommendations, NTIMC spurred the creation of a national unified goal for TIM in the United States. The National Unified Goal (NUG) has provided state and local agencies a framework for efforts to improve TIM. The goal has also encouraged common multidisciplinary policies, procedures, and practices to support responder safety, safe, clearance, and prompt, reliable collaboration across operations.

Accident duration is defined as “the time between an accident and a roadway clearance” (Lee & Wei, 2010, p. 132). This time frame is divided into three segments: reporting time, which extends from the time the accident occurred to the time of notification; response time, between the time of notification and the arrival of rescue services; and clearance time, the time between rescuer arrival and the accident road clearance. All three times should be improved as a result of the NUG. Key strategies for clearance that earned strong stakeholder support included unified incident command; standardized operations, response, and scene safety practices; more timely and coordinated utilization of technology; 24/7 availability of transportation TIM responders; joint, accredited incident management training; and clearance performance goals (NTIMC, 2006). With respect to clearance goals, the most widely used performance metric by TIM programs was the classification of incident clearance time as either average or maximum. However, the states have historically used different criteria on which to base clearance performance goals. Additionally, public officials could be resistant to the adoption of specific performance goals due to fears about public opinion if performance goals are not met or when compared to other states.

At the time of the inception of the NUG, performance measurement was a new phenomenon for transportation operations professionals, although other responders (fire, EMS, and law enforcement) had been publicly accountable for response times for many years (NTIMC, 2006). The NTIMC recognized that effective performance measurement would entail allocation of additional resources in many states and localities to ensure capability for continuous data collection and analysis. The NUG offered a mechanism for creating a common language for measuring performance that would provide a foundation for reaching agreement on sharing performance data across agencies. Along with agreement on the definition of performance metrics, establishing a uniform, structured mode of reporting was one of the goals of the NUG. The presence of a standardized framework as the basis for evaluation was thought to provide a foundation for agreement on setting clearance goals based on facility and roadway classification and incident types to replace the historically vague performance measures that precluded public accountability.

The National Transportation Operations Coalition (NTOC) developed a set of clearance performance metrics for evaluating the management and operations activities of its members (NTIMC, 2006). Documented benefits of TIM include reduced traffic congestion, reduced economic costs, energy conversation and benefits to the environment, reductions in crashes and secondary crashes, fewer roadway fatalities, fewer hospital deaths due to faster emergency medical service (EMS) response, more efficient deployment of public safety personnel, improved responder safety, and increased consumer satisfaction (NTIMC, 2006). The future of effective incident management rests on continued evaluation of measures nationally and locally.

North Carolina Best Practices

As an important part of its research on traffic incident management, Caltrans (2010) has identified best practices employed by the states as well as best practices in research and reporting. They cite the sharing of best practices as an important strategy for helping transportation agencies decrease major incident clearance times.

Delcan's (2010) report has delineated several best practices for TIM Teams and illustrates examples of best practices implemented by teams in different states. Notably, the North Carolina teams are cited in several examples of best practices; practices adopted by the state of North Carolina in response to quick clearance laws are also cited in national reviews of best practices in TIM and quick clearance laws (Carson, 2008, 2010). The TIM Team responsible for these practices is the North Carolina Executive Committee for Highway Safety. The best practices cited include the following:

- *Abandoned vehicle laws:* North Carolina has enacted quick clearance legislation allowing the immediate clearance of any abandoned vehicle on the paved roadway or shoulder on any state maintained roadway (GS 20-161).
- *Abandoned vehicle immediate tow:* NCDOT has a memorandum of understanding (Memorandum of Understanding, 2011) with the City of Greensboro to allow Incident Management Assistance Patrols (IMAP) to tow or impound any abandoned vehicles off roadway shoulders using the city's towing rotation protocols.

- *Multi-vehicle collision response plan:* The North Carolina Executive Committee for Highway Safety was established in 2006 in the wake of a multi-vehicle collision involving more than 90 vehicles. The incident was triggered by a single car collision with a median barrier as a result of speeding and quickly escalated to a catastrophic event. The TIM team was formed as a result of this incident and the lessons learned from it, and resulting in the formation of the Committee was the development of a “Multi-Vehicle Collision Response Plan.”
- *North Carolina Incident Management Best Practices Video/DVD, cards and cones:* The development of an Incident Management Best Practices video grew out of collaboration between the State Incident Management Engineer and responders, including the state Fire Marshal and law enforcement officials. The video covers NFPA 1901, updating fire equipment and traffic cone placement, high visibility chevron striping and other related practices, and also covers safe vehicle placement and traffic control, as well as other areas. The video serves as a training tool for all responders; the DVD is part of statewide training in the fire academy and is standard training in the Highway Patrol academy (Delcan, 2010; Carson, 2010).

Secondary Incidents

Effectively categorizing events demands a comprehensive technique for identifying secondary incidents. Using incident data from Hampton Roads, Virginia, Zhang and Khattak (2010) investigated roadways where one or more secondary incidents were most likely to occur. They noted that secondary incidents could take place in either direction near or inside a spatial boundary linked with a primary incident, and at any point in the duration of the primary incident. They use the term *event* to denote a group of one or more secondary incidents, which could be categorized on an ordinal scale. Their research examined three questions that would have to be resolved to create the scale the researchers envisioned: (1) what routes are problematic from the perspective of secondary events, (2) what factors are associated with secondary events, and (3) what are the implications of their findings for the purpose of incident management?

Zhang and Khattak (2010) obtained data for the Hampton Roads area on incidents, traffic, and road inventory for 2005. The records covered a total of 43 variables. Queue-based techniques were used to identify adverse events, covering secondary incidents over multiple segments. According to the researchers, this strategy compensates for limitations in studies that based analyses on a fixed geographic boundary. The techniques employed by the researchers enabled them to identify incidents in the opposite direction as well as events with multiple secondary incidents and with high rates of secondary incidents on specific routes. Crashes and incidents with long durations both increased the probability of secondary incidents, which bolsters the argument for safe, quick clearance, further highlighting the universal recognition and vital importance of fast response.

The analyses revealed that multiple vehicle involvement and lane blockage each had independent effects on the occurrence of secondary incidents, and both were strongly linked with more secondary incidents (Zhang & Khattak, 2010). Findings for road geometric configuration showed that incidents occurring on short segments were more often associated with secondary incidents, though curves were not significantly linked with secondary incidents. A number of factors were associated with secondary incidents: crashes, shorter segment, multiple vehicle involvement, lane blockage, longer incident duration, shorter road segment length, and high traffic volume were the major factors. Knowledge of these conditions could guide monitoring of the roadways by traffic managers. Zhang and Khattak (2010) emphasized the pronounced association between lane blockage and secondary incidents, which has implications for quick clearance and traffic diversion strategies. On the whole, the results could be used to deploy resources to areas where secondary crashes are more likely to occur and under the conditions where that probability increases.

The assessment of secondary incidents has relied heavily upon accurate assessment of traffic patterns during the primary incident. Imprialou et al. (2014) criticized Zhang and Khattak (2010) for their lack of attention to the evolution of traffic conditions over the course of the primary incident. According to Imprialou et al. (2014), accurately evaluating whether an incident occurred both temporally and spatially within the parameters of a primary incident requires a technique for identifying the spatiotemporal evolution of traffic flow upstream from the primary incident. They presented two strategies for defining the dynamic boundaries of the impact area of the primary incident using detailed data from upstream loop detectors in the Attica Tollway, an urban motorway connecting the Athens International Airport and the city center.

First, Imprialou et al. (2014) utilized an Automatic Tracking of Moving Jams (ASDA) model to provide information on the spatiotemporal evolution of traffic flow and the incidence of disruptions upstream of the incident. This strategy disclosed effects of the initial traffic conditions and implied effects for other factors such as vehicles involved in the primary incident and the number of blocked lanes. In the next step, the researchers applied real influence area (RIA) techniques, which provide more detailed information on traffic speed evolution. The dynamic methods appear to be superior to static methods for identifying secondary incidents, which does not seem surprising given that the primary incident alters the dynamics of traffic flow. Furthermore, the dynamic methods are easier to implement, although Imprialou et al. (2014) noted that the dynamic techniques have the disadvantage of requiring large amounts of data. They have suggested that the complementary application of analytical techniques may be able to eliminate this issue and even compensate for missing or unreliable data.

The use of archived data has become the basis of many secondary incident prevention models. Chou and Miller-Hooks (2010) noted that static threshold filtering techniques, which use spatial and temporal boundaries for identifying secondary incidents, are frequently utilized, in spite of evidence that those techniques are prone to inaccurately characterize incidents as secondary when they are actually isolated incidents. As a more accurate alternative, they proposed using simulation-based incident filtering (SBSIF), which is based on first identifying the area impacted by the primary incident and then using that data to discern secondary incidents from archived data. Incident data from New York State collected over a period of six months was used to test the validity of the technique in identifying secondary incidents.

The data covered a 16 km segment of Interstate 287 in which 693 primary events were recorded (Chou & Miller-Hooks, 2010). The use of the SBSIF technique with regression analyses, as compared to static methods, reduced the rate of misclassification of incidents by at least 58 percentage points. As it turned out, SBSIF erroneously identified three incidents as secondary; however, the conventional methods inaccurately identified as many as 23 as secondary incidents. According to Chou and Miller-Hooks (2010), the use of SBSIF methods will prove especially advantageous when used with large datasets and will have their greatest utility for agencies that currently have calibrated simulation models of roadways.

Synthesizing the various events during an incident could also improve the practice of incident management. Sun and Chilukuri (2010) focused on *secondary crashes,* noting that the use of the term "secondary crash" rather than "secondary incident" was deliberate in order to emphasize the potential for reducing secondary crashes by improving incident management. Their research presented a strategy for classifying secondary crashes from an easily-deployed crash database. The main source of data was the crash database maintained by the Missouri Highway Patrol. However, Sun and Chilukuri acknowledged that a police database provides only limited information because it only describes downstream conditions, and the data is temporally as well as spatially limited, thus additional data was drawn from intranet incident reports. The traffic reports covered a total of 480 incidents on I-70 and I-270 in St. Louis; these reports all had some type of queue information.

By synthesizing the highway patrol crash data and the traffic incident reports, Sun and Chilukuri (2010) created an Incident Progression Curve (IPC) for a dynamic model of secondary crash identification. Like Chou and Miller-Hooks (2010), Sun and Chilukuri are critical of static models for accurately identifying secondary incidents. They believe that IPCs have many useful applications, particularly incident management. Beyond improving incident management per se, Sun and Chilukuri view secondary crash identification as valuable for improving public safety; using secondary crash statistics could raise public awareness of secondary crashes. They advocate capitalizing on the potential of real-time traffic incident information to help distinguish secondary crashes from primary incidents to accomplish that goal.

Incident Management

Key to incident management has been the facilitation of traffic flow on heavily travelled roads during an incident. According to Liu et al. (2013), the prompt implementation of appropriate diversion tactics would allow drivers to circumvent congested sections of highway by detouring through parallel arteries. In order to accurately guide this type of operation, the governing agency must have the capacity for timely detection of the incident and for implementing effective strategies at all strategic control points within the corridor system, including off-ramps and intersections. Various traffic diversion and route guidance strategies have been developed, giving precedence to either system-optimal or use-optimal traffic conditions on the highway corridor system.

The most basic responsive route guidance tactics are based on current data from the surveillance system without the use of real-time mathematical models (Liu et al., 2013). More sophisticated strategies have employed a dynamic network flow model to predict future traffic conditions based on current traffic status, control inputs, and projected future demands. However, Liu et al. (2013) have been somewhat skeptical of their accuracy. Instead, they utilized a generalized diversion control model of a complex corridor with multiple detour routes composed of several on-ramps and off-ramps, and where sections of parallel arterials are used for diverting traffic in the wake of incidents. The sophisticated model was designed to portray the flow of multi-route traffic along the ramps and surface streets in addition to portraying congestion caused by the drastic increase in traffic demand and changes in patterns in response to the diversion. A 12-mile section of the I-94 East-West corridor between downtown Milwaukee and Waukesha with 12 freeway ramps and 29 signalized intersections along the alternate route (US-18) was selected for the case study.

The findings confirmed the utility of the diversion control model as a strategy for freeway incident management (Liu et al., 2013). The model was sufficiently flexible for traffic operators to decide the appropriate time and control points to initiate diversion control and was significantly superior to a single-segment model; it proved reliable enough to use under conditions where there is a substantial degree of variation in drivers' behavior patterns.

Yin, Murray-Tuite, and Wernstedt (2012) also studied diversion, from the perspective that increasing congestion and delays makes it imperative to understand the effects of traffic diversion. Their research investigated diversion in reaction to incidents, using loop-detector data and records of incidents that occurred on a 12-mile segment of I-66 between Manassas and Falls Church, Virginia. The analysis involved records of 469 incidents that took place in 2009.

According to Yin et al. (2012), their study departed from previous research by including the magnitude of diversion as well as its occurrence, relying on field data as opposed to surveys, and statistically associating diversion behavior and magnitude to quantifiable incident features and traffic conditions. Notably, incident duration was a key factor in diversion; the longer the accident lasted, the more likely it was to spur diversion. The degree of disruption to traffic flow was another significant factor, with more blocked lanes related to more diversion. Drivers were also more likely to divert on weekends than at times dominated by work commutes. Diversion was also more probable in the presence of VMS. Schroeder and Demetsky (2011) explored the effects of VMS displays on diversion in detail. All of these factors substantiate the need for thorough planning related to incident response.

Traffic incident response plans are an essential component of TIM (Carson, 2008, 2010; Delcan, 2010; Vasconez, 2013). Ma et al. (2014) created an algorithm that could be used to generate a traffic incident response plan automatically. They noted that traffic response plans fall primarily into three main types. A *text plan* is a basic plan outlining schemes for responding to potential incidents based on past cases and experiences. A *graphic plan* makes use of a multimedia format, typically using words, pictures, and videos. A *reasoning plan* builds on a graphic plan; intrinsic to some models are simulations of the implementation of a response plan followed by performance evaluation. Most agencies rely on the first two types of plans, but both are inherently limited as they cannot be disseminated during an actual incident response. A text plan could also easily become outmoded because response plans are continually updated, and a plan in book form is not conducive to repeated revision.

The medium of choice for most agencies has typically involved technology. Ma et al. (2014) argue that responding effectively requires “a much more digital, intelligent, and visual type of response plan,” which describes a reasoning plan (p. 2). Case-based reasoning (CBR) and Bayesian Theory were used to develop a reasoning plan that could be automatically generated. Testing with a dataset containing 23 traffic incident cases showed the technique to be feasible and effective. Use of the strategy would add to the value of an ITS as an intelligent system for managing traffic.

Al-Alawi (2010) also proposed a system for optimizing ITS technology. The proposed ITS makes use of Embedded Web Servers (EWS), which simplify the design of systems that require internet connections to carry out monitoring and controlling functions. EWS are microcontrollers that support TCP/IP communications. Therefore, EWS based devices could be connected to any Ethernet network. Users could monitor and control embedded applications with any standard browser. Common uses include industrial control, power-supply monitoring and control, environmental monitoring, telecommunications, health care, home security, and robotics. Highlighting the simplicity of this technology, it has been found in many consumer electronic devices.

The Ethernet has provided an infrastructure for communication between individual nodes dispersed at various intersections and a central traffic management unit (Al-Alawi, 2010). The model is cost-efficient and user friendly; one of its strong points is the speed and simplicity in which it could generate VMS in real time. The EWS-based ITS, has been the ideal host for the reasoning plan described by Ma et al. (2014). The implementation of an ITS per se has increased the effectiveness and efficiency of traffic management (NCDOT, 2014; Omercevic et al., 2008). Incorporating new technologies as they become practical should further improve traffic incident management. Agent technology should be very valuable, but its real-world application to traffic management is still limited (Chen & Cheng, 2010). Many designs are still in the prototype stage.

Accident Duration

Data related to accident duration could enhance the technology used to develop predictive models for incident management. Lee and Wei (2010) employed a data fusion approach to create a multi-period forecast model for accident duration that decreases traffic uncertainty. Real-time traffic data and accident records served as the primary sources of data. In prior research, Lee and Wei identified several factors that are highly significant for developing an accident duration model. These factors include occupied lane, turn over, number of vehicles, and type of vehicles involved in the accident. Genetic algorithm (which decreased the number of model inputs while maintaining important traffic characteristics) and artificial neural network techniques were used to develop the models, which were based on the input variables of accident characteristics, traffic data gathered from vehicle detectors (VDs), time relationships, space relationships, and geometric characteristics, while referring to highway features that may affect the duration of accidents of a similar type. For example, an accident that occurs near a service area is likely to have a different duration than one that takes place near an interchange.

Two accident duration models were derived from the analyses (Lee & Wei, 2010). Model A presents a preliminary forecast based on data capturing traffic conditions just before the accident occurred. Model B comes into play after the accident notification and performs forecasts which are updated every five minutes. Lee and Wei acknowledged that the model might underestimate accident duration time by failing to fully account for lingering congestion. The mean absolute percentage error for forecasting at each time point was typically under 29%, which is adequate. Thus the models could feasibly be integrated into an ITS.

Hazard-based time models, a type of statistical method for examining the occurrence and timing of events, were initially utilized for problems in biomedical, engineering, and social sciences (Ji et al., 2014). They subsequently came to be used to address time issues in transportation. In a hazard-based model, incident time is a depiction of a continuous random variable with a cumulative distributive function known as the failure function. Added to the model are a probability function, survival function, and a hazard function. The relationships between the four functions are formulated according to means probability.

Ji et al. (2014) developed their prediction models using incident data drawn from the Queensland Department of Transport and Main Roads' STREAMS Incident Management System (SIMS) for South East Queensland urban networks from November 2009 to November 2010. During that time records of 35,103 incidents could be classified into nine types: crash, fault, flood, hazard, planned incident, road works, and stationary vehicles. Only three - crash, hazard, and stationary vehicles - were used to develop the models, with a specific distribution model emerging as a best fit for each one. Fourteen significant property variables were associated with clearance time and eight with arrival time, demonstrating that the two times have different impact factors.

Literature Related to Key Variables and Concepts

There has appeared to be an escalating trend toward the use of performance metrics for evaluating and improving TIM (Balke et al., 2002; Caltrans, 2010; Feyen & Eseonu, 2009). Not surprisingly, different conceptions of incidents have translated into the use of different performance measures (Balke et al., 2002). *Response time* was a key indicator for both transportation agencies and emergency service providers, but with significant distinctions in how it was operationalized. To transportation agencies, response time typically denoted the time differential between the report of an incident to the TMC and the time the first responder from *any* agency arrived at the scene. For emergency responders, response time referred to the time differential between the time the call came through to *their* dispatcher and the time *their* first response vehicle arrived at the scene. *Clearance time* and *incident duration* (total time) were also defined differently by transportation and emergency services.

Several years later, Feyen and Eseonu (2009) observed similar disparities in operational definitions employed by the different agencies involved in TIM, which in turn, result in the application of different performance measures. Feyen and Eseonu approached the issue from the perspective of interagency collaboration. The aim of their research was to identify metrics that could be utilized for performance evaluation across agencies. From this goal, they derived a set of time-based metrics that could effectively evaluate TIM performance for all the agencies involved. As demarcated by Feyen and Eseonu, these metrics are:

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

- *Overall incident time:* Detection to all clear time (p. 32).

Employing a process-centered approach, Feyen and Eseonu (2009) found that these metrics were conducive to performance evaluation of incident response based on internal benchmarking data. Variables that tended to have the greatest impact on the duration of incident response included location, time of day, direction of travel, type of incident, weather conditions, number and type of vehicles involved, number and location of lanes involved, number and type of responders needed on scene, and traffic queues (delay). The set of set of metrics derived from the research could be effectively applied for performance evaluation aligned with the overarching goal on which there was consensus among agencies: *Without compromising safety, minimize the time spent dealing with a traffic-related incident* (Feyen & Eseonu, 2009, p. 53).

The work of Feyen and Eseonu (2009) was cited by the Caltrans Division of Research and Innovation as an example of Best Practices in Data Management and Performance Measurement (Caltrans, 2010). The focus of the Caltrans research was improving clearance time. The investigators found that some state DOTs and regional transportation authorities were actively engaged in assessing TIM performance and striving to improve incident clearance times but many others were not. They found evidence of few innovative programs toward this aim. Despite the growing number of studies in this line of research, studies on accident duration forecasting are scarce (Lee & Wei, 2010). Traffic incident clearance is rarely the main focus of research despite recognition of the importance of clearance in reducing congestion and increasing safety (Carson, 2008, 2010; Federal Highway Administration, 2014).

In 2005, representatives from the National Traffic Incident Management Coalition (NTIMC), the FHWA, the Transportation Research Board (TRB), and the American Association of State Highway and Transportation Officials (AASHTO) gathered best practices in Traffic Incident Management (TIM) from several European countries (Vasconez, 2013). Based on 25 recommendations, NTIMC spurred the creation of a national unified goal for TIM in the United States. The National Unified Goal (NUG) provides a framework for efforts to improve TIM by state and local agencies. The goal promotes common multidisciplinary policies, procedures, and practices to support responder safety, safe, clearance, and prompt, reliable communication across operations.

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Balke et al. (2002) conducted an early study, soliciting the perspectives of individuals from transportation, law enforcement, fire, and EMS/rescue agencies working in 15 states. While there was no precise definition of what an "incident" was, most respondents defined an incident as "any event to which they are dispatched or requires a 'response' or action by them (p. 3). The respondents tended to classify incidents according to the tenets of their respective disciplines. That is, transportation agency personnel classified incidents based on their impact on traffic, while law enforcement and emergency response personnel classified incidents based on the number and severity of potential injuries and the amount of equipment required for an effective response. Their study identified the following variables as being associated with interagency communication and efficient performance in traffic incident management responses:

- The type of incident,
- The severity of the incident; and
- The number of traffic lanes that were blocked.

The California Department of Transportation (Caltrans, 2010) recognized the importance of quick clearance of traffic incidents. A strategy identified in the Caltrans Strategic Plan 2007-2012 is to improve incident management. Caltrans Division of Research and Innovation surveyed thirteen departments of transportation to inquire about their particular measurements of the efficiency of incident clearance. Five of the responding agencies measured the efficiency of their response against a set criterion of a number of minutes to incident clearance (e.g. 90 minutes). Three of the agencies reported using “graduated” response criteria which depended upon categories of incident severity and types of incidents. For example, Idaho accessed incident clearance in terms of the following incident severities and incident types:

- Response A: Responses up to 30 minutes involving stalled vehicles; minor accidents
- Response B: Responses of 30 to 120 minutes involving severe accidents requiring investigation and clean-up
- Response C: Responses of greater than 120 minutes involving catastrophic accidents

Major incidents are defined to occur when the California Highway Patrol (CHP) and Caltrans (2010) both respond to the incident. Although there have been improvements made since reporting on this performance measure began in 2005, the average clearance time for major incidents is still longer than the target clearance time of fewer than 90 minutes.

The Balke et al. (2002) and Caltrans (2010) surveys found that the key variables associated with both interagency collaboration and efficiency of incident clearance were: type of incident and incident severity (including number of traffic lanes blocked). Due to the varied scaling of incident severity described above (i.e. some scales with “4” designating maximum severity, and other scales with “1” designating maximum of severity), it was decided to use a well-recognized standard scale of incident severity published in the *Manual of Uniform Traffic Control Devices* (USDOT, 2009). The metric employed on this scale are discussed in Chapter 3.

Studies of clearance of traffic incidents have employed different definitions of response time. These different definitions are tied to the specific mission of the agency responding to the incident, for example, a state trooper, an EMS technician, or a state department of transportation worker. Scales on which the severity of the incident were reported were highly variable, some scales rating a high severity incident as a “1” and other scales rating a high severity incident as a “4.” Some performance metrics were reported as actual response times (i.e., elapsed times defined in different ways, as noted above). Other performance metrics were reported in terms of the proportion of response times meeting a preset criterion or goal.

Summary

The United States’ Strategic Plan cites traffic congestion as one of the nation’s single largest threats to economic prosperity (USDOT, 2015). Traffic incidents and associated congestion accounted for 4.2 billion hours of wasted time, 2.8 billion wasted gallons of fuel and cost approximately 87.2 billion dollars in lost revenue (TTI, 2009). In a study of traffic incident management involving fifteen states, Balke et al., (2002) reported that two principal state agencies with overlapping missions involving traffic incident clearance were state departments of transportation and state and local law enforcement agencies. Balke et al. and other researchers have cited the lack of appropriate interagency collaboration between agencies such as the North Carolina Department of Transportation (NCDOT) and the North Carolina State Highway Patrol (NCSHP), which have such overlapping missions. The studies by Balke et al. and Caltrans (2010) identified the following salient factors influencing interagency collaboration regarding traffic incidents and the efficiency of incident clearance: the type of incident that occurred, and the severity of the incident (including the number of blocked traffic lanes).

There were a number of definitions of response times and incident clearance times depending upon the mission of the agency responding to the incident. The rating of severity of the incident sometimes depended upon the nature of the incident (e.g., major collision, “fender bender,” stalled vehicle) as well as how long it took to clear the incident. Incident severity was scaled and reported using radically different and conflicting numerical scales.

The purpose of this nonexperimental, quantitative, archival study is to investigate the circumstances under which the NCDOT and the NCSHP communicate with each other to cooperate in the efficient clearance of traffic incidents. Neither of these issues has been well studied. It is hypothesized that communication between the agencies are related to the factors identified in the Balke et al. (2002) and Caltrans (2010) surveys, as well as by other researchers (Admi, Elion, Hyams, & Utitiz, 2011; Delcan, 2010; Hogan et al., 2008; Hossain & Kuti, 2008, 2010; Scholtens, 2008).

The study’s findings could be useful in enhancing interagency collaboration as part of the Traffic Incident Management training of members of both agencies, increasing the efficiency of responses rendered by both agencies to traffic incident events, and providing data to State administrators to be used in fiscal and workforce allocations. It is believed that providing data to State administrators could lead to a more efficient allocation of fiscal and human resources. More efficient accident clearance could lead to a reduction in traffic delays which cost personal and commercial road users millions of dollars per year, as well as causing unnecessary damage to the environment.

Chapter 3 provides a discussion of the methodology used in conducting the study, including a discussion of the sample and target populations, archival data sources, and statistical techniques to be employed.

Chapter 3: Research Methodology

Introduction

The problem addressed by this study was the lack of collaboration between two state agencies with overlapping responsibilities in emergency management. The purpose of this nonexperimental, archival study was to investigate the extent and circumstances of collaboration between the North Carolina State Highway Patrol (NCSHP) and the North Carolina Department of Transportation (NCDOT) in the management and the efficiency of resolution of these traffic incidents.

The research questions addressed by the study were the following:

- What is the current extent of collaboration between the NCSHP and the NCDOT in the management and resolution of traffic incidents?
- Under what circumstances did this interagency collaboration take place?
- Which factors or attributes of traffic incidents were associated with the efficiency of incident clearance?
- To what extent did the level of potential administrative dysfunction in collaborative traffic incident management represent an example of public policy failure?

This chapter discusses the dependent and independent variables to be investigated, the sources of data, the population of traffic incidents to be investigated, the statistical and research methodologies to be employed, and the research ethics pertaining to the study.

Research Design and Rationale

This section contains concise definitions of the independent and dependent variables. There were no covariates employed in the study.

Definitions of the dependent variables to be investigated in the study included the following:

- The NCDOT reported clearance time for an incident, which was defined as the elapsed time between the initial notification to the NCDOT of an incident and the time that traffic at an incident site began to flow normally;
- The NCSHP reported clearance time for an incident, which was defined as the elapsed time between the initial notification to the NCSHP of an incident and the time that the state trooper left the scene of the incident; and
- The request to NCDOT to collaborate with the NCSHP in the clearance of a traffic incident of major severity.

From a search of the research literature, the independent variables found to be associated with the collaboration of multiple agencies in incident clearance included:

- The severity of an incident as defined by the *Manual on Uniform Traffic Control Devices,*
- The type of incident that occurred, and
- The number of lanes that were blocked.

The independent variables hypothesized to be associated with efficiency, as measured by both the NCDOT and the NCSHP incident clearance times, included:

- The severity of an incident as defined by the *Manual on Uniform Traffic Control Devices* (USDOT, 2009),
- The type of incident that occurred, and
- The number of lanes that were blocked.

This was a quantitative, nonexperimental, archival study using secondary data from data sources maintained by the NCDOT and the NCSHP. These archives stored data on the independent and dependent variables above and pertain to actual traffic incidents.

Methodology

The research design was a nonexperimental archival study investigating the population of traffic incidents that occurred on the North Carolina portion of Interstate 95 between January 2014 and December 2014 and that involved the following types of incidents: collisions, hit and run, property damage, fire, direction of traffic at the incident site, and vehicle fires.

Population, Sampling, and Sampling Procedure

The data source maintained by the North Carolina State Highway Patrol Communications Center contained records for 1,580 incidents meeting the above criteria. A census of all 1,580 incidents was included in the study. The North Carolina Department of Transportation State Operations Center has data records for the subset of these incidents in which the NCDOT was requested to collaborate in incident clearance. These data records were examined to extract further data relative to the NCDOT's participation in the clearance of that particular incident, including the NCDOT incident clearance time.

The power of a statistical test is the probability of rejecting the null hypothesis when it is false (Cohen, 1969). As the sample consists of a census, that is, the entire target population, no more cases could be sampled. Therefore, this section addresses the statistical power possible with a fixed sample size of 1,580 cases. The alpha level (probability of Type I error) selected was 0.05, which is a traditionally acceptable level of Type I error in behavioral research. The statistical power calculations, employing tables from Cohen (1969), were based upon the requirement of a level of statistical power for each analysis of at least 0.80. Based upon the statistical power calculations, which are discussed in detail in Appendix B, the sample size of 1,580 was sufficient to ensure a level of statistical power of at least 0.80 at an alpha level of 0.05 for each of the proposed analyses.

Archival Data

The data for the study were extracted from two data sources: the North Carolina State Highway Patrol (NCSHP) Communications Center databank and the databank maintained by the North Carolina Department of Transportation's State Transportation Operations Center (NCDOT STOC). I had been given permission from both the NCDOT and the NCSHP to request data, which were output in the form of spreadsheets generated by data managers from both agencies. Due to data security policies, I *did not have direct access* to the databanks within which these requested data were stored. The Data Use Agreements can be found in Appendix C of this study. The historical data retrieved from both the NCSHP and the NCDOT STOC communication centers represented the best source of data for this study, as they were the sole sources of information concerning their respective agencies' responses to traffic incidents. These data were considered public information as defined by the North Carolina Freedom of Information Act. The NC Public Record Law first passed in 1935 and was later amended in 1996 to encompass electronic data, which allowed these data to be acquired for the purpose of public inspection (Public Records, 2014).

Instrumentation

The sources of the data to be analyzed were logs recorded by operators employed by the North Carolina State Highway Patrol Operations Center and operators working at the North Carolina Department of Transportation's State Transportation Operations Center. The data consisted of times of traffic incidents that had occurred on Interstate 95 within the state of North Carolina, which had been forwarded to me in the form of spreadsheets. Because this was an archival and not an experimental or quasi-experimental study, threats to internal validity were not relevant.

Operationalization and Measurement of the Variables

The research variables were measured as follows:

- The NCDOT clearance time was measured as the number of minutes between an initial incident report and the time that traffic begins to flow normally, as logged in the North Carolina Department of Transportation's State Transportation Operations Center (NCDOT STOC) database;
- The NCSHP clearance time was measured as the number of minutes between an initial traffic incident report and the time that the state trooper left the scene of the incident, as logged in the North Carolina State Highway Patrol (NCSHP) database;

- The request of NCDOT to collaborate in the clearance of a particular incident (Yes or No) was retrieved from the record stored in the NCDOT STOC database for each particular incident;
- The rating of the severity of an incident was assessed by the scale appearing in the *Manual on Uniform Traffic Control Devices,* which rates incidents on the following scale: low severity, medium severity, and high severity (U.S. Department of Transportation, 2009);
- The type of incident (e.g., vehicle crash, disabled vehicle) was ascertained from the NCSHP database record for each particular incident by using the NCSHP "Tens Code," which is used to classify incident types; and
- The number of lanes blocked was ascertained from the NCDOT database record for each particular incident.

Spreadsheets provided by data managers of the two agency databanks contained the data necessary to measure the dependent and independent variables analyzed.

Software

The program used to analyze the data was the latest version of SPSS.

Data Cleaning and Screening

The data were delivered in the form of an Excel spreadsheet and then transferred into SPSS. Missing data fields for each case were coded on the Excel spreadsheet as "-1." The data values for each variable were examined using the SPSS *Descriptive* procedure, which provides information on the following:

- The minimum and maximum value for each variable, which provided a range check to identify suspicious outliers and potentially miscoded values, which was then correctly coded before the analyses were performed, and
- The number of missing cases for each variable.

Research Questions

The general research questions that guided this inquiry were as follows:

- What factors were associated with collaboration between the two agencies in resolving a traffic incident? More specifically, what incident factors or attributes were associated with a request to the NCDOT for assistance in the clearance of a traffic incident?
- In what proportion of major traffic incidents was a request for collaboration with NCDOT made?
- What factors were associated with the efficiency of task completion with regard to a traffic incident? More specifically, what factors or attributes of the incident (e.g., incident severity, type of incident) were associated with the incident clearance times reported by the NCSHP and those reported by the NCDOT?

Specific Null and Research Hypotheses

Specific null and research hypotheses involving incident-attribute, indicator-level variables, which were derived from these general questions, are as follows:

- $H_0 1$: There will be no association between incident severity and the request for assistance of the NCDOT in the clearance of an incident.

- $H_1$1: There will be an association between incident severity and the request for assistance of the NCDOT in the clearance of an incident.
- $H_0$2: There will be no association between incident type and the request for assistance of the NCDOT in the clearance of an incident.
- $H_1$2: There will be an association between incident type and the request for assistance of the NCDOT in the clearance of an incident.
- $H_0$3: The proportion of major traffic incidents in which the NCDOT is requested for assistance by the NCSHP in incident clearance will equal zero.
- $H_1$3: The proportion of major traffic incidents in which the NCDOT is requested for assistance by the NCSHP in incident clearance will be greater than zero.
- $H_0$4: There will be no association between incident severity and the incident clearance time reported by the NCSHP.
- $H_1$4: There will be an association between incident severity and the incident clearance time reported by the NCSHP.
- $H_0$5: There will be no association between incident type and the incident clearance time reported by the NCSHP.
- $H_1$5: There will be an association between incident type and the incident clearance time reported by the NCSHP.
- $H_0$6: There will be no association between incident severity and the incident clearance time reported by the NCDOT.

- $H_1$6: There will be an association between incident severity and the incident clearance time reported by the NCDOT.
- $H_0$7: There will be no association between incident type and the incident clearance time reported by the NCDOT.
- $H_1$7: There will be an association between incident type and the incident clearance time reported by the NCDOT.
- $H_0$8: There will be no association between number of lanes blocked and the incident clearance time reported by the NCDOT.
- $H_1$8: There will be an association between number of lanes and the incident clearance time reported by the NCDOT.

Data Analysis Plan

Descriptive statistics were calculated for all of the incident-attribute, indicator-level variables. Inferential analyses involving pairs of categorical variables employed contingency table type analyses (e.g., chi-square tests for independence). Hypothesis tests involving the continuously-scaled incident clearance time measures employed analyses of variance. Details of these procedures are discussed in Chapter 4.

Threats to Validity

Threats to External Validity

The principal issue of the external validity of the results of an archival study employing secondary data concerns the generalization of the results to new populations or contexts (Bracht & Glass, 1968). The results of the study could be logically generalized to future incidents occurring on I-95, other interstate highways located in other states that have similar traffic patterns and characteristics, and other states or political jurisdictions with similar administrative structures that deal with traffic incidents.

Threats to Internal Validity

As an archival study involving extraction of these secondary data from a publically available data source, this study did not have to meet the requirements of internal validity of an experimental or quasi-experimental study.

Threats to Construct Validity

The dependent and independent variables in this study were directly measured and were not indicators of latent constructs or variables. Moreover, there were no hypothetical constructs or intervening variables in the data analytic model. Therefore, threats to construct validity were not relevant.

Ethical Procedures

Information concerning each incident was obtained from the North Carolina Department of Transportation State Transportation Operations Center. Permission to use these data was obtained from the NCDOT safety systems engineer. Permission to use information concerning traffic incidents responded to by the North Carolina State Highway Patrol was obtained from the Colonel of the NCSHP.

Each traffic incident was classified as an event and assigned a number. I encoded the response in a manner that did not reveal particulars about the incident. Information was not coded on the identities of individuals involved in the incidents in the sample. All data were kept on a password-protected computer and kept in a locked office to which only I had access. Once the study is completed, data will be kept for 7 years and then destroyed. All publications or presentations will keep data from the study confidential, and no participants will be identified in any research papers or forums. Therefore, the data will remain anonymous.

Ethical approval was sought by the Ethics Review Office of the Vice-President, Research and Associate Provost at Walden University. Data collection only occurred once the Proposal was reviewed, completed and approved. I abided by the processes outlined by the Institutional Review Board (IRB) at Walden University, United States of America. Data was obtained with permission under IRB Number: 09-16-16-0034587. Data was stored in a locked filing cabinet on an Excel Spreadsheet on my password-protected computer. I completed the National institute of Health's training on "Protecting Human Research Participants" following the informed consent process.

Summary

The purpose of this nonexperimental archival study was to investigate the circumstances under which the NCSHP and NCDOT collaborated with each other in the efficient clearance of traffic incidents. To accomplish this purpose, data were collected on selected characteristics of 1,580 traffic incidents occurring on the North Carolina portion of Interstate 95 between January 2014, and December 2014. The association between these traffic incident characteristics and the occurrence of interagency collaboration between the NCDOT and NCSHP was investigated. Also investigated was the association between these incident characteristics and the efficiency of incident clearance exhibited by both agencies. Specific hypothesis tests and procedures for data acquisition from existing secondary databases were outlined. The results of the descriptive and inferential analyses of the data will be discussed in Chapter 4.

Chapter 4: Results

Introduction

The purpose of this study was to investigate the circumstances under which the NCSHP and NCDOT collaborated with each other in the clearance of traffic incidents and the efficiency of traffic incident clearance achieved by both agencies. In order to accomplish this, data were obtained from the North Carolina State Highway Patrol (NCSHP) Communications Center databank and the databank maintained by the North Carolina Department of Transportation's State Transportation Operations Center (NCDOT STOC) on selected characteristics of 1,580 traffic incidents occurring on the North Carolina portion of Interstate 95 between January 2014 and December 2014. The association between characteristics of these traffic incidents and (a) the occurrence of interagency collaboration between the NCDOT and NCSHP and (b) efficiency of the clearance of these incidents was investigated.

The following research questions for the study were formulated:

- What traffic incident factors or attributes were associated with collaboration between the two agencies concerning a traffic incident? More specifically, what factors were associated with a request to the NCDOT for assistance in the clearance of a traffic incident?
- In what proportion of major traffic incidents was a request for collaboration with NCDOT made?
- What factors were associated with the efficiency of task completion with regard to a traffic incident? More specifically, what incident factors or

attributes were associated with the traffic incident clearance times (i.e., efficiency) reported by the NCSHP and those reported by the NCDOT?

Results

The first part of this section reports the descriptive statistics for the indicator variables employed in the study. The second section describes the results of the hypotheses tests.

The SPSS Descriptive Procedure uncovered an extreme observation on the NCDOT clearance time of 789 minutes for one case. This observation exceeded the mean by 3.93 standard deviations and was in the 99^{th} percentile of the distribution of observations for this indicator. It was therefore considered an outlier, and the case in which it appeared was omitted from the data analysis. Complete data, therefore, were available for 1,579 incidents or 99.93% of the 1,580 incidents in the target population.

Table 1 displays the sample statistics for the NCSHP and NCDOT incident clearance times for the 1,579 incidents, a subset of 114 of which was also responded to by the NCDOT (row 2 of the table).

Table 1

Descriptive Statistics for NCSHP and NCDOT Incident Clearance Times (in Minutes)

				Range		Percentiles					
	N	*M*	*SD*	Min	Max	25	50	75	90	95	99
SHP	1,579	78.48	45.58	1	370	48	71	100	135	159	233
DOT	114	115.92	86.57	0	446	53	95	159	241	295	441

The mean clearance time for the NCSHP was 78.48 minutes with a standard deviation of 45.58 minutes and a median clearance time of 71 minutes. The mean clearance time for the subset of 114 incidents in which the NCDOT also participated in the clearance was

115.92 minutes with a standard deviation of 86.56 minutes and a median clearance time of 95 minutes.

The *Manual on Uniform Traffic Control Devices* (US Department of Transportation, 2009) rated incidents on the following scale of severity: minor severity (incidents of fewer than 30 minutes anticipated duration), intermediate severity (incidents of between 30 minutes and 120 minutes of anticipated duration), and major severity (incidents of greater than 120 minutes of anticipated duration). The distribution of the ratings of the severity of the traffic incidents in this sample is displayed in Table 2.

Table 2

Distribution of Incident Severity Using the Manual on Uniform Traffic Control Devices Standard

Severity	*N*	%
Minor	156	9.9
Intermediate	1,201	76.1
Major	222	14.1
Total	1,579	100.0

The type of traffic incident is reported by the NCSHP as a “Ten Code.” The Ten Codes for the incidents in this sample and their frequencies are displayed in Table 3.

Table 3

Frequencies of NCSHP Ten Codes for Incident Types

Code	*N*	%
Collision (Property Damage, Personal Injury, Fatality)	1,418	89.9
Hit/Run (Property Damage, Personal Injury, Fatality)	103	6.5
Direct Traffic	13	0.8
Vehicle Fire	45	2.8
Total	1,579	100.0

The number of traffic lanes blocked as reported by the NCDOT in the incidents to which it responded is displayed in Table 4.

Table 4

Number of Traffic Lanes Blocked in Incidents Responded to by the NCDOT

No. of Lanes Blocked	No. of Incidents	%
0	24	21.2
1	69	61.1
2	16	14.2
4	4	3.5
Total	114	100.0

Hypothesis Tests

In this section, I report and discuss the results of the tests of the specific research hypotheses enumerated in Chapter 3.

Research Hypothesis 1: There will be an association between incident severity and the request for assistance of the NCDOT in the clearance of an incident.

Table 5 displays the relationship between incident severity and request for assistance of the NCDOT in clearance of the incident. The association between the two indicators was statistically significant (*chi square* = 80.02; $df = 2$; $p < 0.001$). As can be seen from the data in the third row of the table, NCDOT was most likely to be requested for assistance in major incidents, that is, in 21.6% of such incidents.

Table 5

Incident Severity and Request for Assistance of NCDOT

Severity of incident	Request for NCDOT assistance		Total no. of incidents
	No	Yes	
Minor	95.5%	4.25%	156
Intermediate	95.1%	4.9%	1,201
Major	78.4%	21.6%	222
Total no. of incidents	1,465	114	1,579

As shown in the last row of Table 5, collaboration between the two agencies in incident clearance occurred in 114 or 7.2% of all of the incidents in the sample.

Research Hypothesis 2: There will be an association between incident type and the request for assistance of the NCDOT in the clearance of an incident.

In Table 6, the relationship between incident type and request for assistance of the NCDOT in clearance of the incident is displayed. As hypothesized, this relationship was statistically significant (*chi square* = 19.0; *df* = 3; *p* < 0.001). In terms of the raw number of incidents, NCDOT assistance was requested most often for collisions. However, as can be seen from the data in the fourth row of the table, the category in which the highest percentage of requests for NCDOT assistance was made was for assistance in incidents that involved vehicle fires (i.e., in 22.2% of such incidents).

Table 6

Incident Type and Request for Assistance of NCDOT Within Each Incident Type

Incident type	Request for NCDOT Assistance		Total no. of incidents
	No	Yes	
Collision (prop. damage, pers. injury, fatality)	92.9%	7.1%	1,418
Hit/run (property damage, personal injury, fatality)	97.1%	2.9%	103
Direct traffic	100.0%	0.0%	13
Vehicle fire	77.8%	22.2%	45
Total no. of incidents	1,465	114	1,579

Research Hypothesis 3: The proportion of major traffic incidents in which the NCDOT is requested for assistance by the NCSHP in incident clearance will be greater than zero.

The NCDOT was requested by the NCSHP to collaborate in the clearance of 21.6% (i.e., 48) of the 222 major incidents in the sample. This proportion was significantly different from 0.0 ($Z = 7.46$; $p < 0.001$). The 95% confidence interval for the sample proportion was 16.2% - 27%.

Research Hypothesis 4: There will be an association between incident severity and the incident clearance time reported by the NCSHP.

Table 7

Means and Standard Deviations of NCSHP Clearance Times in Minutes by Incident Severity

Severity of incident	*M*	*SD*
Minor	19.04	7.82
Intermediate	70.70	25.53
Major	162.33	43.59
Total	78.48	45.58

As can be seen from the pattern of means in Table 7, there was a monotonic increasing relationship between incident severity and mean NCSHP clearance time. This relationship represented a significant quadratic trend among the means (F (Quadratic) = 161.55; df = 1, 1576; $p < 0.001$).

Research Hypothesis 5: There will be an association between incident type and the incident clearance time reported by the NCSHP.

Table 8

Means and Standard Deviations of NCSHP Clearance Times in Minutes by Incident Type

Type of incident	*M*	*SD*
Collision (property damage, personal injury, fatality)	78.81	44.43
Hit/run (property damage, personal injury, fatality)	71.31	47.30
Direct traffic	49.08	42.06
Vehicle fire	92.96	68.35
Total	78.48	45.58

Table 8 displays the mean NCSHP clearance times for each incident type. There was a significant association between type of incident and NCSHP clearance time (F = 4.22; df = 3, 1575; $p < 0.006$). Scheffė post hoc comparisons indicated that the mean NCSHP clearance time for the direct traffic incident type differed significantly from the mean clearance time for the vehicle fire incident type; however, the means for the other types of incidents did not significantly differ from each other.

Research Hypothesis 6: There will be an association between incident severity and the incident clearance time reported by the NCDOT.

Table 9

Means and Standard Deviations of NCDOT Clearance Times in Minutes by Incident Severity

Severity of incident	***M***	***SD***
Minor	17.50	9.77
Intermediate	73.81	26.42
Major	201.16	80.47
Total	115.92	86.57

As shown in Table 9, and as was the case with incident severity and mean NCSHP clearance time, there was a significant monotonic increasing relationship between incident severity and mean NCDOT clearance time (F (Quadratic) = 10.25; df = 1, 111; $p < 0.002$).

Research Hypothesis 7: There will be an association between incident type and the incident clearance time reported by the NCDOT.

Table 10

Means and Standard Deviations of NCDOT Clearance Times in Minutes by Incident Type

Type of incident	*M*	*SD*
Collision (property damage, personal injury, fatality)	111.89	86.76
Hit/run (property damage, personal injury, fatality)	84.00	56.56
Vehicle fire	166.20	80.10
Total	115.92	85.57

The mean NCDOT clearance times for the different types of traffic incidents are presented in Table 10. There were no statistically significant differences among the mean clearance times ($F = 2.037$; df = 2, 111; $p < 0.135$) among the incident types.

Research Hypothesis 8: There will be an association between number of lanes blocked and the incident clearance time reported by the NCDOT.

Table 11

Means and Standard Deviations of NCDOT Clearance Times in Minutes by Number of Lanes Blocked

No. of lanes blocked	*M*	*SD*
0	97.96	81.21
1	120.43	84.99
2	106.00	78.76
4	179.00	159.13

The mean NCDOT clearance times for the number of lanes blocked are displayed in Table 11. Note that there is a reversal in the magnitudes of the mean clearance times in rows 1 and 2 of the table. As there were only 16 incidents to which the NCDOT responded and in which two lanes were blocked and only four incidents to which the NCDOT responded and in which all four lanes of I-95 were blocked, the data in the last two rows of the table should probably be ignored for inferential purposes. The *F* test for the overall association between number of lanes blocked and the NCDOT clearance times was not statistically significant ($F = 1.18$; $df = 3, 109$; $p < 0.320$).

Summary

The association between traffic incident characteristics and the occurrence and efficiency of interagency collaboration between the NCDOT and NCSHP in incident clearance was investigated. The sample for the study consisted of the population of 1,580 traffic incidents that had occurred along the North Carolina portion of Interstate Highway 95 between January 2014, and December 2014. Complete and usable data were available for 1,579 of these incidents. Significant findings included the following:

- The mean NCSHP clearance time was 78.48 minutes with a standard deviation of 45.58 minutes.
- The mean NCDOT clearance time for the subset of 114 incidents in which NCDOT collaborated with NCSHP was 115.92 minutes with a standard deviation of 86.57 minutes.
- Collaboration between the two agencies occurred in 114 or 7.2% of all of the incidents in the sample, with collaboration most likely to occur in severe incidents.
- Interagency collaboration occurred in 21.6% of the 222 incidents of major severity in the sample.
- Incident severity was significantly related to both NCSHP and NCDOT incident clearance time.
- The type of incident was significantly related to NCSHP incident clearance time, but not to NCDOT incident clearance time.
- The highest mean NCSHP incident clearance time was for vehicle fires (92.96 minutes).
- In terms of raw numbers, the type of incident in which collaboration most likely occurred was in clearing collisions (the overall most frequently occurring type of incident). However, the incident category with the greatest *percentage* of collaboration was vehicle fires. Collaboration between the two agencies occurred in 22.2% of all of the vehicle fire incidents.

- The number of lanes blocked was not significantly related to NCDOT incident clearance time.

In Chapter 5, I discuss the findings in light of other empirical research and theory and offer suggestions and recommendations for public policy and further research.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The purpose of the study was to investigate the circumstances under which the NCSHP and NCDOT collaborated with each other in the efficient clearance of traffic incidents and the efficiency with which both agencies cleared traffic incidents. Data were obtained from the North Carolina State Highway Patrol (NCSHP) Communications Center databank and the databank maintained by the North Carolina Department of Transportation's State Transportation Operations Center (NCDOT STOC) on selected characteristics of 1,580 traffic incidents occurring on the North Carolina portion of Interstate 95 between January 2014 and December 2014. Complete and useable data were available for 1,579 of the incidents. The association between these traffic incident characteristics and the occurrence of interagency collaboration between the NCDOT and NCSHP, and the efficiency of incident clearance was investigated.

The principal findings of the study were as follows:

- The mean NCSHP clearance time was 78.48 minutes.
- The mean NCDOT clearance time for the subset of 114 incidents in which NCDOT collaborated with NCSHP was 115.92 minutes.
- Interagency collaboration occurred in only 114 (7.2%) of the 1,579 incidents.
- Interagency collaboration occurred in only 21.6% of the 222 major incidents in the sample (as classified by the rubric for incident severity published in the *Manual on Uniform Traffic Control Devices*).
- Incident severity was significantly related to both NCSHP and NCDOT incident clearance time.

- The type of incident was significantly related to NCSHP incident clearance time, but not to NCDOT incident clearance time.
- The highest mean NCSHP incident clearance time was for vehicle fires (92.96 minutes).
- In terms of raw numbers, the type of incident in which collaboration most likely occurred was clearing collisions (the most frequently occurring type of incident). However, the incident category with greatest *percentage* of collaboration was vehicle fires. Collaboration between the two agencies occurred in 22.2% of all of the vehicle fire incidents.
- The number of lanes blocked was not significantly related to NCDOT incident clearance time.

Interpretation of the Findings

As found by Feyen (2009) and Balke (2002), incident severity was significantly related to incident clearance time. This association was found for both the NCSHP and NCDOT incident clearance times.

Similar to the finding of Feyen and Eseonu (2009), the type of incident was also associated with incident clearance times for the NCSHP but not for the NCDOT clearance times. This finding is not surprising, as the missions and goals of each organization are different. While both ensure safe highways, the NCDOT has the additional responsibility to maintain the infrastructure of roads and efficient flow of traffic. This issue is discussed in additional detail below.

Contrary to findings of Balke (2002), Kim et al. (2010), and CALTRANS (2002), the number of lanes blocked was not significantly related to NCDOT incident clearance time. This finding may be due to the difference in the initial report of the blockage and the on-scene assessment of the lane blockage. Many times, upon arriving on scene, the responder will render an assessment that is based upon the causes of the incident and thus change the report of the number of blocked lanes.

In terms of raw numbers, the type of incident in which collaboration between the two agencies most likely occurred was in clearing collisions. This is a logical finding, as collisions were the most frequently occurring type of incident.

However, the incident category with greatest *percentage* of collaboration between the two agencies was vehicle fires. Collaboration between the two agencies occurred in 22.2% of all of the vehicle fire incidents. This is consistent with the findings of Birenbaum (2009), Berenger (2010), Carson (2008, 2010), and Ouyang (2013). Kozuch (2015) and Jensen and Waugh (2014) discussed the norms of Incident Command Systems (ICS), which originated in fire services and which govern much of the public safety sector. Out of this system has emerged a more tightly knit group of responders who are more likely to collaborate with other agencies because collaboration is more normalized for fire departments, as appeared to have occurred in this category of incident in the sample.

The mean NCSHP clearance time was 78.48 minutes. This finding simply reflects the reporting officer's arrival and departure from the scene. This time is not indicative of the time related to when the incident occurred and when the incident was cleared from the road. Therefore, this time does not capture the complete picture of the severity of the incident, but solely captures the amount of time the officer spent *on the scene* with the incident. This time may also reflect the time between the officer's declaration of his presence on scene and his declaration that his report was complete as related to the incident.

Interagency collaboration occurred in only 21.6 % of the 222 incidents of major severity in the sample. An incident is not declared a major incident until the time to clear has been determined, which occurs once traffic is restored to its normal flow of 70 MPH. The request for assistance for NCDOT in these incidents would have required an estimate by the responding officer upon his or her arrival that clearance could require more than 120 minutes. The failure to request NCDOT for assistance in nearly four out of five major incidents points to several problems. One major problem could have been lack of appropriate on-scene assessment by responding parties. Typically, responding parties utilize TIMS (Traffic Incident Management System) training to accurately predict clearance time. However, the low proportion of interagency collaborations of 21.6 % could support misuse of or failure to use protocols that can determine clearance time and thus require the assistance of the NCDOT as per the Memorandum of Understanding between the NCSHP and the NCDOT, which is discussed in detail below.

An additional problem with the lack of requests for assistance is inherent in the reporting of an incident. Various agencies, such as fire departments, 911 dispatchers, and Statewide Transportation Operations Center traffic management specialist operators, have the ability and opportunity to contact NCDOT; therefore, NCSHP is not the sole agency that could request assistance from the NCDOT. NCSHP responds to calls from its own telecommunications center. In addition, the use of two separate communications centers could complicate the communication of the information necessary to facilitate collaboration in clearing traffic incidents.

The mean NCDOT clearance time for the subset of 114 incidents in which NCDOT collaborated with NCSHP was 115.92 minutes. This is well above the national average of 90 minutes as determined by the National Highway Traffic Safety Administration (NHTSA). This time reflects not only the time that NCDOT cleared the scene, but also the time that the highway traffic resumed its normal 70 MPH flow.

The level of cooperation and collaboration between the NCSHP and NCDOT, as revealed in the findings of this study, was along the lines predicted by the "normative" emergency management models of Drabek (2004), Delcan (2010), and Jensen (2010), and fell within the policy success/failure spectrum developed by McConnell (2010). Both tactical management models, ICS and TIM emphasized the need for agencies to narrow their missions while simultaneously creating space for working with other agencies. Jensen's (2010) theory of convergence explains how the characteristics of an incident have a direct impact on the type of response from emergency responders; Jensen argued that the management of convergence had yet to be tested to its fullest extent. Governing these agencies are policies and regulations that highlight the ways in which they will operate and, more specifically, how they will respond to incidents and collaborate with other agencies. The success of the implementation of the Memorandum of Understanding (MOU), which governs the extent of collaboration between the NCDOT and the NCSHP, can be viewed within McConnell's policy failure framework.

Drabek (2004) and Delcan (2010) asserted that a TIM model should be the basis for interagency collaboration and communication. This model indicates that safety and speed of incident management are the goal of such collaboration. The MOU that governs the collaboration between the NCDOT and the NCSHP has defined the ways in which traffic incidents are managed. Therefore, with an average clearance time well above the national average, the tactic agreed upon in the MOU must be revisited for its effectiveness within TIM performance measures.

Jensen's (2010) theory of convergence posits that the characteristics of an incident will directly affect the response. NCDOT was requested to collaborate on more vehicle fires (on a percentage basis) than any other type of incident. The characteristics of a vehicle fire specifically encouraged collaboration with NCDOT, as fires could spread quickly and thus could affect lane closures and cause damage to the road. NCDOT was also requested to collaborate on major incidents (i.e., those lasting longer than 120 minutes). The MOU between the NCSHP and NCDOT, consistent with TIM, has committed staff to clearing incidents as quickly as possible using the most necessary of tactics. The complexities of major incidents, and the lengths of time the incidents last, have required a response that invokes collaboration between agencies.

McConnell (2010) has noted that policy success or failure involves determining implementation of the policy, understanding of the policy, measurement of the policy's effects, or evaluation and modification of policy. The findings have indicated that the MOU, which contains the agreement between NCDOT and NCSHP to facilitate the clearance of incidents quickly and safely, may fall near the policy failure end of the spectrum. Due to finding that the average clearance time for incidents in which collaboration took place was well over the national average, as well as the low percentage of major traffic incidents addressed in collaboration by both agencies, the goals of the MOU are not being met. As such, the NCDOT and NCSHP need to determine whether the policy failed due to lack of implementation/practice, misunderstanding of the policy, inaccurate measurement of the achievement of the policy's objectives, or lack of evaluation and corresponding modification of the policy.

Limitations of the Study

This was a nonexperimental archival study employing data on selected indicators provided by the North Carolina State Highway Patrol Communications Center and the North Carolina Department of Transportation's State Transportation Operations Center. The principal threat to external validity of the interpretation of the results was the inappropriate generalization of the results to another population or context that differs from the one in which the original research was conducted (Bracht & Glass, 1968). Under the assumptions that traffic patterns on the North Carolina portion of Interstate 95 and the latency of response to traffic incidents on the part of the NCSHP and NCDOT have not significantly changed during from those during the past 2 years, it would be logical to posit that the results from this study of traffic incidents on Interstate 95 occurring between January 2014 and December 2014 could be potentially generalized to future traffic incidents and traffic incidents occurring on interstate highways in other states which have similar traffic patterns. If, on the other hand, traffic patterns and/or response times on the part of the NCSHP and NCDOT have changed from those present at the time of the study, such generalizations to incidents occurring in future years, or incidents occurring on other interstate highways, would be inappropriate and potentially invalid.

Unlike much of the interstate highway system, the North Carolina portion of Interstate 95 investigated in this study has provided for only two lanes of traffic in each direction. While the number of lanes blocked was not found to be significantly related to incident clearance time, this structural limitation on traffic flow on the North Carolina portion of I-95 might still have some bearing on the generalization of the results to portions of the interstate system that have more lanes running in each direction.

Another potentially quite important limitation on the generalization of the results concerns the nature of the relationships between or among the emergency response organizations. The more similar an organization is to the NCSHP and the NCDOT, the greater the potential for generalization of the results to that organizational context.

Recommendations for Research

Studying the amount of time associated with the clearance of traffic incidents has presented a one-dimensional picture of incident severity. The *Manual on Uniform Traffic Control Devices* has defined its categories of incident severity strictly on the basis of time on the scene of the incident. This limited criterion is similar to the use of the Saffir-Simpson Hurricane Scale, which uses wind speed to categorize a hurricane from the lowest wind speed of 1 to the highest wind speed of 5. During North Carolina's encounter with Hurricane Matthew in 2016, this scale was insufficient to measure the magnitude of flooding that would damage roads and isolate towns for weeks. One-dimensional scales only provide a variable to measure an outcome, which in this study was incident severity. The measurement of incident severity is a challenging task due to a wide range of variables that could affect incident clearance time. A more comprehensive collection of data related to variables that affect clearance times would help further define the various levels of incident severity and as such could impact response times to incidents as well as clearance times. Research on other variables that could determine incident severity as defined by estimated time of clearance could assist incident responders in assessing the scene more quickly and efficiently.

The NCDOT STOC has collected information regarding the number of lanes blocked during a traffic incident. However, the STOC has not collected information about incidents that occur on the shoulder of the road that could still impact normal traffic flow. More research into the impact of incidents on the shoulder of the road could greatly alter the practices of NCSHP and NCDOT when it comes to quick clearance.

Vehicles fires on highways perhaps pose more of a threat to other drivers than collisions. Due to the special nature of fires, more research could be conducted on how NCDOT could more efficiently respond to fires and collaborate with local fire departments.

Implications

Incident severity is determined by the amount of time necessary to clear the road; this is the intent of quick clearance legislation. Feyen and Eseonu (2009) have echoed that collaboration is necessary due to the complex nature of major incidents. Quick clearance policy, enacted by the majority of state governments in the early 2000s, is used so that government entities have the means to respond to incidents and clear them from the road. NCDOT and law enforcement could invoke quick clearance to best use resources when responding to incidents. While nationally incident managers strive for the 90-minute clearance time, quick clearance does not guarantee this, but simply enables incident managers to clear an incident with additional means. This allows access to specialized heavy equipment, contractors, and towers with extensive experience in traffic incident removal, which, in turn, requires extensive collaboration between NCDOT and any law enforcement agency on scene, which could include NCSHP as well as county or city law enforcement. Quick clearance requires that NDCOT and law enforcement concur on the methods of clearance.

The data in this study point to the need for agencies to determine how quick clearance is used. Drabek (2004) and Delcan (2010) have reiterated the need to clear the roads as quickly and safely as possible. The low degree of collaboration between the two agencies in incident clearance, especially in the case of severe incidents, supports the inference that Delcan's key components of coordinated detection and response traffic incident management were present only in an attenuated form. Neudorff et al. (2006) supported the assertion that TIM systems are essential to the effective collaboration of incident managers. Drabek urged incident responders to make sensible decisions about incident management. Quick clearance, requiring an incident assessment from both law enforcement and NCDOT, becomes problematic when circumstances change and a party has already cleared the scene. Effective collaboration is the foundation of traffic incident management models; therefore, the process of collaboration between agencies requires constant evaluation.

Determining when and how quick clearance is used would inform changes to the policy to more effectively clear incidents from roads. Collaboration between NCDOT and law enforcement that shows quick clearance is necessary, and an accountability system for fidelity to the policy, would inform future use of the policy and training related to understanding quick clearance procedures.

The use and development of technology as related to incident management could provide ease of collaboration and clearance of incidents for NCDOT and NCSHP. Research into the types of technology available, as well as how technology could be used to enhance collaboration among agencies could improve clearance times. Research into the use of technology to notify motorists of incidents could impact clearance time and number of roads blocked.

Impact for Positive Social Change

Highway traffic incidents can be dangerous for all involved and clearing traffic incidents has been listed as a top priority in North Carolina's Strategic Plan. Ensuring that the clearance of all traffic incidents can happen without injury is the priority of all incident responders. Because North Carolina's congestion rate for non-recurring traffic incidents and accidents was between 30 to 40%, efficient management of highway accidents can lead to gains for North Carolina's economy (Hartgan, 2007).

Tourism is a large draw for travelers to North Carolina. Families can travel knowing that the path to their destination will be safe and will allow them to enjoy the beaches, mountains, and history that North Carolina offers. The Interstate 95 corridor is not only a major vein to other highways that connect travelers to vacation destinations, but the highway is a major path for Americans in Northern states to reach Southeastern U.S. beaches, which give the South its appeal. Ensuring traffic is smooth opens up landscape and history to a vast majority of the East Coast that lacks such diversity.

The Interstate 95 corridor is also a draw for businesses and organizations. These entities can transport goods up and down the East Coast, providing easy access to large cities such as Charlotte and Raleigh. Research Triangle Park, a consortium of research universities in the vicinity of Raleigh, is also a draw because of its cutting edge research and pool of skilled graduates. Businesses and organizations that locate hubs in North

Carolina can provide much needed jobs and a thriving tax base for local schools and governments because of its effective highway system.

NCDOT must become an equal player when responding to emergencies on the road. The recognition of its essential role in incidents should be equal to those in the public safety sector of government. State governments should grant NCDOT more authority concerning incident response on highways. This could enhance the collaboration between agencies and foster mutual respect for their common but unique missions.

Recommendations for Practice

NCDOT and NCSHP should prioritize the collection of data on scenes of incidents. The collection of a common set of data could enhance the use of quick clearance, reducing the NCDOT clearance time of incidents from 118.82 minutes to the national guideline of 90 minutes. Collecting data about resources used through quick clearance, and an analysis of which resources were used to effectively clear incidents, would lay the groundwork for more effective collaboration between agencies. A more thorough collection and analysis of data could provide the basis for the development of common response practices, further streamlining and enhancing the efficiency of the clearance of incidents.

A set of data that could provide insight into traffic incident management is the documentation of secondary crashes. The current form, DMV 349, does not have an explicit question about secondary crashes. The majority of responders note these types of incidents in the narrative portion of the form. However, a more direct collection of data related to secondary crashes would impact the communication and management of incidents. Knowing the common factors among incidents that spur secondary crashes would help agencies understand how to prevent them or manage the primary incident as to prevent secondary crashes. As of this study North Carolina has not tracked secondary crashes in a systematic way, as other states have.

NCDOT is not an agency whose specialty is emergency incident management; it relies upon entities such as NCSHP for expertise related to the emergency management portion of incidents. However, NCDOT could function more efficiently through the reorganization of STOC and, as such, enhance their duties and responsibilities with respect to incident management. This may require specialized training of employees or recruitment of staff who have experience in multiple disciplines, which would foster collaboration and streamline data collection to develop best practices to be used by all agencies involved in incident management.

Agencies should reinforce educational efforts for all responders in traffic incident management. Traffic incident management (TIM) is a model that provides a framework for understanding incident response; nearly every responder, in some way, in trained using this model. Breakdowns in the process occur when the missions of the responding agencies do not mesh. As such, it becomes critical that agencies collaborate not just on scene, but on the development of protocols for the management of incidents. Specialized instructional staff could bridge the instructional gap related to incident management. Teaching TIM through a team approach, pulling personnel from fire, EMS, law enforcement and transportation, can provide the perspective necessary to impart that collaboration is essential to incident management.

Conclusion

Policy makers and state legislatures rely upon data to make decisions about the urgency and necessity for new policy. NCDOT and NCSHP offer clearance times as evidence that policy is working. However, clearance time data, as well as the data collected in this study, provide a limited view of the hardships on state budgets, infrastructure, and personnel created by incidents on highways. Very little useful data exists that can truly improve the response to incidents in North Carolina. In fact, agencies that respond to incidents on North Carolina highways operate parallel to each other instead of in sync with each other with regard to processes of incident management.

State agencies have an obligation to keep people safe. Even though state agencies must work within the boundaries of their respective missions, state agencies with an interest in incident management must work together. Collecting data is a noble beginning, but this currently cannot capture the complexities of incident management in North Carolina. Bringing all the stakeholders together to form a clear and common set of practices that stem from useful data would improve the quality of life for not just North Carolinians, but for the millions of Americans that travel its roads for business or pleasure.

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Appendix A: Calculation of Statistical Power for Hypothesis Tests

The power of a statistical test is the probability of rejecting the null hypothesis when it is false (Cohen, 1969). As the sample in this study consists of a census, that is, the entire target population, no more cases can be sampled. Therefore, this appendix assumes a fixed sample size of 1,580 cases. The alpha level (probability of Type I error) was selected to be the traditional 0.05 – level, which is a scientifically acceptable level of Type I error in behavioral research (Cohen, 1969) and for which power tables exist in references such as Cohen (1969). The estimates of statistical power included in this appendix are based on tables published in Cohen.

The one-way fixed effects analysis of variance is used to test the difference among more than two group means. The estimate of statistical power of a one-way ANOVA requires that the analyst specify an estimated difference between the group means or "effect size" (Cohen, 1969). It was decided that a mean difference in clearance time of 20 minutes was a reasonable and meaningful effect size to use. The rationale was as follows: Motorists are used to delays of 10 – 15 minutes during rush hour. However, delays of 20 minutes or more are perceived as clearly noticeable and "too long."

The standard deviation of the NCSHP clearance times for incidents occurring on Interstate Highway 95 in North Carolina between June, 2012 and June, 2013 was 51.27 minutes (NCSHP, 2014). Using 51.27 minutes as an estimate of sigma and an effect size of 20 minutes, the statistical power of the proposed one-way ANOVA can be estimated as follows (Cohen, 1969):

Step 1: Calculate the difference between the smallest and largest hypothesized group mean as a proportion of the within group standard deviation, σ, i.e.,

$d = (\mu largest - \mu smallest) / \sigma$

Assumption: If we are comparing three group means spaced 20 minutes apart (i.e., the meaningful effect size that was discussed above) the difference between the largest and smallest cell mean (in a collection of three means) would be estimated to be 40 minutes. That is, the two most extreme means would be 40 minutes apart. Thus,

$d = 40.0 / 51.27$

$= 0.78$

Step 2: Calculate the parameter necessary to enter the power table. Using Cohen's notation:

$f2 = (d / 2) \sqrt{[(K+1) / 3(K-1)]}$ where: K = Number of Groups

For three groups:

$f2 = (d / 2) \sqrt{[4 / 3(2)]}$

$= (d/2) \sqrt{(4/6)}$

$= (d/2)\ 0.8165$

$= d\ (0.408)$

$= 0.78\ (0.408)$

$= 0.3184$

Entering Table 8.3.1 (Cohen, 1969, p. 306) with $\alpha = 0.05$, $f = 0.3$, $df = K - 1 = 2$, *the desired power of 0.8 would require a sample size of at least 36 incidents per group, or a total of 3 x36 or 108 incidents for three levels of the independent variable*. Assuming that there will be a minimum of 36 cases in each group (which, given a total of 1,580 cases, should be a reasonable assumption), the sample size of 1,580 cases should more than suffice to provide for a statistical power of at least 0.80 at an alpha level of 0.05.

The hypotheses concerning factors associated with request of the NCDOT to participate in the clearance of a traffic incident involve categorical variables. The appropriate statistical test for theses hypotheses is the chi-square test for independence (Cohen, 1969). The effect size (*e*) for these tests can be estimated by using a variant of the familiar chi-square statistic (Cohen,1969, p. 214):

$$\mathbf{e} = \Sigma \left[(P_{Obs} - P_{Exp})^2 / P_{Exp} \right]$$

where: P_{Obs} = the observed proportion, and

P_{Exp} = the expected proportion under the null hypothesis,

and the summation is over the R x C (i.e., rows *x* columns) in the contingency table.

The largest contingency table in the analyses of the NCDOT request binary variable will likely be a two by four by contingency table, which has (2 – 1) x (4 – 1) or three degrees of freedom. For a sample size of 500 or more the statistical power associated with this chi-square test for independence ($df = 3$) would be 0.99 for an effect size of 0.05 or greater (Cohen, 1969, p. 229, Table 7.3.17). As in the case of the one-way analyses of variance, the sample size of 1,580 cases should be more than sufficient to provide adequate statistical power.

In order to estimate the power of a one-sample Z test for a single proportion, a null hypothesized proportion must first be chosen. A null-hypothesized proportion of 0.05 was chosen, as a low but still hypothetically possible value and very close to zero. Cohen (1969, pp. 197 - 198) has described the following steps for the calculation of the statistical power for a one-sample test for proportions:

Step 1: Choose an appropriate effect size, e.g., 0.10.

Step 2: Calculate the difference between the arcsine transformation of the proportion posited by the null hypothesis (i.e., 0.05) and the arcsine transformation of the proportion posited by the alternative hypothesis (in this case, 0.05 + 0.10 (the effect size) = 0.15).

Step 3: Multiply this difference by $\sqrt{2}$.

Step 4: Enter Table 6.3.5 (Cohen, 1969, p. 189) with the result of the calculation in Step 3, the chosen alpha level, and the sample size.

Applying these steps, the statistical power associated with detecting a difference of 0.10 (or larger, i.e., the effect size) from the null hypothesized value of 0.05 with an alpha level of 0.05 and a sample size of 80 can be estimated to be 0.9. Therefore a sample size of 1,580 was more than suffice to insure an appropriate level of statistical power for this test.

Appendix B: Permissions

DATA USE AGREEMENT

This Data Use Agreement , effective as of March 15, 2015 ("Effective Date"), is entered into by and between Debroah Leonard, MPA (NCDOT) ("Data Recipient") and Meredith McDiarmid, PE, (NCDOT) ("Data Provider"). The purpose of this Agreement is to provide Data Recipient with access to a Limited Data Set ("LDS") for use in research in accord with the HIPAA and FERPA Regulations.

1. Definitions. Unless otherwise specified in this Agreement, all capitalized terms used in this Agreement not otherwise defined have the meaning established for purposes of the "HIPAA Regulations" codified at Title 45 parts 160 through 164 of the United States Code of Federal Regulations, as amended from time to time.

2. Preparation of the LDS. Data Provider shall prepare and furnish to Data Recipient a LDS in accord with any applicable HIPAA or FERPA Regulations

3. Data Fields in the LDS. No direct identifiers such as names may be included in the Limited Data Set (LDS). In preparing the LDS, Data Provider shall include the data fields specified as follows, which are the minimum necessary to accomplish the research: all calls for service on Interstate 95 in North Carolina for a period beginning January 1, 2014 to December 31, 2015. Included in the calls for service all begin and end times of each event as well as any notes particular to each event.

4. Responsibilities of Data Recipient. Data Recipient agrees to:

   a. Use or disclose the LDS only as permitted by this Agreement or as required by law;

   b. Use appropriate safeguards to prevent use or disclosure of the LDS other than as permitted by this Agreement or required by law;

   c. Report to Data Provider any use or disclosure of the LDS of which it becomes aware that is not permitted by this Agreement or required by law;

   d. Require any of its subcontractors or agents that receive or have access to the LDS to agree to the same restrictions and conditions on the use and/or disclosure of the LDS that apply to Data Recipient under this Agreement; and

   e. Not use the information in the LDS to identify or contact the individuals who are data subjects.

5. Permitted Uses and Disclosures of the LDS. Data Recipient may use and/or disclose the LDS for its Research activities only.

6. Term and Termination.

   a. Term. The term of this Agreement shall commence as of the Effective Date and shall continue for so long as Data Recipient retains the LDS, unless sooner terminated as set forth in this Agreement.

   b. Termination by Data Recipient. Data Recipient may terminate this agreement at any time by notifying the Data Provider and returning or destroying the LDS.

   c. Termination by Data Provider. Data Provider may terminate this agreement at any time by providing thirty (30) days prior written notice to Data Recipient.

   d. For Breach. Data Provider shall provide written notice to Data Recipient within ten (10) days of any determination that Data Recipient has breached a material term of this Agreement. Data Provider shall afford Data Recipient an opportunity to cure said alleged material breach upon mutually agreeable terms. Failure to agree on mutually agreeable terms for cure within thirty (30) days shall be grounds for the immediate termination of this Agreement by Data Provider.

   e. Effect of Termination. Sections 1, 4, 5, 6(e) and 7 of this Agreement shall survive any termination of this Agreement under subsections c or d.

7. Miscellaneous.

   a. Change in Law. The parties agree to negotiate in good faith to amend this Agreement to comport with changes in federal law that materially alter either or both parties' obligations under this Agreement. Provided however, that if the parties are unable to agree to mutually acceptable amendment(s) by the compliance date of the change in applicable law or regulations, either Party may terminate this Agreement as provided in section 6.

   b. Construction of Terms. The terms of this Agreement shall be construed to give effect to applicable federal interpretative guidance regarding the HIPAA Regulations.

   c. No Third Party Beneficiaries. Nothing in this Agreement shall confer upon any person other than the parties and their respective successors or assigns, any rights, remedies, obligations, or liabilities whatsoever.

   d. Counterparts. This Agreement may be executed in one or more counterparts, each of which shall be deemed an original, but all of which together shall constitute one and the same instrument.

e. Headings. The headings and other captions in this Agreement are for convenience and reference only and shall not be used in interpreting, construing or enforcing any of the provisions of this Agreement.

IN WITNESS WHEREOF, each of the undersigned has caused this Agreement to be duly executed in its name and on its behalf.

DATA PROVIDER	**DATA RECIPIENT**
Signed: William Grey	Signed: Debroah L. Leonard
Print Name: William Grey	Print Name: Debroah L. Leonard
Print Title: Coroner	Print Title: Student/Researcher

e. Headings. The headings and other captions in this Agreement are for convenience and reference only and shall not be used in interpreting, construing or enforcing any of the provisions of this Agreement.

IN WITNESS WHEREOF, each of the undersigned has caused this Agreement to be duly executed in its name and on its behalf.

DATA PROVIDER	**DATA RECIPIENT**
Signed: Meredith McDiarmid	Signed: Deborah L. Leonard
Print Name: Meredith McDiarmid	Print Name: Deborah L. Leonard
Print Title: State Systems Operations Engr.	Print Title: Student /Researcher

CONFIDENTIALITY AGREEMENT

Name of Signer: David B. West, Ph.D.

During the course of my activity in collecting data for this research: "Incident Traffic Management Response: A Quantitative Analysis of Clearance Times" by Debbie Leonard I will have access to information, which is confidential and should not be disclosed. I acknowledge that the information must remain confidential, and that improper disclosure of confidential information can be damaging to the participant.

By signing this Confidentiality Agreement I acknowledge and agree that:

1. I will not disclose or discuss any confidential information with others, including friends or family.
2. I will not in any way divulge, copy, release, sell, loan, alter or destroy any confidential information except as properly authorized.
3. I will not discuss confidential information where others can overhear the conversation. I understand that it is not acceptable to discuss confidential information even if the participant's name is not used.
4. I will not make any unauthorized transmissions, inquiries, modification or purging of confidential information.
5. I agree that my obligations under this agreement will continue after termination of the job that I will perform.
6. I understand that violation of this agreement will have legal implications.
7. I will only access or use systems or devices I'm officially authorized to access and I will not demonstrate the operation or function of systems or devices to unauthorized individuals.

Signing this document, I acknowledge that I have read the agreement and I agree to comply with all the terms and conditions stated above.

[signature] 3-20-15

Signature: **Date:**

Certificate of Completion

The National Institutes of Health (NIH) Office of Extramural Research certifies that **Debroah Leonard** successfully completed the NIH Web-based training course "Protecting Human Research Participants".

Date of completion: 05/27/2015

Certification Number: 1770516

Appendix C: Interagency Memorandum of Understanding

INTERAGENCY MEMORANDUM OF UNDERSTANDING
NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
DIVISON OF HIGHWAYS
NORTH CAROLINA DEPARTMENT OF CRIME CONTROL AND PUBLIC SAFETY
DIVISON OF STATE HIGHWAY PATROL

REMOVAL OF VEHICLES FROM ROADWAY

This memorandum of understanding made this 1ST day of JUNE, 2011 by and between the North Carolina Department of Transportation (NCDOT) and the North Carolina State Highway Patrol (SHP) is to provide guidance for implementation of the Quick Clearance provision of N.C.G.S. 20-161(f) on the State highway system.

WHEREAS, in an effort to minimize the potential personal injury and/or economic loss associated with disruptions to the regular flow of traffic, the North Carolina Legislature has enacted specific legislation authorizing the immediate removal (Quick Clearance) of vehicles and/or property which interfere with the regular flow of traffic or otherwise constitute a hazard on the State highway system; and

WHEREAS, the parties herein recognize the potential hazards and economic loss that may occur from wrecked, abandoned, disabled, unattended, burned, or partially dismantled vehicles, cargo, or other personal property on the State highway system when such occurrence or condition interferes with the regular flow of traffic; and

WHEREAS, the North Carolina Legislature has vested in investigating law enforcement officers the authority to immediately remove or cause to be removed such vehicles or property only when such vehicle or property interferes with the regular flow of traffic or otherwise constitutes a hazard and when done in conjunction with the concurrence of the North Carolina Department of Transportation;

NOW THEREFORE, the North Carolina Department of Transportation and State Highway Patrol each agree to the following described guidelines and delineation of specific authority and obligations in order to implement the provisions of the Quick Clearance legislation.

I. General:

Whenever a state highway is closed or partially blocked by a wrecked, abandoned, disabled, unattended, burned, or partially dismantled vehicle, cargo, or other personal property, the priority shall be to clear the road and reopen the roadway as soon as possible. It is understood that damage to vehicles and / or cargo may occur as a result of clearing the road on an urgent basis. Nonetheless, while reasonable attempts to avoid such damage should be taken, the highest priority is public safety. Additionally, while consideration for the vehicle and /or owner's preference for utilization of a wrecker service and related service providers and for the integrity of the power unit, trailer and cargo are not to be ignored in every circumstance, public safety and convenience of the motoring public shall be paramount. Consistent with this public safety and motoring public priority, the following procedure is hereby established.

II. <u>SHP Duties and Responsibilities</u>

Members and officers of the North Carolina Highway Patrol who respond to any of the above-described conditions (vehicle wrecks, spilled cargo, etc) on the State highway system must make an initial assessment of the scene and determine whether the Quick Clearance provisions of N.C.G.S. 20-161(f) are appropriate.

While it is understandable that vehicle and cargo owners may desire extreme measures be taken to protect their property from further damage, such measures may not be prudent if it is a time consuming endeavor that will require restricting the flow of traffic or may constitute a hazardous situation. In such cases, the authority of N.C.G.S. 20-161(f) should be utilized to get the vehicles and cargo off the road so that the flow of traffic may resume in a timely manner.

Consistent with the need to get the highway open, if required, members and officers of the State Highway Patrol will conduct their required investigation in as expedient a manner as possible, considering the severity of the collision and the need to maintain a high quality investigation. This may mean that certain "non-critical" portions of an investigation be conducted at a later time when traffic congestion is non-existent (i.e., non-peak periods). However, in the event of a motor vehicle wreck or other occurrence involving death or serious personal injury, no removal shall occur until the investigating member or officer determines that adequate information has been obtained for preparation of a crash report (DMV-349).

With the concurrence of the Division Engineer or his representative, the investigating member or officer may initiate appropriate steps to immediately clear the road of vehicles, cargo and other obstructions and debris consistent with this MOU and N.C.G.S. 20-161(f). In order to accomplish this task, the investigating member or officer may request the assistance of the Division Engineer or his representative and may utilize the services of immediately available rotation wrecker firms, the closest available rotation wrecker firm and/or available DOT resources. For major lane blocking or traffic disruption related incidents, such as overturned tractor trailers, hazardous material spills, fatal investigations or multi-vehicle wrecks, contact should be made with the NCDOT State Traffic Operations Center (STOC) at 877-627-7862 (877-NCS-STOC). If concurrence between NCDOT and SHP is given, the STOC can assist with the coordination of detours, traveler information, traffic conditions and contacting appropriate towing and recovery resources.

III. <u>Procedure / Requirements – NCDOT</u>

A. General

By signing this memorandum of understating, SHP concurs that for minor incidents, such as abandoned or disabled vehicles and minor crashes that occur on the paved or main-traveled portion of any highway <u>that</u> IMAP service patrols, if available, may properly mark the location of vehicles, assist in traffic control and/or relocate vehicles to a non-hazardous location without additional concurrence for Quick Clearance from the Highway Patrol. In cases where abandoned or disabled vehicles are left in a non-hazardous position off the roadway, the vehicles may be tagged and removed after 24 hours by the Highway Patrol, IMAP, or another law enforcement agency. IMAP shall contact SHP communications with the vehicle's tag and VIN information so that proper investigation can be performed. In the event that IMAP tags a vehicle and it is later towed based on IMAP's time stamp, litigation or complaints that arise due to elapsed time issues will be borne by NCDOT and/or their Attorney General's office.

NCDOT will make every effort to ensure that there are designated on-duty personnel with the authority and expertise to grant the necessary concurrence to put into effect the Quick Clearance procedures described herein.

NCDOT will make every effort to ensure that each Highway Patrol Troop Communications Center is kept apprised of all necessary recall numbers for on-duty personnel responsible for implementing Quick Clearance procedures. This information will be also readily available at the STOC at 877-627-7862.

NCDOT will make every effort to cooperate with the Highway Patrol in responding to all major incidents and in determining whether and to what extent the Quick Clearance procedures authorized by N.C.G.S. 20-161(f) is warranted. For major incidents where Quick Clearance occurs or other issues arise, NCDOT will perform after incident reviews to discuss positive and/or negative effects of decisions made at the incident scene.

In any case where a determination is made that the use of NCDOT equipment is the most expedient and prudent manner in which to move vehicles, cargo or other personal property, NCDOT will make every effort to relocate cargo or other personal property in the shortest possible time, using whatever equipment is necessary. All such materials will be relocated as short a distance as necessary to clear the travel lanes or otherwise avoid any traffic hazard.

In any case where NCDOT personnel and equipment are used to clear a highway pursuant to the provisions of this MOU, the Division Engineer or his representative shall prepare a list of the personnel, materials, traffic control devices, and equipment used and the work hours involved so that the party responsible or owner of the vehicle and / or cargo can be billed for the work pursuant to the provisions of N.C.G.S. 20-161(g).

B. Hazardous / Flammable / Exploding Materials

No attempt shall be made by NCDOT personnel to move any hazardous, flammable, or explosive materials for any reason. If NCDOT is first on the scene and cargo content is not readily identifiable, the Division Engineer or his representative will contact the proper authorities to ascertain if special measures should be taken.

Only after the load has been identified and appropriate Haz Mat precautions and/or clean up procedures have been completed shall the Quick-Clearance measures described herein be adhered to.

IV. Public Safety Priority:

As indicated above, this MOU reflects the understanding and agreement of NCDOT and SHP that public safety must be afforded the highest priority in reopening traffic lanes blocked by motor vehicle crashes or other incident. Further, utilization of the Quick Clearance procedures authorized by N.C.G.S. 20-161 to expeditiously remove vehicles and cargo blocking highways, and thereby creating a safety hazard, may require the utilization of available resources and should immediately be put into effect.

Appropriate NCDOT and SHP personnel shall review this MOU on an as needed basis to determine if any modifications are necessary.

In Witness Whereof, each party hereto has caused this agreement to be executed in its name and on its behalf by its duly authorized officer or agent as of this day and year first above written.

Reuben F. Young
Secretary
North Carolina Crime Control and Public Safety

Eugene A. Conti, Jr.
Secretary
North Carolina Department of Transportation

Michael W. Gilchrist
Colonel
North Carolina State Highway Patrol

Terry R. Gibson, P.E.
State Highway Administrator
North Carolina Department of Transportation