Economic Impact of Traffic Incidents on North Carolina's Interstate Facilities

Final Report

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16. Abstract

Unexpected delays due to traffic incidents represent a significant proportion of overall delay, especially in urban areas. The resulting uncertainty can represent major costs to businesses and travelers, as well as restrict employment opportunities. This study focuses on North Carolina's Interstate facilities and businesses across the State that rely on these facilities for their daily operations and are influenced by traffic congestion due to their shipping needs. The first portion of the study examines the occurrences and costs of unexpected delay for North Carolina businesses, using telephone and face-to-face interviews. Results show that delays due to incident-induced congestion impose significant costs, which may increase over time as expected congestion and the number of incidents on the North Carolina interstates continue to grow. These costs are most severe in the Manufacturing industrial sector and in the Charlotte metropolitan area. Additionally, numerous firms commented on the need for better communication between NCDOT and the business community. The second portion of the study is devoted to developing case studies to simulate the impact of strategies to reduce incident congestion costs in North Carolina. Results show that incident management assistance patrols and advanced traveler information systems can significantly reduce unexpected delays and associated costs. The implications of the findings for economic growth are discussed.

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Executive Summary

Incidents account for a major portion of traffic congestion in urban areas. By adding uncertainty to travel times, incidents and resulting congestion can restrict employment opportunities. Incidents also impose costs on businesses in terms of vehicle and driver costs of delay, and late deliveries, etc. Mitigating the effect of incidents can benefit businesses and non-business users. This study quantifies the costs of incident-induced congestion on businesses and explores the impacts of strategies that can reduce incident-induced congestion in North Carolina.

To determine the business-related costs of incident-induced traffic congestion, the study focuses on North Carolina interstate facilities. First, we conducted analysis of truck traffic on Interstate facilities and developed criteria for carefully selecting firms that are representative of NC industries, rely on interstates for their daily operations, and are likely influenced by traffic congestion due to their shipping needs. After selecting the firms, we conducted a series of telephone interviews (N=29) and face-to-face interviews (N=12). We obtained information about the impact of congestion on firms' planning and operations. We then analyzed the data to identify and quantify the impacts of congestion caused by traffic incidents on the firms. Overall, firms reported that unexpected delays due to incident-induced congestion impose some level of cost, which may increase over time with the expected continued increase in congestion and the number of incidents on North Carolina interstates.

The analysis shows that the average hourly cost of unexpected delay of $145 is in line with existing research. A more focused analysis shows that average hourly costs are by far the highest in the Southeast region, perhaps due to limited facilities and rerouting opportunities. While Transportation and Warehousing displayed the highest hourly cost among sampled industrial sectors, Retail Trade and Manufacturing were very close behind. Analysis of total annual costs shows that the Charlotte metropolitan region incurs the highest overall costs, mostly due to its large employment base. Manufacturing incurs the highest overall cost among sampled industrial sectors. However, if not for a significantly conservative estimate for the Transportation and Warehousing sector, it might have shown even higher cost.

The most common behavior for coping with unexpected delay reported by businesses in the study was to reroute the shipment. A majority of businesses used route-guidance devices to keep track of vehicles and shipments. However, very few sought pre-shipment traffic information or were aware of NCDOT traffic information services. In general, businesses expressed a desire for better communication and information services from NCDOT.

A portion of the research effort was devoted to developing case studies to analyze the impact of promising strategies (intelligent transportation systems), to reduce the costs of incident-induced congestion. Specifically, the case studies evaluated the success of providing incident patrol service, and also of disseminating (dynamic) traffic information, in reducing incident-induced congestion. The method takes into consideration the impacts of information dissemination and incident patrols on commercial and non-commercial users separately. Using realistic traffic data and network assumptions, modeling results show the benefits of providing real-time information and adding incident management assistant patrols. The analysis captured the effects of traveler information and incident patrol service according to different user characteristics, especially for commercial carriers and firms.

1. Introduction

Congestion continues to grow in America's urban areas and unexpected delay form a large part of the problem. According to the latest Urban Mobility Report produced by the Texas Transportation Institute (Schrank & Lomax, 2005), the annual cost to motorists of being stuck in traffic in the largest 85 urban areas is more than $65 billion. However, that is simply the "on-the-road costs" of individuals' wasted time and fuel. What about the costs to business operators of having shipments stuck in traffic, especially when the congestion is unexpected? Congestion costs business operators not just additional vehicle operation and in-transit inventory but also reduction in market areas for workers, customers, and incoming/outgoing deliveries. However, little research has been done to assess these additional costs.

Further, business operations are largely affected by the unreliability/uncertainty of congestion rather than the length of delay in congestion, which makes the assessment more complicated. In today's business landscape, more companies are adopting just-in-time (JIT) manufacturing or inventory management (Rao & Grenoble, 1991). JIT systems rely on tightly scheduled and frequent deliveries of supplies and parts to reduce warehousing and inventory needs. Therefore, the reliability of product delivery has become an increasingly important factor in business successes.

It is estimated that incidents account for 60% of total congestion on freeways and 52% on arterial roadways (Garrison & Mannering, 1990). The cost of incident-induced congestion is incurred by users in terms of: delays, added travel-time uncertainty, late arrival at destination, higher vehicular costs in fuel consumption and wear and tear; greater likelihood of secondary crashes; and greater health risks due to increased pollution (Weisbrod et al., 2001). By adding uncertainty to travel times, incidents and resulting congestion can restrict employment opportunities. Incidents also impose costs on businesses in terms of vehicle and driver costs of delay, cost of keeping additional inventory, just-in-time processing costs, and reductions in the surrounding areas from which workers can be drawn. In addition, congestion can reduce or eliminate agglomeration benefits that firms get from co-locating in larger urban areas. For trucks, about 60 percent of delay, is estimated to be caused by non-recurring congestion, the result of transitory events such as construction work zones, crashes, breakdowns, extreme weather conditions, and suboptimal traffic controls.

Mitigating the effect of incidents clearly benefits businesses and non-business users. Nationwide incidents create significant costs each year for motorists alone. Businesses incur additional costs due to lost wages, wasted driver time and vehicle costs. However, little is known about the overall costs of incident-induced congestion in North Carolina, and their impacts on commercial users. The objectives of this study are to:

- Interview businesses to quantify the costs of incident-induced congestion on North Carolina businesses.
- Explore the impacts of deploying Incident Management Assistance Patrols (IMAPs) and advanced traveler information systems (ATIS) —high-impact strategies that can reduce incident-induced congestion in North Carolina.

To determine the costs of incident-induced traffic congestion on businesses that use North

Carolina Interstate facilities, the study conducted a series of telephone and face-to-face interviews with major private employers in the state. These firms rely heavily on the interstate highway system for their day-to-day operations, e.g., trucking companies and delivery services. We elicited their views on the impact of congestion on their operations. We carefully selected the firms to be interviewed by dividing North Carolina into regions and reviewing the employment and industry sectors in the region, e.g., Transportation, Utilities, Government, Agriculture, Construction, Services, Manufacturing, Wholesale Trade, and Retail Trade. We then interviewed representative companies and selected those most likely to be affected by travel uncertainty. The results helped us develop case studies, which lead to quantifying costs of uncertainty and insights regarding how industry sectors are coping with uncertainty in travel times. Taking the results of the interviews, the study simulated the impacts of congestion caused by traffic incidents in specific situations and quantified the potential reduction in costs to NC businesses and the impacts on North Carolina's economic growth by implementing appropriate incident management assistant patrols and traveler information systems.

2. Literature and Developments

Costs of Congestion on Businesses

Shippers and receivers in various industry sectors place a high value on reliable service. Small et al. (1997) cite shipper and carrier interviews indicating reliability or dependability of service as one of the most significant factors in the choice of carrier or mode. There is also evidence from NCHRP 2-18 that commercial carriers value travel time highly, at $144.22–$192.83 per hour, and savings in late schedule delays at $371.33 per hour. Typically, travel time for individuals is valued at a much lower rate, e.g., between $10 and $20 per hour. NCHRP-463 shows compelling evidence that businesses are willing to pay significant amounts of money to reduce the uncertainty (standard deviation) associated with incoming or outgoing shipment times. Of course, this willingness to pay varies by industry and the type of goods being shipped.

This study expands on Khattak & Rouphail (2005) to comprehensively estimate the costs of incident-induced congestion and evaluate the impact of IMAPs as well as traffic information dissemination. This expansion of scope relates to evaluating the impacts of incidents on businesses. There have been two National Cooperative Highway Research Program (NCHRP) projects focusing on measuring the business-related congestion costs—NCHRP 2-17 (1995) and NCHRP 2-21 (Weisbrod et al., 2001). The NCHRP 2-17 (5) study found that business managers do not explicitly track the cost of congestions and hence seldom attribute their business costs to urban congestion. The NCHRP 2-21 conducted by Weisbroad et al. examined how urban traffic congestion impose economic costs within the metropolitan area. The data used in the NCHRP 2-21 study are secondary data from a variety of sources, e.g. Commodity Flow Survey (CFS), U.S. census journey-to-work files, MPO's (Metropolitan Planning Organizations) traffic observations and zonal economic data, and MPO's trip generation and distribution data. Based on those available data, composite values of shipping costs, reliability costs, and shipment values associated with delivery delay were calculated for each urban zone. The calculated costs were further linked to levels of business activities in urban zones by applying regression analysis and the results show that congestion effectively shrinks business market areas and reduces the agglomeration economies of businesses operating in large urban areas.

When looking abroad, a vast body of literature exists on measuring business costs of traffic congestion. Mckinnon (1998) investigated the effects of traffic congestion on business through interviewing 23 managers at seven distribution centers in the fast moving consumer goods (FMCG) sector in the UK. Results show that traffic congestion was inflating the distribution centers' warehousing costs by 20%. The Hague Consulting Group (HCG) (1998) undertook a study of investigating the magnitude and cost of delays to freight traffic in the UK, France, Poland, and the Czech Republic. The research suggests that indirect (off-the-road) costs of congestion to businesses exceed the direct (on-the road) costs. Bozuwa and Hoen (1995) conducted a Dutch study and asked 230 haulers and shippers who regularly used congested sections of motorways to place a monetary value on reliability. Their results suggest that unreliability added 8-11% to the costs of congestion. O'Mahony and Finlay (2004) analyzed data from a survey of 584 companies in Ireland. The survey requested information on company characteristics, whether it transported goods by road, the impact of traffic congestion on businesses, and the coping strategies the companies used to deal with traffic problems. The findings indicated that traffic congestion has an impact on a large portion of companies to a major degree.

The identifiable variation in data, methods and results in the literature suggests the complexity of the problem and shows that there is a need to further explore economic costs of unexpected congestion, especially the costs incurred by the private sector. As Weisbrod et al. (2003) pointed out, "it presents a starting point—showing many facets of congestion impacts on businesses and local economies, illustrating the types of data necessary to document the costs, and demonstrating how analysis can be carried out and ultimately improved".

Incident Management Assistance Patrols

In a pre-cursor study, Khattak et al. (2004) provide a literature review of Freeway Service Patrols (FSP), also referred to as IMAPs in North Carolina. They investigated the value of IMAPs in North Carolina, which help smooth traffic flow by aiding stranded motorists and assisting in incident clearance. Their new approach helps determine the most beneficial locations for patrol deployment using expanded placement criteria in North Carolina. Analysis of three incident/crash indices was combined with spatial analysis, incident type distributions, average hourly freeway traffic volumes, and incident delay estimations to identify, evaluate, and compare FSP/IMAP expansion candidate facilities. Results of the research have been incorporated into a decision-support tool that allows easy planning and operational assessment of candidate sites by comparing performance values between sites, modeling the effect of IMAP and estimating their key potential benefits and associated costs. By using the methodology, NCDOT can quickly assess the needs of different facilities to make an informed, cost-effective decision as to where to implement the next service patrol. There is ample evidence that IMAPs are a cost-effective ITS strategy and that their benefits often exceed the costs, when implemented in the appropriate context (Khattak et al., 2004).

Advanced Traveler Information Systems

In recent decades, ATIS have emerged to support more informed travel decisions. Individuals or commercial users now can receive dynamic information through a variety of sources, e.g., Internet, 511, television, radio, kiosks, and in-vehicle systems. Many studies have pointed out that disseminating real-time traffic information to travelers could offer significant benefits in terms of ameliorating traffic congestion, improving network performance, and enhancing travel safety, thus providing economic and environmental advantages (Ben-Akiva et al., 1991; Khattak et al., 1993; Adler & Blue, 1998). A comprehensive academically-oriented review of advanced traveler information systems (ATIS) literature is provided in Lappin and Bottom (2001) and will not be repeated here. These systems provide static and dynamic information before and during a trip to support pre-trip and en-route decisions. By dynamically adjusting schedules, modes and routes, individual travelers and truck drivers can respond to system uncertainty (Golob and Regan 2005). The literature further shows that real-time traveler information may be particularly useful in the context of incident-induced congestion (Levinson, 2003; Al-Deek et al., 1998), since real-time traffic information could reduce the uncertainty caused by incidents. Additionally, drivers on interstates have a higher likelihood of diverting from their normal route than on other roadway types (Abdel-Aty and Abdalla, 2004).

However, the true potential of disseminating ATIS has not been thoroughly studied in the literature yet, although a few researchers have already questioned whether the impact of traffic information is known to a sufficient extent (Arnott et al, 1991; Hall, 1993; Chatterjee et al, 2002). For instance, Arnott (1991) argued that traveler information technologies may counter-productively lead travelers to congest alternate routes, ultimately degrading network performance. Additionally, the impacts of disseminating information to various user groups (i.e., individual travelers vs. commercial users), remain limited.

Different User and Vehicle Effects

On the one hand, different types of road network users should have different kind of responses even to the same traveler information, because of their particular characteristics and circumstances (Peeta et al. 2005). For example, drivers of large trucks may have a lower tendency to divert than motorists in incident situations, and their re-routing might be subject to trucking firms' priorities. Studies considering such differential aspects of user behavior when evaluating traveler information technologies remain scarce, with a few exceptions of the particular information needs of trucking companies (Golob and Regan 2002a, 2002b, 2005). For instance, Freeway Changeable Message Signs (CMS), CB radio reports from other drivers and traffic reports on the radio were reported to be most useful for truck drivers (Golob and Regan 2002a). In addition, traffic reports on commercial radio stations and face-to-face reports among drivers at truck stops and terminals were also reported to be useful, though dedicated Highway Advisory Radio (HAR) was viewed least useful by drivers, partly due to limited availability. Managers of carriers reported that locations of freeway incidents and lane closures, weather information, and travel times on alternative routes as important for their drivers. These preferences for information content are in conformance with preferences of individual travelers.

On the other hand, different types of vehicles also may have particular impacts on traffic congestion, especially on incident-induced congestion. First, the share of trucks in traffic could be a statistically significant factor affecting incident occurrence (Konduri et al., 2003). Second, components of traffic flow such as percentage of heavy trucks may influence incident duration, i.e., large trucks may interfere more with incident clearance operations (Khattak et al., 1995).

Moreover, network performance imposes different costs on commercial and non-commercial users, especially for incident-induced congestion. Traffic congestion is more costly for businesses than individual travelers (Weisbrod et al., 2001). In addition to vehicle and driver costs of delay, the negative impacts of incident-induced congestion on businesses could be late incoming/outgoing deliveries, and the cost of keeping additional inventory, etc. Therefore, as a growing trend, truck traffic and business users should be specifically concerned with the negative impact of such congestion. In other words, we should pay attention to these particular commercial carriers / trucks during the course of modeling, developing, and evaluating traveler information systems.

Summary
Overall, the literature provides information regarding incident congestion costs and also mitigation strategies. However, it does not directly address North Carolina's needs. Specifically, they do not give us a sense of the incident congestion costs incurred by business (and non-business users) in North Carolina. More broadly, the impact of travel time uncertainty on NC business/economic development is not known. Furthermore, we know little about the relevance of IMAPs or dynamic traffic information for businesses in North Carolina. This study addresses these issues by conducting interviews, developing case studies and employing modeling tools.

3. Conceptual Structure

Broadly speaking, the study covers the role of transportation in industry and how improvements in transportation can influence economic development (Figure 1). We focused on the economic costs to industry in North Carolina by closely examining the role of travel time uncertainty experienced by businesses. Uncertainty due to roadway incidents, work zones, and adverse weather can negatively impact businesses. By reducing the costs to businesses through improvements in the performance of the transportation system, we can improve efficiency and stimulate economic growth. In this study, we explore the overlap of transportation and economic impacts in industries (carriers and firms with large requirements for incoming and outgoing shipment) that are located in areas that rely heavily on North Carolina's interstate system.

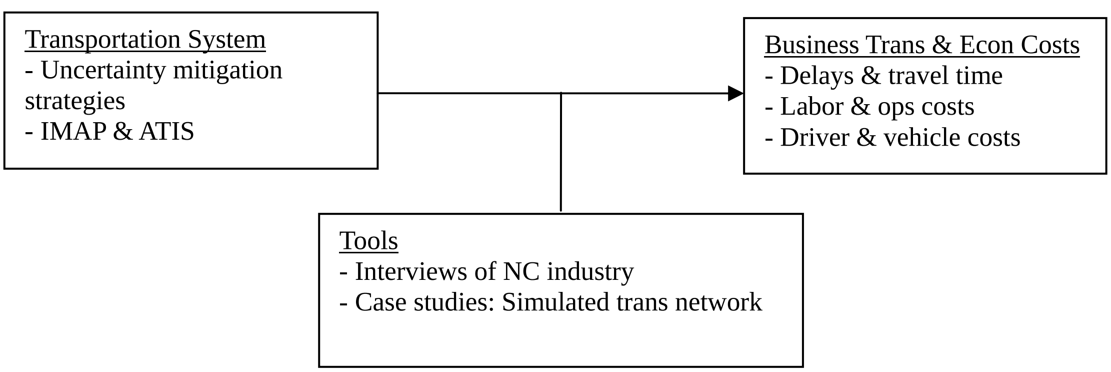


Figure 1: Conceptual Structure Relating Transportation and Economic Impacts

While it is generally recognized that there is a correlation between transportation and economic activity, this study contributes by using surveys (telephone interviews and in-depth case studies) and simulation tools to quantify the costs of unexpected congestion. Importantly, it explores the impacts of uncertainty mitigation strategies that include incident management assistance patrols and advanced traveler information systems. Thus the study provides insights on the forms of transportation investments that can potentially reduce economic costs (and improve economic productivity) in North Carolina.

4. Methodology and Data

This study assesses the impacts of incident-induced congestion in terms of costs to businesses in North Carolina and how these costs might be reduced by implementing IMAPs or ATIS. Specifically, we first estimated the percentage of commercial traffic on major NC freeway facilities, i.e., interstates. We then carefully selected representative businesses and designed telephone and face-to-face interviews. The results of the interviews are reported and analyzed to quantify congestion costs. The study asked businesses about the effects of travel time uncertainty in terms of vehicle and driver costs of delay.

A simulation was undertaken to estimate the impact of ITS strategies on transportation system performance. This effort took into account the congestion costs reported by NC businesses in the interviews. The FREEVAL-based IMAP tool was used to evaluate the impact of incident management assistance patrols and advanced traveler information systems. We document incident congestion costs and the appropriateness of ITS (Intelligent Transportation Systems) for commerce and economic development in North Carolina.

Telephone and Face-to-Face Interviews

The study area is defined as counties that contain or are adjacent to a county that contains interstate facilities. The volume-to-capacity ratio (V/C), calculated from average annual daily traffic (AADT) and average annual daily truck traffic (AADTT) was used to select highways for inclusion. Profiles of selected counties were developed to provide a general view of the demography and economy in the study area.

The firms in our sample were selected to insure that they represent NC industries that contribute to NC economic development, heavily rely on the interstate system to operate their businesses, and are relatively time-sensitive for their incoming and outgoing shipments. The selection criteria, the information and data sources used for making potential selections, and the decision-making process were documented in Appendix A. Furthermore, the process of selecting the sample, tabulating the selected companies, and developing firm profiles also was documented (Appendix A). The final firm sample reflected the comments and suggestions of the NCDOT project steering committee members. However, firms are sometimes either no longer in operation in NC or decline to participate in the study. As a result, new firms were selected based on their similarities to lost firms, including location, industry type, and susceptibility to unexpected travel delays.

The final sample includes 29 firms; 25 non-carrier firms (from a wide variety of industrial sectors that included manufacturing, distribution, and retail) and 4 commercial carriers (trucking transportation). The firms have a wide range in terms of size, with all having at least 100 full-time equivalent employees, and 38% having more than 1,000. The firms also represent 19 different industry sectors (3-digit NAICS codes), from food manufacturing to specialty trade contractors (Table 1). Additionally, the firms shipped numerous types of incoming and outgoing goods (Table 2). Shipment weights and values varied widely across firms and carriers, but reporting discrepancies make it difficult to report accurate ranges.

Table 1.
Firm Characteristics

County	FTE	Industry Sector NAICS Title and Code	
ALAMANCE	250-499	Specialty Trade Contractors	238
BUNCOMBE	1,000+	Food and Beverage Stores	445
BUNCOMBE	250	Construction Machinery Manufacturing	333
CABARRUS	NA	Warehousing and Storage	493
CABARRUS	1,000+	Beverage and Tobacco Product Manufacturing	312
CATAWBA	1,000+	Furniture and Related Product Manufacturing	337
CATAWBA	1,000+	Electrical Equipment, Appliance, and Component Manufacturing	335
CLEVELAND	1100	Warehousing and Storage	493
CUMBURLAND	600	Electrical Equipment, Appliance, and Component Manufacturing	335
DAVIDSON	335	Truck Transportation	484
DURHAM	NA	General Merchandise Stores	452
FORSYTH	500-999	Computer and Electronic Product Manufacturing	334
GASTON	1,000+	Textile Mills	313
GRANVILLE	NA	Miscellaneous Manufacturing	339
GUILFORD	NA	Couriers and Messengers	492
GUILFORD	1,000+	Postal Service	491
GUILFORD	200	Truck Transportation	484
GUILFORD	NA	Air Transportation	481
HENDERSON	500-999	Electrical Equipment, Appliance, and Component Manufacturing	335
IREDELL	580	Nonmetallic Mineral Product Manufacturing	327
MECKLENBURG	NA	Truck Transportation	484
MECKLENBURG	1,000+	Plastics and Rubber Products Manufacturing	326
NASH	1,000+	Miscellaneous Manufacturing	339
NORTHHAMPTON	250-499	Food Manufacturing	311
RANDOLPH	NA	Heavy and Civil Engineering Construction	237
ROBESON	1,000+	Food Manufacturing	311
ROWAN	105	Electrical Equipment, Appliance, and Component Manufacturing	335
SURRY	200	Truck Transportation	484
WILSON	1,000+	Nonmetallic Mineral Product Manufacturing	327

Notes: NAICS = North American Industry Classification System
FTE = Full Time Equivalent (An FTE of 1.0 means a full-time worker)

Table 2. Shipped Goods	
Incoming Shipments	**Outgoing Shipments**
Steel Coils	Lighting Fixtures
Lighting Parts	Control Panels
Raw Steel	Computer Hardware
Electrical Components	Passengers
Computer Parts	Mail
Passengers	Fresh & Processed Chicken
Mail	Asphalt
Live Chickens	Cigarettes
Raw Materials	Copper & Fiber-optic Cable
Tobacco	IV Solutions
Copper	General Merchandise
Plastics	Finished Thread/Materials
Packing Materials	Feed Stock
Sugar	In-shell Peanuts
Salt	Furniture
General Merchandise	Cosmetics
Un-dyed Yarn	Medical/Surgical Supplies
Raw Peanuts	Crane Parts
Fabric	Wire
Chemicals	Cable
Components	Conductors
Highly Perishable Groceries	Breaker Boxes
Medical/Surgical Supplies	Tires
Crane Parts	Catalytic Converters
Wire	Construction Equipment
Cable	Auto Filters
Conductors	School Supplies
Natural Rubber	Crude Rubber
Synthetic Rubber	Home Supplies & Tools
Raw Talc Powder	
Vehicle Parts	

The geographic distribution of the firms includes 22 NC counties. The socio-economic representation of these counties is listed in Table 3. While only 45.8% of the state's 2005 population is represented in these counties, they also include 53.1% of the state's total 2005 workforce and 67.5% of 2002 announced investments. This level of coverage makes us confident that the firms interviewed adequately represent the businesses that are affected by travel time uncertainty and shipping contexts common to North Carolina.

Table 3. Socio-Economic Representation of Final Sample Counties	
Measure	**Percent of NC Total**
Population (2005 Estimated)	45.8%
Total Employment (2005)	46.8%
Total 2002 Announced Investments	67.5%
Total Workforce (2005)	53.1%
Gross Retail Sales FY 2005	52.6%

Source: US Bureau of Labor Statistics, 2005.

A total of 29 firms participated in telephone interviews. Additionally, 9 non-carrier firms and 3 carriers participated in a more in-depth on-site face-to-face interview used to develop individual case studies. The research team traveled to the location of the firms spread throughout the state in order to conduct the on-site interviews. Unless indicated otherwise, much of the data used in this study come from a combination of both the phone and face-to-face interviews. However, only the face-to-face interviews provided actual cost data that are analyzed to assess the costs of incident congestion.

The interview instruments are provided in Appendix B. The instruments used in this study were developed based on inputs from NCDOT staff, examining earlier questionnaires used in the Small and Chu (1997) study, and the overall project objectives. While the phone interviews were more general in nature, the face-to-face interviews were much more specific and divided into four sections:

1. General company attributes that included employment size, employment type, sales, revenues, and potential NC business expansion.
2. Specific product and shipment attributes including product types, geographic distribution of shipments, amounts, values, locations, and shipment operations.
3. Costs of delay that include unexpected delays (for incoming and outgoing shipments) and effects on operations, cost-saving scenarios regarding inventory, driver/vehicle costs, market area for workers and products, and just-in-time manufacturing.
4. Incident-related cost-saving behavior including use of traffic-related tools, route-guidance devices, congestion coping strategies, and Interstate Level of Service (LOS) satisfaction.

Descriptive statistics for all four survey types are provided in Appendix C.

Case summaries were created for each firm that participated in the face-to-face interviews. The summaries give an outline of key information provided by each firm with respect to how they are affected by unexpected events and mitigate unexpected delay due to incidents. These summaries are given in Appendix D.

A key output of the interviews is the costs of incidents to firms. The hourly cost of unexpected delay for incoming and outgoing shipments for each firm was calculated using information given in questions 13 from the phone interviews, 7, 21, 22, and 24 from the non-carrier face-to-face interviews, and 13 and 14 from the carrier face-to-face interviews. Equations 1 – 3 below were applied to both incoming and outgoing shipment data. The equations build into a final calculation of hourly cost of unexpected delay (first two equations providing an input in the third equation):

Annual Delayed Shipments = (Shipments per Day * # of Shipment Days)*Proportion of Shipments Delayed
…….. Equation 1.

Annual Unexpected Delay (hours) = Annual Delayed Shipments*Average Unexpected Delay
…….. Equation 2.

Hourly Cost of Unexpected Delay = Annual Cost of Unexpected Delay/Annual Unexpected Delay
…….. Equation 3.

The hourly incoming and outgoing shipment costs of unexpected delay for each firm were then summed to create a total hourly cost of unexpected delay.

Firms also are separated by sample region and industrial sector. Industrial sectors used in this study are consistent with US Bureau of Labor Statistics categories and are based on data included in the face-to-face interviews. The sectors represented in this study include Government, Retail Sales, Transportation and Warehousing, Manufacturing, and Construction. However, the lack of any Construction firms participating in the face-to-face interviews resulted in no cost data for that sector. The sample regions are based on geographic clustering of interviewed firms across the state. The counties included in each sample region are listed in Table 4 and are outlined in Figure 2 below.

Table 4.
Study Regions

Region 1 West	**Region 2 Charlotte Metro**	**Region 3 Triad**	**Region 4 East**	**Region 5 Southeast**
Buncombe Henderson	Cabarrus Catawba Cleveland Gaston Iredell Mecklenburg Rowan	Alamance Davidson Forsyth Guilford Randolph Surry	Durham Granville Nash Northampton Wilson	Cumberland Robeson

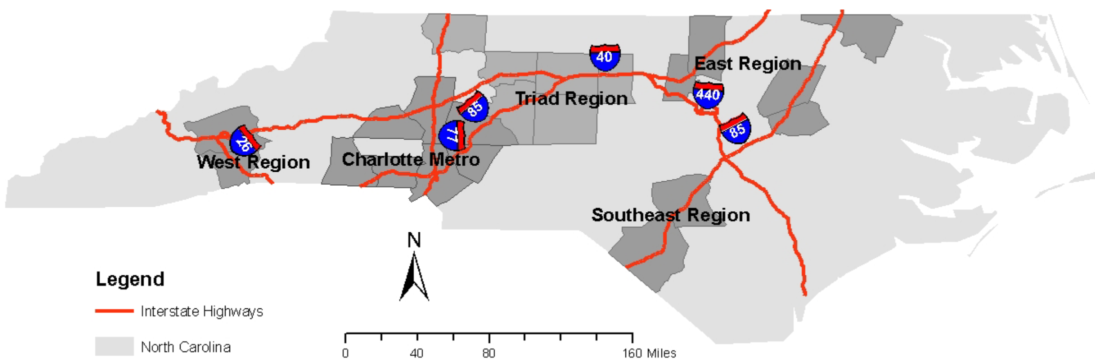


Figure 2. Map of Study Regions

The estimated total annual cost of unexpected delay was calculated using Equations 4 and 5 below. The result of Equation 4 is an input in Equation 5. Region and sector averages were used in those regions and sectors that lacked firm data.

Region-Sector Per Employee Cost = Total Annual Cost of Interviewed Region-Sector Firms / Total Employees of Interviewed Region-Sector Firms
…….. Equation 4.

Total Annual Cost = Region-Sector Per Employee Cost*Total Region-Sector Employees
…….. Equation 5.

Using hypothetical data as an example, if manufacturing firms in the West region reported a total annual cost of $10,000 and 1,000 employees, the annual per employee cost would be $10. The annual per employee cost for manufacturing firms in the West region would then be multiplied by the total number of manufacturing employees in the West region – 10,000 for this example – and come to a total annual cost of $100,000 for the Manufacturing sector in the West region.

5. Interview Results and Analysis

The key statistics of these interviews are shown in Tables 5 to 8, with Appendix C containing supporting descriptive statistics. The firms that were interviewed via telephone were mainly involved in manufacturing (e.g., manufacture of lighting systems, computers, furniture, tires, ceramics, construction equipment), and also included firms doing construction of buildings, trade (retailers), health, and government (postal service). Interviews with commercial carriers are not included here and they are described later. The interviewees were often transportation managers, e.g., individual who deal with logistics and warehousing, shipping and receiving, and fleets. The results from the phone interviews (Table 5) show that nearly half of the firms (46%) recently experienced unexpected delays. Those who experienced delays reported shipment delays that averaged 2 hours (N=11). The negative consequences of delays included driver/vehicle costs, production costs, and a loss of reputation/sales (in one case). Responses to delays were quite varied and included “no response”, re-routing the shipment, shifting unloading of delivery to another location, and if a receiving company was involved, then informing them about the delay. The firms had highly variable shipment operations and many had shipment windows for incoming or outgoing deliveries. They valued shipment reliability highly. Most of the incoming and outgoing shipments were not delayed, as reported by the representatives of the firms, i.e., the on-time performance was at or greater than 95%.

Face-to-face interviews were conducted with firms selected from the telephone interviews and included manufacturers of lighting systems and electrical hardware, computers, tires, and construction equipment. These interviews involved a significant time commitment on the part of the researchers and interviewees; they were conducted on-site at the company’s location and involved follow-ups regarding data and confirmation of figures reported by the interviewees. The results in Table 6 indicate variation similar to the phone interview results, as expected. While one of the firms ships only within North Carolina, others ship a substantial portion outside North Carolina, indicating the national character of the firms interviewed. Almost all firms had experienced unexpected delays in their shipments and the reported average unexpected delay ranged from 1.5 to 420 minutes during 2005. Most of the shipments were not delayed-one of the firms reported no unexpected delays affecting their operations but another firm reported that 90% of their shipments were delayed unexpectedly, indicating a wide range of experiences. The reported annual cost of unexpected delay ranged from $0 to $150,000. These costs were reported by the interviewees and could include the direct vehicle and driver costs of delay, the costs to businesses include higher inventory costs, and schedule delay costs, e.g., idle labor or production disruption costs. They do not include indirect costs of congestion such as added pollution and crashes. In some cases, a zero cost (to the firm was reported) despite (relatively small) delays-obviously the interviewees did not account for the driver and vehicle costs in these cases.

Table 5.
Firm Phone Interviews - Key Results

Firm ID	Recent Unexpected Delay	Negative Consequences	Primary Incoming Shipments Per Day	Primary Outgoing Shipments Per Day	Shipment Windows	On-time % Incoming	On-time % Outgoing	Shipping Reliability Highly Valued
2	Yes	None	20	10	No	NA	99.0	Yes
3	No	NA	12	9	No	98.0	98.0	Yes
4	Yes	>Driver/Veh Costs Production Costs	40	17	No	97.0	98.0	Yes
5	No	NA	NA	NA	NA	NA	NA	NA
6	Yes	None	119	119	No	98.0	98.0	Yes
7	Yes	>Driver/Veh Costs	40	40	Yes	100.0	100.0	Yes
8	Yes	>Driver/Veh Costs Production Timing Costs	137*	137*	Yes**	100.0	100.0	Yes
9	No	NA	100	100	Yes**	100.0	100.0	Yes
10	Yes	>Driver/Veh Costs Production Costs Reputation Suffered Inventory Costs	62	103	Yes**	95.0	95.0	Yes
11	No	NA	22	40	No	100.0	97.5	Yes
12	Yes	>Driver/Veh Costs Production Costs	175	135	No	NA	99.8	Yes
13	No	NA	15	30	No	100.0	100.0	Yes
14	No	NA	Highly Variable	Highly Variable	Yes	80.0	90.0	No
15	Yes	>Driver/Veh Costs	7	31	Yes**	NA	NA	Yes
17	Yes	Production Costs	NA	NA	Yes	95.0	90.0	No
19	Yes	Inventory Costs Reputation Suffered Other: Lost Sales	1	NA	Yes**	97.0	NA	Yes
20	No	NA	3	6	Yes	100.0	100.0	No
22	No	NA	33	33	No	100.0	100.0	Yes
23	No	NA	Unavailable	Unavailable	No	100.0	100.0	Yes
25	No	NA	1.1	0.1	Yes**	100.0	100.0	Yes
26	No	NA	2	7	No	100.0	90.0	Yes
27	No	NA	16.4	32.9	Yes**	99	99	Yes
28	Yes	None	1.4	1	Yes	80	80	No
29	Yes	Production Costs	15	7	Yes	95	95	Yes

** Multiple facilities.*
*** Incoming or outgoing shipments only, not both.*

The willingness to pay for improvements to address the occurrence and length of unexpected delays followed closely each firm's annual cost, with only a few exceptions. Many firms found it difficult to estimate the cost of 10% of incoming shipments arriving one day late, which was a hypothetical question posed to provide insights on tradeoffs between delays and costs. As such, their estimates too varied widely, ranging from $240 to $3 million.

The results also show that the costs of unexpected delays are disproportionately associated with incoming shipments rather than outgoing shipments (Table 6). This indicates a relatively high sensitivity of the production process to unexpected delays compared to that of product delivery. Although one firm reported a higher cost of outgoing shipment delays compared with incoming delays.

The majority of open-ended comments made by firms were related to better communications in terms of both NCDOT services and real-time incident information. They included much discussion of more and better facilities for truck drivers, most notably rest areas. Security in rest areas was also raised as a concern.

Table 6 (a).
Firm Face-to-Face Interviews - Key Results

Incoming							
Firm ID	**Shipment % Within NC**	**Average Unexpected Delay**	**% Shipments w/o Unexpected Delay**	**Annual Cost to Firm**	**Expected % w/o Unexpected Delay**	**Willingness to Pay for Improvement**	**Cost of 10% Incoming 1-Day Delay**
2	10	120 min	96	$24,000	99	$36,000	$5,500
3	20	60 min	90	$150,000	100	$150,500	$200,000
4	30	1.5 min	99	$0	100	$0	$2 mil
6	45	30 min	95	$0	95	$25,000	$2.5 mil
12	50	30 min	99.8	Minimal	100	$0	Unavailable
25	0	60 min	99	NA	99	$0	Unknown
26	100	420 min	90	$100,000	90	$100,000	$300,000
27	NA	NA	100	$0	100	NA	$3 mil
29	20	150 min	95	$29,000	100	$0	$240

Table 6 (b). Firm Face-to-Face Interviews - Key Results						
Outgoing						
Firm ID	**Average Unexpected Delay**	**% Shipments w/o Unexpected Delay**	**Annual Cost to Firm**	**Expected % w/o Unexpected Delay**	**Willingness to Pay for Improvement**	**Overall Comments**
2	120 min	94	$120,000	99	Minimal	NCDOT needs to better publicize their services (in magazines, cross-dept mailings, interstate signs). Also need better facilities at rest areas.
3	45 min	85	$0	97	$0	Proportion of international shipments is increasing, which will increase the importance of ports. Also, NCDOT should do all it can to do less road maintenance during the day.
4	NA	100	$0	100	NA	NCDOT needs to build more rest areas.
6	30 min	95	$0	95	$25,000	No complaints about NC routes, although they wish there was less construction.
12	45 min	NA	NA	NA	NA	The company is not willing to pay to reduce delay because it already pays for this by compensating drivers well (only a 4% driver turnover rate). NCDOT needs more rest areas, more parking & better safety at rest areas.
25	NA	NA	NA	NA	NA	No additional comments.
26	120 min	98	$0	100	$0	NCDOT needs to do a better job of preparing for future volumes and congestion.
27	NA	100	$0	100	NA	No extra comments.
29	150 min	95	$0	100	$0	Interstates need more information signs and should place them further out from typical congestion areas to give drivers adequate distance to reroute.

Turning our attention to commercial carriers, most of those interviewed served the manufacturing and trade industrial sectors (N=5). The interviews were aimed at relatively large national carriers with operations in the state of North Carolina and also local North Carolina carriers. They provided a range of transportation services and included LTL (Less Than Truckload) services.

Operationally, some were focused on the Southeast, others on the East Coast, and still others provided services throughout the United States. The average full-time drivers were 122.3, their total wages averaged $7.10 Million and the companies reported having nearly 97 vehicles on average, ranging from 66 to 169 vehicles (Appendix C). The context in which the interviewed carriers operate is quite varied, given that some of them have time windows and others do not, shipping times varied substantially, and shipping reliability was highly valued by some but not by others (Table 7). Some of the carriers offered guaranteed delivery within an hour or a longer pre-specified time period. The interviewed carriers experienced a recent unexpected delay. Considering the much heavier flow of vehicles for carriers compared to non-carrier firms, it is expected that they would experience a higher rate of recent unexpected delay as indicated in Table 7. Again as expected, the most common consequence of such delays was additional driver and vehicle costs. The carriers also noted that their reputation suffered as a result of late deliveries and one of them reported being paid less for the product delivered. Therefore, carriers suffer substantial quantitative and qualitative consequences as a result of unexpected delays. A common response to dealing with unexpected delays was to re-route the shipment. The overall on-time performance was fairly high, with 95% or more of the deliveries being on-time.

Table 7.
Carrier Phone Interviews - Key Results

Firm ID	Primary Industries Served	Recent Unexpected Delay	Negative Consequences	Primary Customer Shipments Per Day	Average Ship Time (hrs)	Shipment Windows	On-time % Outgoing	Shipping Reliability Highly Valued
1	Manufacturing and Trade	Yes	>Driver/Veh Costs Reputation Suffered	7	60	Yes	99.8	No
16	Manufacturing Trade and Construction	Yes	>Driver/Veh Costs Reputation Suffered	20	1.75	No	97.5	No
18	No Primary Industry	Yes	>Driver/Veh Costs Paid Fee to Customer Reputation Suffered	9	15	No	100.0	Yes
21	Manufacturing	Yes	Was Paid Less Per Unit of Product	137	2	Yes	98.5	Yes
24	Manufacturing	Yes	>Driver/Veh Costs Reputation Suffered	1	8	No	95.0	Yes

Table 8 shows that each carrier that participated in the detailed face-to-face interview, selected from those who participated in the telephone interview, listed “On-time Arrival” as a very important attribute of their business. The companies shipped various products that included filters, auto supplies, chemicals, batteries, foam products, furniture, flour, and appliances over fairly long distances, i.e., thousands of miles. The reported annual costs of unexpected delay were somewhat low ($4000 to $10,000), and only one carrier reported they would be willing to pay for transportation improvements. Interestingly, none used pre-trip traffic information provided by NCDOT, their use of route guidance devices was limited, and two of the three stated that current information services were not adequate for their business. They were not aware of the ncsmartlink.org website, but two of the firms reported awareness of North Carolina’s 511 service. The open-ended comments largely echoed those of the non-carrier firms.

Table 8 (a). Carrier Face-to-Face Interviews - Key Results						
Firm ID	**Very Important Attributes**	**Outgoing Shipments % Within NC**	**Average Primary Product Shipping Distance**	**Average Outgoing Unexpected Delay**	**% Outgoing Shipments w/o Unexpected Delay**	**Annual Cost to Firm**
1	On-Time Arrival Shipping Cost	0	2500 mi	90 min	95	$10,000
16	On-Time Arrival	60	178 mi	60 min	95	$10,000
24	On-Time Arrival	8	335 mi	60 min	95.3	$4,000

Table 8 (b) Carrier Face-to-Face Interviews - Key Results						
Firm ID	**Expected % Outgoing w/o Unexpected Delay**	**Willingness to Pay for Improvement**	**Pre-Trip Traffic Information**	**Current Info Services Sufficient**	**Incident Management Satisfaction**	**Overall Comments**
1	98.1	$10,000	No	No	Moderate	NCDOT needs better maintenance planning.
16	98	$0	No	Yes	Neutral	Most delay issues in NC are expected delay in Charlotte and Triangle areas.
24	99	$0	No	No	Moderate	NCDOT needs better real time communication with transportation industry.

Shipment Attributes

Shipment attributes varied across the sample of firms. Some firms' outgoing shipments were to local customers or distribution centers contained within NC. However, most firms shipped all over the country. Average shipment distances ranged from less than ten miles to 2,500 miles (N = 12). Only 17.4% of firms that participated in the face-to-face interviews had more than 50% of their outgoing shipment destinations within NC, indicating the regional and national scale of many NC businesses.

Firms that participated in the face-to-face interviews were asked to rank the importance of key shipment attributes to their business, with 1 equaling "Not Important" and 5 equaling "Very Important." Carriers ranked the importance of each attribute to their business, and the standard businesses ranked the importance of each attribute to the carriers they hired. The high average score of 4.8 for on-time arrival indicates significant temporal shipping sensitivity across multiple industry sectors. This is further supported by the fact that 75.9% of all 29 firms interviewed stated that they valued shipment reliability highly due to a just-in-time manufacturing or inventory process. However, only 48.3% of the firms stated that their shipments involved scheduled time windows. Those firms with scheduled time windows are theoretically more sensitive to unexpected delay since they have dedicated the labor to planning and handling shipments at a specific time. The impacts of unexpected delay on firms without scheduled time windows may be more uncertain. The lower average score of 3.7 for shipping time reflects the lower value placed on overall shipping time compared to shipment reliability. The high average score of 4.3 for cost is not surprising. However, the fact that it scored lower than on-time arrival shows again the importance of reliability. The importance of reliability is supported by the fact that several firms indicated they were willing to pay more for more reliable shipping performance.

Firms that participated in the face-to-face interviews also were asked to rank their performance in these attributes in 2005, with 1 equaling "Very Dissatisfied" and 5 equaling "Very Satisfied." The high average score of 4.3 for on-time arrival implies that firms experienced relatively few delays, expected or unexpected, in 2005. This is in line with the general sentiment provided by each firm that unexpected delay is a relatively infrequent occurrence in NC for their purposes. About 58% of all 29 firms interviewed stated that they had experienced a delay of at least thirty minutes in the past three months. Additionally, a thirty minute delay did not seem disruptive to most of the firms interviewed. However, the fact that more than half of the firms had experienced this delay points to the fact that this is an issue for many firms across the state. The low average score of 3.2 for cost is largely influenced by the significant increase of fuel costs in 2005, which also was stated by many of the firms.

Firms that participated in the face-to-face interviews were additionally asked to rank the multiple characteristics of North Carolina's interstate system, with 1 equaling "Very Dissatisfied" and 5 equaling "Very Satisfied." The characteristics included existing infrastructure, capacity, safety, incident management, and information services. In general firms were moderately satisfied with the NC Interstate system, with average scores ranging only from 3.4 to 3.8. Most relevant to this study, incident management received a score of 4 or 5 from 8 of the 12 firms interviewed, such that it was one of the two highest-rated attributes, along with safety, with a score of 3.8. These modest overall scores indicate that firms, while not dissatisfied with the Interstate system in NC, see ample room for improvement.

Costs of Delay

Firms that participated in the face-to-face interviews were requested to estimate the percentage of shipments that experienced an unexpected delay of at least thirty minutes, the average time of delay, and the total annual costs of those delays in 2005. Occurrences of unexpected delay (of 30 minutes or more) ranged from 0% to 5% for incoming shipments and from 0% to 15% for outgoing shipments. Average delay times for both incoming and outgoing shipments ranged from 1.5 minutes to 7 hours, although only two firms reported an average delay of more than 1 hour.

Total annual costs of unexpected delay reported by interviewees ranged from $0 to $150,500. These reported costs clearly do not capture all the direct and indirect costs to the firms. Firms that reported $0 cost had one or more explanations: not employing a just-in-time manufacturing or inventory system, shorter than average shipment distances, complete transfer of shipment responsibility once product left the facility, or built in business practices to account for potential unexpected delays (i.e. padding shipping times). Additionally, one firm stated that 0% of its total shipments had been unexpectedly delayed. Just over 62% of all firms reported additional driver and vehicle costs as a consequence of unexpected delay, making it the most prevalent cost type.

Information obtained from each firm was used to calculate an average and median hourly cost of unexpected delay using the equations outlined in the methodology section. One firm acknowledged there were costs of unexpected delay, but was unable to calculate an amount. As a result, the average incoming and outgoing shipment hourly cost of unexpected delay for the remaining sample was used.

The hourly reported cost of unexpected delay ranged from $25.12 to $391.39 (Table 9). The average hourly cost of $144.77 is somewhat consistent with previous studies, e.g., Small (1995) reported that commercial carriers value travel time at $144.22–$192.83 per hour, and savings in late schedule delays at $371.33 per hour. The reported median hourly cost in North Carolina is $65.13, indicating that the distribution of unexpected delay costs is skewed. While all unexpected delay creates some amount of cost, at the very least from increased driver and vehicle costs, one firm reported that such delays created no additional direct cost for them. This is due to this firm's ability to insulate themselves from such impacts so that unexpected delays are infrequent and short in duration, and any associated cost is absorbed by the carriers that serve them. However, while it is unstated, the firm experiences some cost to develop and operate such a system. In an effort to report the most accurate cost of delay possible, the minimum cost for non-carrier firms was used for this firm in the calculations of total costs.

Table 9.
Unexpected Delay Descriptive Statistics

	Hourly Cost of Unexpected Delay	Length of Unexpected Delay (hrs)	Annual Unexpected Delay (hrs)
Average	$144.77	1.1	989.9
Median	$65.13	0.5	715.0
Min	$25.12	0.0	10.2
Max	$391.39	4.5	4,803.4
Std Dev	$134.45	1.4	1,402.0

Firms also were asked the amount they would be willing to pay to eliminate the unexpected delay they experience. Results ranged from $0 to $150,500, with most firms willing to pay an amount equal to the associated annual cost. The average amount willing to be paid was $32,150, although a little more than half the firms were unwilling to pay. Most of those firms stated that their current payments in taxes should be sufficient to address unexpected delay at the state level. The average amount willing to be paid by those firms that stated an amount greater than zero was $64,300.

Coping Behavior

Firms that participated in the face-to-face interviews were asked several questions to determine how they prepared and responded to unexpected delays. In terms of preparing for unexpected delays, 75% of the firms or their carriers use some type of route guidance device on their shipping vehicles, while only 33.3% seek any pre-trip traffic information on a regular basis. Additionally, only 16.7% of the firms were aware of the NCSmartLink.org website and only 33.3% were aware of the toll-free 511 telephone number for real-time traffic information. This implies that there is potential (for NCDOT) to inform firms and carriers about the availability of these services.

Overall only 50% of the firms stated that current information systems in NC were sufficient for their business. Additionally, several firms stated that more and improved truck stops were needed along North Carolina interstates. Safety and security was the one specific point of improvement requested. Other firms also commented on the amount and timing of maintenance on the interstates. Better planning for the timing of maintenance would be a benefit to several of the firms interviewed.

In terms of responding to unexpected delay, each carrier interviewed and the only standard business that did not use a carrier stated that the most common immediate response to an unexpected delay was to reroute the shipment, if possible. At the business management level, 70.8% of standard businesses stated they would consider changing suppliers to respond to continued unexpected delay of incoming shipments. There was no trend, however, in the response to continued unexpected delay of outgoing shipments, with each firm giving a unique response. Interestingly, each carrier stated that it would respond to continued unexpected delay of outgoing shipments by implementing new technology.

Sectors and Regions

Sector and regional analyses provide additional insights, despite the small sample size (N = 12) and limited representation of industrial sectors or geographic regions. Table 10 shows each region's industrial sector composition, counting only sectors from which firms were interviewed and are part of the sample. The included sectors represented 43.9% to 48.6% of the total employment in each region. Government employment represented the highest percentage in the West, East, and Southeast, while Manufacturing represented the highest percentage in the Charlotte metropolitan area and the Triad region. Transportation & Warehousing and Construction represented relatively low percentages in each region.

Table 10.
Industries by Region

Region	**Government**		**Retail Trade**		**Transportation & Warehousing**		**Manufacturing**		**Construction**		**Total**	
	FTE	% of Total	FTE	% of Total	FTE	% of Total	FTE	% of Total	FTE	% of Total	FTE	% of Total
West	27,415	16.8	18,897	11.6	4,195	2.6	19,425	11.9	8,949	5.5	78,881	48.3
CLT	101,683	11.7	89,877	10.3	42,034	4.8	103,883	11.9	45,208	5.2	382,685	43.9
Triad	73,213	10.8	70,094	10.3	31,471	4.6	119,244	17.6	32,554	4.8	326,576	48.2
East	59,638	18.9	24,633	7.8	4,566	1.4	52,994	16.8	11,520	3.7	153,351	48.6
SE	32,739	19.1	20,381	11.9	6,192	3.6	15,735	9.2	7,515	4.4	82,562	48.1
Total	**294,688**		**223,882**		**88,458**		**311,281**		**105,746**		**1,024,055**	

The results in Table 11 show that every sector but Construction had at least 50% of firms recently experience unexpected delay (N = 29). Additionally, the average cost of delay per hour is about the same across retail, transportation, and manufacturing sectors, although the public sector (Government agency) costs are substantially lower (N = 12). The public sector considers shipment reliability less valuable. Thus, the results do not vary substantially by industry sectors considered here, mainly because of aggregation and selected firms having high levels of shipping needs.

Table 11. North Carolina Industrial Sector Analysis					
Survey Question	**Government** (N = 1/1)*	**Retail** (N = 2/1)*	**Transportation** (N = 8/4)*	**Manufacturing** (N = 15/6)*	**Construction** (N = 3/0)*
% of Firms Reporting Recent Unexpected Delay	100	50	75	53.3	33.3
% of Firms Reporting Driver/Vehicle Costs**	NA	0	80	50.0	100.0
% of Firms Reporting Shipment Windows	100	100	62.5	53.3	33.3
% of Firms Reporting Reliability Highly Valued	0	100	50	66.7	66.7
Average Cost of Delay per Hour	$25.12	$156.37	$160.88	$153.50	NA

*N=x/y, where x is the number of firms included in the phone interviews, and y is the number of firms included in the face-to-face interviews. Only the average cost of delay per hour taken from face-to-face interviews.
**Based only on those firms that reported experiencing a recent unexpected delay.

The results in Table 12 show that every region but East had at least 50% of firms recently experience unexpected delay (N = 29). Additionally, the average cost of delay per hour varies substantially across regions (N = 12). Note that the regions analyzed in this study represent 22 counties that were selected based on several criteria (presence of Interstate, traffic congestion, etc.), although the firms providing cost data represent only 10 counties. The Southeast region has a relatively higher reported cost, followed by the West, East, Triad and Charlotte metropolitan region. The high cost in the Southeast may be due to the existence of only one interstate in the area and limited rerouting opportunities. The reported costs are also substantially lower for the Charlotte metropolitan region, perhaps because of the type of firms interviewed in that region and a limited sample for the cost data (N = 2).

Table 12. Sample Regional Analysis					
Survey Question	**West** (N=2/1)*	**CLT Metro** (N=10/2)*	**Triad** (N=9/5)*	**East** (N=5/1)*	**Southeast** (N=2/1)*
% of Firms that Reporting Recent Unexpected Delay	100	50	50	40	50
% of Firms Reporting Driver/Vehicle Costs**	0	80	100	50	100
% of Firms Reporting Shipment Windows	50	70	13	80	50
% of Firms Reporting Reliability Highly Valued	100	70	63	60	100
Average Cost of Delay per Hour	$168.78	$46.54	$132.60	$156.37	$342.47

*N=x/y, where x is equal to the number of firms included in the phone interviews, and y is equal to the number of firms included in the face-to-face interviews. Only the average cost of delay per hour taken from face-to-face interviews.
** Based only on those firms that reported experiencing a recent unexpected delay.

A key result of this research is the cost of congestion to businesses caused by incidents on NC Interstate facilities. Table 13 shows that substantial costs of incident delay are imposed on businesses that are located along interstates and have substantial shipment needs—the costs are in the vicinity of $27.25 million per year in the North Carolina regions selected (2005 dollars). While most firms reported driver and vehicle costs resulting from unexpected delays, additional substantial cost reported was production timing costs that include additional labor and operation costs. The costs clearly vary by region and by industry sector. The Charlotte metropolitan area experiences the largest business costs, as expected (partly because of higher concentration of industry and presence of truck bottlenecks and incident congestion), followed by the East, Southeast, Triad, and West.

The results are valuable in identifying where to concentrate NCDOT efforts that can improve travel time reliability. Although the Charlotte Metro area has fairly wide IMAP and ATIS coverage, there is still potential for reducing business costs in the region through further IMAP and ATIS improvements. Another interesting area of future NCDOT focus is the East and Southeast of North Carolina along Interstate 95, where IMAP and ATIS implementations are relatively few. Khattak and Rouphail (2005) had evaluated the I-95 corridor for IMAP implementation from the perspective of individual travelers and did not find economic justification for IMAPs, as the benefit cost ratio was less than one. However, when viewed from a business perspective and based on our new interviews and analysis, these areas have significant potential for the reduction of business costs related to incident congestion. We recommend that the IMAP tool developed by Khattak and Rouphail (2005) be applied to selected I-95 corridor areas (characterized by the counties in the East and Southeast of this study and using the values of time for businesses and individual travelers) to assess the best locations for future IMAP implementations.

Table 13.
Total Annual Costs of Unexpected Delay

Region	Government	Retail Trade	Transportation & Warehousing	Manufacturing	Total
West	$ 856,719	$ 120,435	$ 30,820	$ 1,547,866	**$ 2,555,840**
CLT	$ 3,177,594	$ 572,808	$ 206,937	$ 6,373,190	**$ 10,330,529**
Triad	$ 2,287,906	$ 446,726	$ 381,467	$ 23,539	**$ 3,139,638**
East	$ 1,863,688	$ 156,992	$ 33,546	$ 4,035,433	**$ 6,089,659**
SE	$ 1,023,094	$ 129,893	$ 45,492	$ 3,933,750	**$ 5,132,229**
Total	**$ 9,209,000**	**$ 1,426,855**	**$ 698,262**	**$ 15,913,777**	**$ 27,247,895**

In terms of total costs, manufacturing sector has higher costs, followed by the Government sector, Retail Trade and a very low cost for the Transportation and Warehousing sector (see Table 13 for details). However, the low cost for the Transportation and Warehousing sector is partly due to differing interview questions. Carriers were asked for cost estimates based on their "primary customer," which for most only accounted for a small percentage of their total shipments. This is compared to non-carrier firms, whose estimates were based on shipments of their "primary product," which accounted for the vast majority of their shipments. Therefore, it is logical to assume that the cost calculation for the Transportation and Warehousing sector is quite conservative.

Thus the impacts of incident congestion (in terms of travel time uncertainty costs) on businesses vary across North Carolina regions, partly depending on the concentration of industry, nature of shipments, and extent of the reported incident costs by selected firms. Typically the nature of industry in the region will also have an effect on the total incident related costs, e.g., some industries are more sensitive to uncertainty in travel times than others, this analysis shows that nearly all industry sectors who have substantial shipping needs report some costs associated with unexpected congestion (some with higher levels of costs). It seems that the Manufacturing sector can potentially benefit substantially from incident congestion reduction. The results also show that the government sector reports relatively low impact in terms of shipment delays and therefore tend to be hurt relatively less by incident-induced delays.

Firm Comments

Both the phone and face-to-face interviews asked firms to provide any additional comments to address issues that were not covered in the interview. While some comments were repeated by several firms, most of them were unique. These comments are summarized in the following list:

- Many firms already devote substantial resources to ensure greater shipment reliability.
- Inbound shipments are the most sensitive to delays (and of concern to the firms) due to decreased inventory, decreased warehousing space, and tighter production schedules.
- North Carolina firms would benefit from improved regular communication with firms to increase their awareness of existing or new information services. This could be achieved through advertisements in transportation-related magazines and including marketing material in related NCDOT mailings to the firms.
- NCDOT should provide more rest areas along North Carolina interstates. Additionally, new and existing rest areas should provide higher levels of quality and security than what currently exists.
- Whenever possible, NCDOT should schedule interstate maintenance during off-peak periods, with consideration of truck traffic.
- The recent increase in overhead electronic signs is helping. However, more of these signs should be installed, and they should be spaced further from typically congested area to ensure they provided adequate distance for drivers to reroute.
- North Carolina firms already pay an adequate amount of taxes to reasonably reduce unexpected delay without additional cost to firms.

6. Simulation Modeling Results

Commercial vehicles/firms are more sensitive to time delays than individual travelers and have a higher value of time (VOT) by virtue of the goods that they carry, as well as the facts that the vehicles are larger and the drivers receive wages for transporting goods. To be more specific, the higher value of time for trucks could come from delay costs due to spoilage for time-sensitive, perishable deliveries, late deliveries, just-in-time processing costs, keeping additional inventory, and undesirable production schedule change, in addition to the direct vehicle and driver costs.

This higher value of time (and associated impacts) often is ignored in calculations of incident-induced congestion costs. We have explored this value of time in interviews presented above and found it to be substantially higher than the value of time for individual travelers. Here we present case studies to reflect the more realistic benefits of existing and potential traffic and incident management services as well as innovative technologies, and their more realistic economic effects.

First, case studies with incident management assistance patrol (IMAP) service were tested, where different levels of IMAP service would bring different levels of reduction in incident duration. Then, case studies with advanced traveler information systems were simulated, where different levels of ATIS deployment would result in diversions to alternative routes. The case studies are based on realistic traffic and incident data, as well as assumptions reflecting real road networks in North Carolina, based on NCDOT recommendations. Modeling results of various case studies indicate that, with high VOT for commercial users, either IMAP service or ATIS deployment tends to return significant monetary savings, and generally a higher level of service/deployment would bring more economic benefits to the transportation system.

Case Studies with Incident Management Assistance Patrol Service

Scenario-based case studies in the IMAP decision tool were conducted to analyze the effects of incident-induced delay on trucks as well as on individual travelers in passenger cars for situations without and with IMAPs on North Carolina's interstate facilities. Recently developed by Khattak and Rouphail (2005), IMAP is a decision support tool that allows easy planning and operational assessment of existing and potential IMAP sites in North Carolina. Its operational level analysis provides the delay savings / benefits at certain selected freeway facilities with and without IMAPs, where the FREEVAL model (which replicates the freeway facility methodology in Chapter 22 of the Highway Capacity Manual 2000 (2000)) is utilized to estimate the effects of queuing and vehicle delay macroscopically.

With information on the roadway facility (location, i.e. urban or rural, AADT[1], length, number of lanes, percentage of trucks, etc.), whether the incident is in peak hour vs. non-peak hour, and incident characteristics (severity, duration etc.), the IMAP decision tool helps users evaluate the scenarios of incident-induced delays without and with IMAP deployment. The outputs include facility-based performance measures, such as facility delay, delay/VMT, delay/vehicle, delay cost, savings and so on. Basic inputs and major outputs of IMAP decision tool are listed in Figure 3.

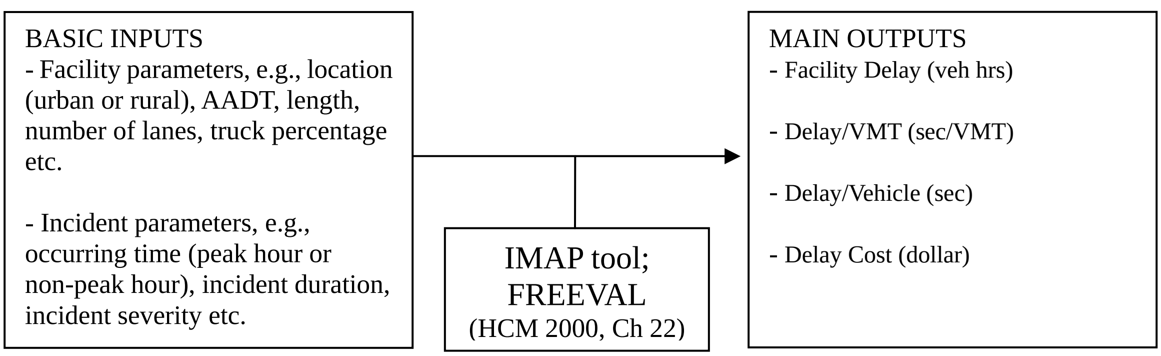


Figure 3. IMAP Inputs and Outputs

The simulated freeway facilities in case studies represent Interstate 40 in an urban area and Interstate 95 in a rural area. Note that based on the interviews and analysis presented earlier, I-95 was identified as a potentially important freeway for IMAP implementation. Several sets of case studies were modeled in IMAP by varying parameters including different percentage of trucks, different incident severity, and different incident durations, etc. (see Table 14 for details).

[1] AADT - Annual Average Daily Traffic.

Table 14. Different Parameters Used in Case Studies with IMAP Service									
Set No.	**Location**	**Truck Percentage**	**Facility Length (miles)**	**AADT**	**Number of Lanes**	**VOT for Cars**	**VOT for Trucks**	**Incident Occurrence Time**	**Incident Severity**
1	I-40 in Urban Area	5%	10	90,000	3	$10	$150	Peak	0.5
2								Peak	0.8
3								Non-peak	0.5
4								Non-peak	0.8
5	I-95 in rural area	10%		60,000	2			Peak	0.2
6								Peak	0.7
7								Non-peak	0.2
8								Non-peak	0.7

Note: Incident Duration = 60 minutes.

Incident Severity: 0.5 (50% capacity remaining, one lane blocked in a three-lane freeway); 0.8 (20% capacity remaining, two lane blocked in a three-lane freeway); 0.2 (80% capacity remaining, shoulder accident in a two-lane freeway); 0.7 (30% capacity remaining, one lane blocked in a two-lane freeway).

Realistic data assumptions were made in the case studies, as follows:

- First, real field data, such as the 2005 average daily traffic (ADT) data (collected from the Triangle Regional Model (TRM)) and real traffic volume data (coming from the Automatic Traffic Recorder (ATR) station), were considered in developing the case studies.
- Importantly, the value of time for trucks used in different case studies is specific for North Carolina businesses. According to our interviews (reported above) and analysis results, the Hourly Cost of Unexpected Delay for commercial users averaged $144.77, with a range from $25.12 to $391.39. We chose $150 (rounded off) as the VOT for trucks in case studies for illustration purpose. This is also consistent with the literature, e.g., Small (1995), which shows similar or larger values.
- Peak hour and non-peak hour for either urban area or rural area were determined according to the real urban and rural traffic volume profiles[2]. Specifically, urban peak hour and non-peak hour time periods were set to 7 am-9 am and 9 am-4 pm, respectively; while peak hour for rural area is 5 pm-8 pm and non-peak hour is 7 am-5 pm.

To identify effects of different levels of IMAP deployment, detailed case studies were conducted using the IMAP tool. Specifically, for each case tested above (Table 14), we compared the different performance measure outputs from IMAP among base, light IMAP deployment, moderate IMAP deployment, and full IMAP deployment. Here, the base case is the situation where an incident occurs but no IMAP service is provided; light, moderate, and full IMAP deployment refer to the scenarios where IMAP reductions in incident duration are about 10%, 30%, and 50%, respectively (note that these reductions are realistic and are based on IMAP literature). Detailed modeling results for different sets of case studies are shown in Table 15. Interesting findings are listed as follows:

- Higher IMAP deployment level improves system performance in terms of all performance measures, e.g. facility delay, delay/VMT, delay/vehicle, and delay cost are lower, and total

[2]See Khattak and Rouphail (2005) NCDOT report: (http://www.ncdot.org/doh/preconstruct/tpb/research/download/2003-06FinalReportPart2.pdf)

dollar savings.

- IMAP deployment will provide more benefits to incidents occurring in the peak hour, especially for the scenarios with moderate or low incident severity. For instance, if the incident severity is about 50% capacity reduction (1 lane blocked[3]), then the benefit of full IMAP deployment in peak hour will be about 10% higher than in non-peak hour (see case study set 1 and 3). However, if the incident severity is about 80% capacity reduction (2 lanes blocked[3]), then the benefit of full IMAP deployment in peak hour is sill higher than in non-peak hour, but the differences are not very remarkable (see case study set 2 and 4).
- With larger traffic volumes (urban vs. rural), providing IMAP service to respond to incidents and reduce incident-induced congestion can bring more benefits to all road users in terms of total dollar savings (see case study 2 and 6 as an example).
- With high levels of incident severity, higher level IMAP deployment will provide relatively more benefits to the whole network. For example, in case study set 2, peak hour, for each level of IMAP deployment, returns high benefits in terms of total dollar savings because IMAP reduces facility delay eventually by reducing incident duration, and the benefit increases with the level of IMAP deployment.
- When incidents occur in rural areas (on I-95) with relatively low AADT and low incident severity, then the benefits with increased IMAP deployment are low, as expected. For instance, in case study set 5 and 7, when the incident severity is about 20% capacity reduction (shoulder accident[3]), there are no notable differences among different levels of IMAP deployment. (In a few cases, the IMAP evaluation tool does not perform well and indicates negative delay cost reductions due to IMAP deployment. This likely is due to the noise in computation of the IMAP decision tool.) Conversely, when incident severity is relatively high, the benefits with increased IMAP deployment are substantial both during peak and off-peak hours.

While these results point to substantial potential of IMAPs both in urban and rural areas, the decision to implement IMAPs must be made on the basis of actual frequency of incidents in these areas. The IMAP tool developed by Khattak and Rouphail (2005) provides the capability of making such assessments and calculating benefits and costs. Also note that we had fixed the percentage of trucks in this analysis. In a future study, it will be valuable to vary the truck percentages and see how the benefits change as more trucks (that have a higher value of time) join the traffic stream.

Case Studies with Advanced Traveler Information Systems

Given the NCDOT interest in advanced traveler information systems (as reflected in Project Number 2006-13, titled Effectiveness of Traveler Information Tools) and in order to illustrate the effect of existing or potential ATIS technologies used for traffic management on North Carolina's interstate facilities, we developed sets of case studies for different levels of ATIS deployments. The unique aspect of the case studies is that they account for different types of road users, i.e., passenger cars vs. commercial carriers. The analysis is based on directly using the FREEVAL macroscopic traffic simulation tool (TRB 2000). FREEVAL's basic inputs and major outputs are listed in Figure 4.

[3] Traffic Incident Management Handbook, Page 1-4, (http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPT_MIS/13286.pdf)

Table 15.
Modeling Results for Different Sets of Case Studies with IMAP Service

Set 1				
Performance Measures	**Base**	**Light Deployment**	**Moderate Deployment**	**Full Deployment**
Facility Delay (veh hrs)	178	157	116	80
Delay/VMT (sec/VMT)	14	12	9	6
Delay/Vehicle (sec)	140	124	91	63
Delay Cost (dollar)	3026	2669	1972	1360
Savings (dollar)	0	357	1054	1666
Savings (%)	0.00%	11.80%	34.83%	55.06%
Set 2				
Performance Measures	**Base**	**Light Deployment**	**Moderate Deployment**	**Full Deployment**
Facility Delay (veh hrs)	2754	2128	1063	559
Delay/VMT (sec/VMT)	217	167	84	44
Delay/Vehicle (sec)	2167	1674	837	440
Delay Cost (dollar)	46818	36176	18071	9503
Savings (dollar)	0	10642	28747	37315
Savings (%)	0.00%	22.73%	61.40%	79.70%
Set 3				
Performance Measures	**Base**	**Light Deployment**	**Moderate Deployment**	**Full Deployment**
Facility Delay (veh hrs)	66	60	47	35
Delay/VMT (sec/VMT)	6	6	4	3
Delay/Vehicle (sec)	62	56	44	33
Delay Cost (dollar)	1122	1020	799	595
Savings (dollar)	0	102	323	527
Savings (%)	0.00%	9.09%	28.79%	46.97%
Set 4				
Performance Measures	**Base**	**Light Deployment**	**Moderate Deployment**	**Full Deployment**
Facility Delay (veh hrs)	1630	1298	718	389
Delay/VMT (sec/VMT)	151	121	67	36
Delay/Vehicle (sec)	1515	1206	667	362
Delay Cost (dollar)	27710	22066	12206	6613
Savings (dollar)	0	5644	15504	21097
Savings (%)	0.00%	20.37%	55.95%	76.13%
Set 5				
Performance Measures	**Base**	**Light Deployment**	**Moderate Deployment**	**Full Deployment**
Facility Delay (veh hrs)	15	15	16	16
Delay/VMT (sec/VMT)	2	2	2	2
Delay/Vehicle (sec)	18	18	18	19
Delay Cost (dollar)	360	360	384	384
Savings (dollar)	0	0	-24	-24
Savings (%)	0.00%	0.00%	-6.67%	-6.67%

Table 15 (continued)

Table 15 (continued)				
Set 6				
Performance Measures	**Base**	**Light Deployment**	**Moderate Deployment**	**Full Deployment**
Facility Delay (veh hrs)	669	547	327	181
Delay/VMT (sec/VMT)	77	63	38	21
Delay/Vehicle (sec)	767	627	375	208
Delay Cost (dollar)	16056	13128	7848	4344
Savings (dollar)	0	2928	8208	11712
Savings (%)	0.00%	18.24%	51.12%	72.94%
Set 7				
Performance Measures	**Base**	**Light Deployment**	**Moderate Deployment**	**Full Deployment**
Facility Delay (veh hrs)	2	2	3	3
Delay/VMT (sec/VMT)	1	1	1	1
Delay/Vehicle (sec)	5	5	6	7
Delay Cost (dollar)	48	48	72	72
Savings (dollar)	0	0	-24	-24
Savings (%)	0.00%	0.00%	-50.00%	-50.00%
Set 8				
Performance Measures	**Base**	**Light Deployment**	**Moderate Deployment**	**Full Deployment**
Facility Delay (veh hrs)	104	88	58	34
Delay/VMT (sec/VMT)	20	17	11	6
Delay/Vehicle (sec)	197	166	109	64
Delay Cost (dollar)	2496	2112	1392	816
Savings (dollar)	0	384	1104	1680
Savings (%)	0.00%	15.38%	44.23%	67.31%

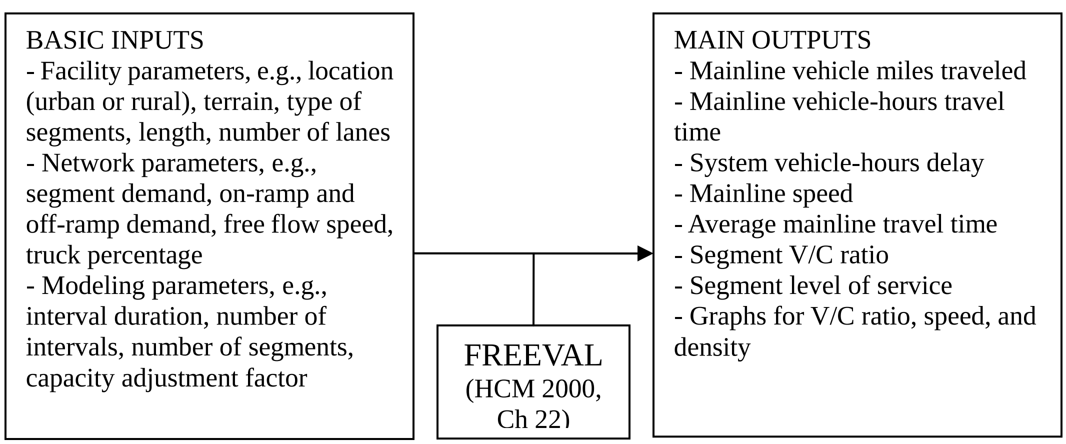
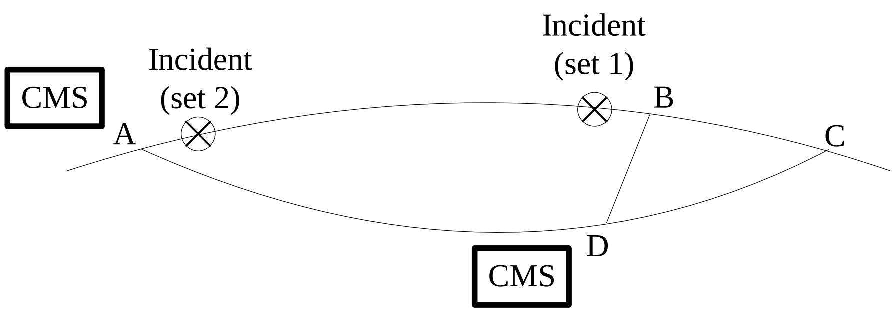


Figure 4. FREEVAL Inputs and Outputs

There are two types of case studies in this portion of the research. One was with an idealized two-route road network, which used FREEVAL and added in a traveler behavior model based on survey data of a real field study (Khattak 1991). The purpose was to address the general effect of ATIS on improving network performance, while considering different user / vehicle features, e.g., different traveler behavior between individual travelers (car drivers) and truck drivers.

The intent of the second type of case studies was to link this study with NCDOT Project Number 2006-13, Effectiveness of Traveler Information Tools, which simulates a similar network. This second type of case studies is based on realistic traffic data, obtained from NCDOT. A portion of the network around the Research Triangle Park (RTP), NC is simulated. Similar to the IMAP case studies, realistic inputs and assumptions, based on real field data, are used to show the effects (in percentage changes of total dollar savings) of existing and potential ATIS deployments on NC businesses.[4]

Idealized Network Case Studies
A simplified road network with five links but a single origin (point A) and a single destination (point C) was used (as shown in Figure 5). Incidents were modeled to occur on link AB and when the traffic conditions were unsaturated. We examined two set of incidents. Incidents in Set 1 were near point B, where travelers could not observe the incident-induced queue and could not divert to the alternate route by themselves. By contrast, incidents in Set 2, which occurred near point A, could be observed by travelers; and travelers themselves (without ATIS) might respond to incident-induced congestion and switch routes at point A.



**CMS = Changeable Message Sign*

Figure 5. Idealized Road Network for Case Study

We added a traveler behavior model into the traveler information evaluation process, which should reflect drivers' actual response to traffic congestion information. Such a model would be useful for testing differences in effects of traveler information due to different road user/vehicle behaviors, since different types of road users and vehicles may have distinct traveler behaviors. The binary logit behavioral model we chose was based on a survey of travelers (Khattak 1991), which was estimated using the responses of those who knew about the traffic delays either by observing them or through traffic information (see Appendix E for more details).

Different incident case studies were tested to demonstrate the ATIS evaluation process and how various assumptions can be changed to suit local conditions. The important and interesting findings were:

- Substantial network performance benefits can be obtained from disseminating traveler information. Network average travel time and total travel cost can be reduced (up to about 9%) by increasing the percentage of electronic traffic information dissemination in incident conditions. However, the benefits of electronic information are lower if travelers can observe the incident-induced congestion and divert to alternate routes. The study finds

[4] The percentage difference is calculated as (original value – new value)/original value.

that savings associated with electronic information are highly context dependent, i.e., they can be almost wiped out if drivers are able to observe traffic congestion.

- Total travel cost and average travel times increase with an increased percentage of truck flow, because truck traffic has a greater impact on traffic flow than passenger cars (see Figure 6 and 7 for more detail). Broadcasting dynamic traffic information under incident-induced congestion situations can provide system benefits by benefiting both individual travelers and commercial users.
- Higher chances of truck diversions are evidently associated with greater total travel cost savings.
- Higher truck values of time might be associated with relatively smaller percentage of savings in total travel cost.

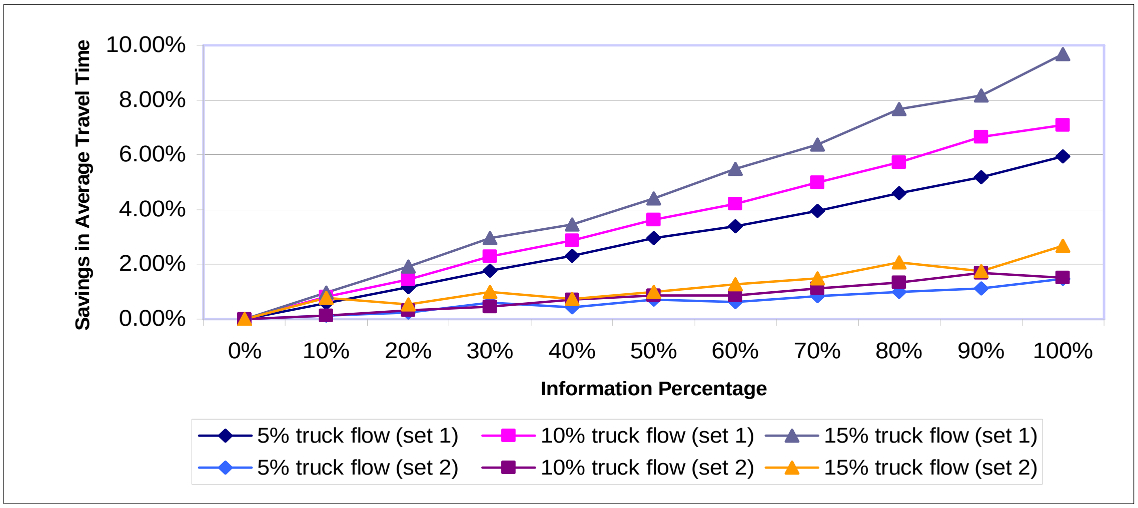


Figure 6. Benefit of Average Travel Time for Two Sets of Case Studies

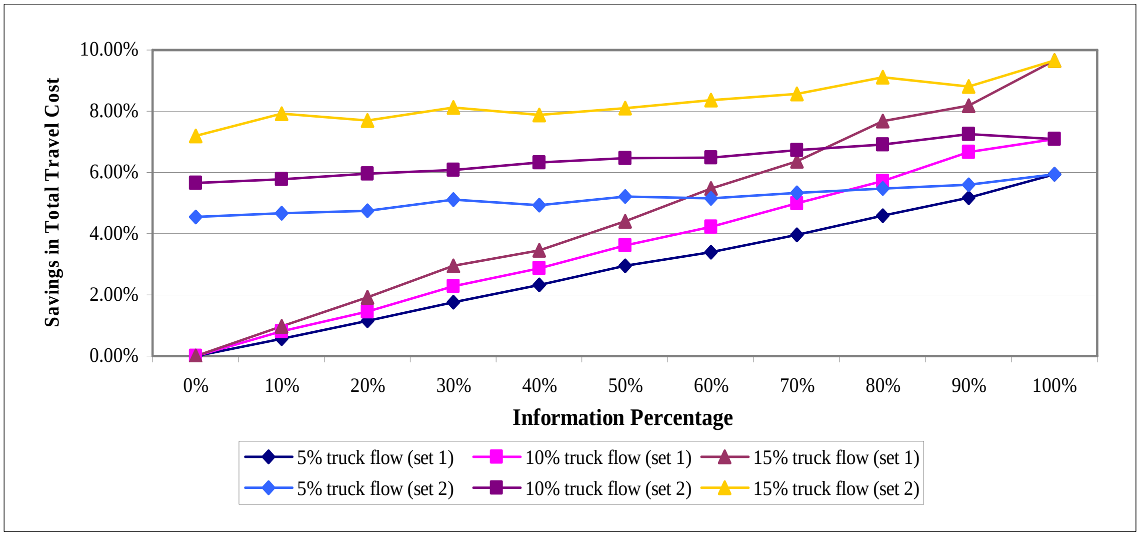
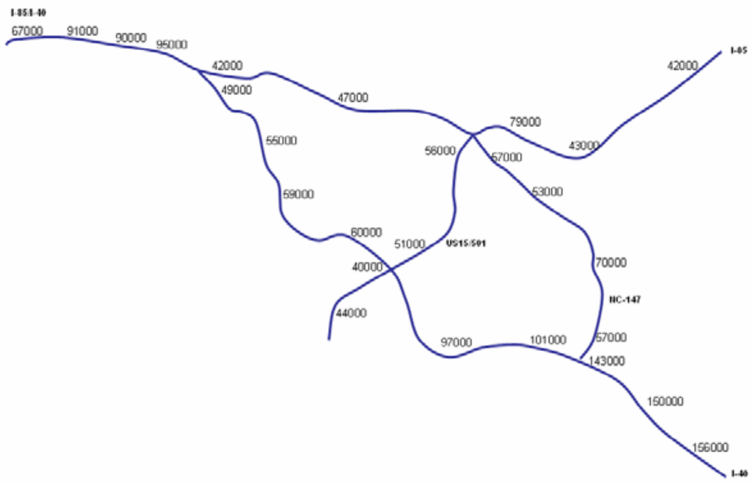


Figure 7. Benefit of Total Travel Cost for Two Sets of Case Studies

For more detailed information about these ATIS case studies within the idealized network, refer to Appendix E. All input parameters of the behavior model and network / incident parameters used here can be changed to reflect the local conditions, if behavioral data, network and incident information are available. These case studies show that ATIS deployment generally has a positive effect in idealized situations. The realistic set of case studies, with realistic inputs and assumptions, provide a more exhaustive account of percentage changes in total savings.

Realistic Network Case Studies

With incident location and severity varying among different sets of case studies, we used FREEVAL to model cases without and with ATIS deployment. The realistic network we chose, based on NCDOT input, is the Durham, Chapel Hill and Hillsborough area in North Carolina, where I-40, I-85 and NC-147 intersect with each other so that travelers could use alternative routes for diversion if one route experiences incident-induced congestion (see Figure 8 for detail of the area and network).



2005 Annual Daily Traffic

Figure 8. Road Network Used in Case Studies (part of I-40, I-85 and NC-147)

Different input parameters used for the case studies are listed in Table 16. Different incident occurrence times were chosen to reflect peak hour and non-peak hour time periods, where peak hour was set to 7 am-8 am, and non-peak hour was set to 8 pm-12 pm (based on real traffic volume profiles[2]).

<table>
<tr><th colspan="9">Table 16.
Parameters Used in ATIS Case Studies</th></tr>
<tr><th>Set No.</th><th>Location</th><th>Truck Percentage</th><th>Facility Length (miles)</th><th># Lanes</th><th>VOT Car</th><th>VOT Truck</th><th>Incident Occurrence Time</th><th>Incident Severity</th></tr>
<tr><td>1</td><td rowspan="4">Durham, Chapel Hill, and Hillsborough Area (including I-40, I-85 and NC-147)</td><td rowspan="4">5%</td><td rowspan="4">47 in total
20 for I-40
21 for I-85 and NC-147
6 for Connecting Links</td><td rowspan="4">2-4</td><td rowspan="4">$10</td><td rowspan="4">$150</td><td>Peak</td><td>0.2</td></tr>
<tr><td>2</td><td>Peak</td><td>0.7</td></tr>
<tr><td>3</td><td>Non-peak</td><td>0.2</td></tr>
<tr><td>4</td><td>Non-peak</td><td>0.7</td></tr>
</table>

Notes: Incident Duration = 60 minutes. Incident Severity: 0.2 (80% capacity remaining, shoulder accident in a two-lane freeway); 0.7 (30% capacity remaining, one lane blocked in a two-lane freeway).

To understand the effect of different levels of ATIS deployment, we compared performance measures between sets of case studies. There was one base case and three levels of ATIS deployment. The base case refers to the situation when an incident occurs but there is no ATIS implementation for traffic management, and hence no real-time travel information is disseminated to the users. In addition, light, moderate, and full ATIS deployment refer to the cases where ATIS will result in the diversion rate equal to 10%, 25%, and 40%, respectively. These diversion percentages were determined by examining existing literature and by behavioral analysis based on recent travel survey data within the study area (the details of the survey are provided in the final report for Project No. NCDOT 2006-13).

Table 17 presents the modeling results in terms of performance measures. Important findings are listed as follows:

- The total dollar savings increase with higher levels of ATIS deployment, except for cases with low incident severity but a relatively saturated network. However, the percentage changes in savings have a wide range, i.e., from 0.80% to 98.22%. Note that the change is calculated as (original value-new value)/original value. This indicates that it will be valuable to consider appropriate levels of ATIS service for different incident and network situations, in order to maximize ATIS efficiency and impacts (benefits to road users), especially for commercial users with high values of time.
- Interestingly, during peak hour, for the cases with low incident severity but a relatively high road network demand/volume, network system performance measures could become worse when travelers take the diversion route by accessing ATIS (see set 1 for detail). A key reason for the increase of total travel time, total delay and declining percentage saving is that given a fixed percentage of diversion assumed in the scenario, delay increases on the alternative route due to additional diverted travelers. These can be higher than the delay reduction on the usual route.
- For set 2 case studies, the VMT for the traffic volumes in the network is less than VMT for demand, which indicates that a portion of the incident-induced queue remains inside the simulated road network even after the modeling duration (60 minutes for these cases). When providing more ATIS deployment and guiding more travelers for diversion, the incident-induced queues become shorter compared to the base case where travelers do not have traveler information and stay on the usual route and join the existing incident queue.
- For cases with high incident severity during peak hour, network performance measures show remarkable benefits of ATIS deployment and the magnitude increases with the level of ATIS deployment. For instance, with light deployment, ATIS could result in savings of 7.98%; while full deployment could bring 98.22% saving (see set 2 for detail).
- For cases with relevantly low road network capacity during non-peak hour, the deployment of ATIS tends to result in relevantly low benefits in terms of percentage saving. And no significant difference could be found for cases with different incident severity. The possible reason is that during non-peak hour, traffic flows in the network are generally far away from the saturation situation, even when there is an incident in the network.

Table 17.
Modeling Results for Different Sets of Case Studies with ATIS

Set 1

Performance Measures	Base	Light Deployment	Moderate Deployment	Full Deployment
VMT (Demand) (mile)	124752.78	124716.92	124663.35	124609.78
VMT (Volume) (mile)	124752.78	124716.92	124663.35	124609.78
Total Travel Time (hour)	1933.99	1933.41	1932.65	1932.04
Total Delay (hour)	14.72	14.69	14.75	14.97
Average Speed (mile/hour)	64.51	64.51	64.50	64.50
Savings (dollar)	0.00	0.52	-0.60	-4.17
Savings (%)	0.00%	0.21%	-0.24%	-1.67%

Set 2

Performance Measures	Base	Light Deployment	Moderate Deployment	Full Deployment
VMT (Demand) (mile)	124752.78	124681.07	124573.93	124466.78
VMT (Volume) (mile)	115147.31	118402.75	123118.12	124466.78
Total Travel Time (hour)	2626.04	2607.91	2550.68	1930.08
Total Delay (hour)	854.55	786.32	656.55	15.21
Average Speed (mile/hour)	43.85	45.40	48.27	64.49
Savings (dollar)	0.00	1159.78	3365.93	14268.72
Savings (%)	0.00%	7.98%	23.17%	98.22%

Set 3

Performance Measures	Base	Light Deployment	Moderate Deployment	Full Deployment
VMT (Demand) (mile)	67982.40	67944.81	67888.22	67831.62
VMT (Volume) (mile)	67982.40	67944.81	67888.22	67831.62
Total Travel Time (hour)	1052.93	1052.30	1051.36	1050.45
Total Delay (hour)	7.05	6.99	6.92	6.88
Average Speed (mile/hour)	64.56	64.57	64.57	64.57
Savings (dollar)	0.00	0.96	2.16	2.84
Savings (%)	0.00%	0.80%	1.80%	2.37%

Set 4

Performance Measures	Base	Light Deployment	Moderate Deployment	Full Deployment
VMT (Demand) (mile)	67982.40	67944.81	67888.22	67831.62
VMT (Volume) (mile)	67982.40	67944.81	67888.22	67831.62
Total Travel Time (hour)	1052.93	1052.30	1051.36	1050.45
Total Delay (hour)	7.05	6.99	6.92	6.88
Average Speed (mile/hour)	64.56	64.57	64.57	64.57
Savings (dollar)	0.00	0.96	2.16	2.84
Savings (%)	0.00%	0.80%	1.80%	2.37%

Note: If VMT (Volume) is less than VMT (Demand), it means that there still is a queue remaining inside the designed road network after the modeling duration (60 minutes for this incident case).

Summary

Table 18 shows a summary of percent saving ranges from IMAP service and ATIS deployment, where the percent saving refers to the different percentage changes in total dollar savings for different levels of IMAP and ATIS deployment while considering a high value of time for commercial users in accordance with the interview results for North Carolina. The percentage changes were calculated from the comparison of total dollar costs of delay between levels of IMAP and ATIS deployment and the base case (with incident but no IMAP or ATIS deployment). The important findings are listed as follows:

- The upper bounds and midpoints of each level of IMAP or ATIS deployment indicates that substantial benefits can accrue to the performance of the transportation network (and to NC businesses) in terms of total dollar savings, while accounting for the high VOT for commercial vehicles. The upper bounds show that in some cases, the incident-induced delays can be nearly eliminated (98.2% reduction in delays) by diverting traffic to alternate routes. We note that the performance numbers for the full deployment are larger than expected, while the numbers for the other deployment levels are in line with expectations.
- With higher levels of deployment, IMAP and ATIS tend to bring more benefits in terms of percentage changes in total dollar savings. This implies that enhancing IMAP and/or ATIS deployment along the road network can bring more monetary benefits to NC business.
- A direct comparison of the IMAP and ATIS deployment is not possible, as they have different assumptions about inputs and processes (e.g., some of the assumptions about diversion rates for ATIS deployment are not relevant for IMAP and, similarly, the percent reductions in incident durations for IMAP are not relevant for ATIS). Both strategies show promise in terms of reducing incident congestion, one by reducing the duration of the incident and the other by reducing the demand.

Table 18.
Percent Saving Ranges for IMAP and ATIS deployments

	IMAP range (midpoint)	**ATIS range (midpoint)**
Base case (no service)	0.0% (0.0%)	0% (0.0%)
Light Deployment	0.0%-22.7% (11.3%)	0.2%-7.9% (3.9%)
Moderate Deployment	0.0%*-61.4% (30.7%)	0.00%*-23.1% (11.5%)
Full Deployment	0.0%*-79.7% (39.8%)	0.00%*-98.2% (49.1%)

Note: *Adjusted percentage

The simulation results show that a wide range of reductions, 0% to 79.7%, are possible when IMAP is improved or implemented at various deployment levels. Separately, the implementation of ATIS also displays a wide range of reductions in costs, from 0.2% to 98.2%. It is important to note that the implementation of both IMAP and ATIS, when considered together, may lead to benefits that are not necessarily simply additive but sub-additive.

The midpoints of each range of IMAP and ATIS deployment may be used in conjunction with the cost estimates derived from the firm surveys to estimate annual monetary reductions for the entire sample, by industrial sector, and by sample region (Tables 19 and 20).

Table 19. IMAP Cost Reduction Estimates			
	Light Deployment	**Moderate Deployment**	**Full Deployment**
Total Annual	$3,079,012	$8,365,103	$10,844,662
Industrial Sectors			
Government	$1,040,617	$2,827,163	$ 3,665,182
Retail	$161,234	$438,044	$567,888
Transportation	$78,903	$214,366	$ 277,908
Manufacturing	$1,798,256	$4,885,529	$6,333,683
Sample Regions			
West	$288,809	$784,642	$1,017,224
CLT Metro	$1,167,349	$3,171,472	$4,111,550
Triad	$354,779	$963,868	$1,249,575
East	$688,131	$1,869,525	$2,423,684
Southeast	$579,941	$1,575,594	$2,042,627

Table 20. ATIS Cost Reduction Estimates			
	Light Deployment	**Moderate Deployment**	**Full Deployment**
Total Annual	$1,062,667	$3,133,507	$13,378,716
Industrial Sectors			
Government	$359,151	$1,059,035	$4,521,619
Retail	$55,647	$164,088	$700,586
Transportation	$27,232	$80,300	$342,846
Manufacturing	$620,637	$1,830,084	$7,813,664
Sample Regions			
West	$99,677	$293,921	$1,254,917
CLT Metro	$402,890	$1,188,010	$5,072,289
Triad	$122,445	$361,058	$1,541,562
East	$237,496	$700,310	$2,990,022
Southeast	$200,156	$590,206	$2,519,924

Light and moderate deployments of IMAP yield greater total annual cost reductions, $3,079,012 and $8,365,103 respectively, than ATIS. However, the cost reduction of full deployment of ATIS, $13,378,716, is greater than the estimated cost reduction of $10,844,662 for full deployment of IMAP. Since the same midpoint value for each level of deployment is applied to each industrial sector and region, this trend is consistent throughout.

7. Findings and Conclusions

For the first time, this study provides a measure of the monetary cost of unexpected congestion to local or regional firms in North Carolina. This is a more complete treatment of the issue than simply accounting for vehicle operating and time costs. The costs reported here include additional business costs (partly based on the perceptions of the firms' staff). This research extends the traditional incident analysis and management by examining how incident-induced congestion affects producers of economic goods and services in terms of business costs and productivity. It shows how various types of North Carolina businesses and regions differ in their sensitivity to unexpected congestion. The end product is a demonstration of strategies that can effectively reduce the economic costs of unexpected congestion in North Carolina. The study explores congestion management strategies that explicitly consider the impacts and costs imposed on firms, providing a more complete treatment of the potential impacts.

Fundamentally, we assessed the impacts of incident-induced congestion in terms of costs to businesses in North Carolina and how these costs might be reduced by appropriately implementing IMAP or ATIS. The estimation of incident-induced costs and the evaluation of IMAP and ATIS for businesses provide a comprehensive view of the problem and of high-impact ITS solutions.

It is clear from this study that businesses incur costs due to unexpected delays on North Carolina's interstate system, adding to the cost of production. Base on our estimation, these costs vary considerably across industrial sectors and regions. For instance, the total annual cost of unexpected delay for the Charlotte metropolitan region was more than $10.3 million, but only slightly more than $2.5 million in the West region. Similarly, the total annual cost for the Retail Trade sector was only $1.4 million, while the cost for the Manufacturing sector was nearly $16 million. It also is important to note that the cost estimates may be subject to change due to the overall sample size, sample sizes within industrial sectors and regions, and the limited scope of cost data obtained from carriers.

Industries in North Carolina use coping strategies to deal with unexpected congestion and reduce costs. While rerouting unexpectedly delayed shipments is by far the most common strategy, businesses also rely on other shipment-level and business-level solutions. These include padding shipment times to absorb potential unexpected delay, using route-guidance devices to more accurately track shipments, and stockpiling adequate inventory to respond to late shipments.

Limitations

There are several caveats that apply to the study and are listed below:

- The estimates of costs presented are based on interviews and as such may contain reporting biases.
- While we selected the interviewed firms to be representative, the interviews are not based on a random sample of firms. Some selection bias is possible.
- The results are applicable to the areas surveyed and do not represent the unexpected delay costs for the entire state of North Carolina. Thus, given the study locations, generalization of the findings to other areas (that will have industry and experience some incident congestion) is limited. At the same time, the interviewed firms represent the ones with greater shipping needs and likely to face incident congestion.
- The simulation results are largely based on simplified networks.

8. Recommendations

While improving the physical condition of the transportation system can be worthwhile strategy to stimulate economic growth, this study indicates that in urban areas, improving the reliability of travel times (through improved incident management) can be beneficial to carriers and businesses, in addition to individual users. It is clear that ITS strategies such as IMAP and ATIS can significantly reduce the costs of unexpected delay, both in general terms, and specifically for North Carolina's interstate system. These results may be used by NCDOT technical staff to make more educated decisions about program spending, expansion and implementation of IMAP and ATIS across the state and in specific regions.

Considering that further investment in IMAP can substantially reduce economic costs of uncertainty, we recommend that NCDOT increase maintenance and investment in IMAP at appropriate deployment levels across the state. Similarly, the potential reduction of costs from full deployment of ATIS also warrants increased maintenance and investment at appropriate deployment levels across the state. Appropriate levels of deployment should be considered especially in those regions with the highest costs, such as the Charlotte metropolitan region and the East region, which includes the Research Triangle area.

Based on repeated comments from multiple firms, it is clear that NCDOT should make a stronger effort to inform businesses about existing and potential public information services. We also recommend that NCDOT begin a dialogue with businesses across the state about the current state of Interstate rest areas and the potential needs and benefits of upgrading existing facilities and the construction of new facilities.

9. Implementation and Technology Transfer Plan

The main products of the study are assessment of incident costs incurred by businesses and exploring the role of incident management strategies. This in turn supports NCDOT's future investment decisions in intelligent transportation systems by identifying locations where costs of congestion are relatively high. A key product of this research is a method that allows us to quantify the impacts of congestion reduction on businesses. The main deliverables are the specific figures for costs of congestion and reductions in congestion from IMAPs and ATIS in various regions of North Carolina, from the perspective of reducing business costs. The impacts of incident congestion on businesses clearly vary across localities, partly depending on the extent of the incident problem and the nature of industry in the region, e.g., some industries are more sensitive to uncertainty in travel times than others.

As a result of the project, NCDOT has information about the costs of incidents on businesses in North Carolina. This can help better manage incidents, assist commercial drivers and reduce incident-induced congestion to derive associated benefits. This contributes to the debate about economic impacts of transportation in the state and helps NCDOT make more informed and educated decisions about resource allocation and program funding. Specifically, the NCDOT technical staff can use the products to make more educated decisions about program spending and expansion and implementation of IMAPs and ATIS. When viewed from a business perspective, we are able to identify a relatively new set of sites for IMAP expansion. Specifically, the technical personnel at the NCDOT Intelligent Transportation Systems Operations Unit can use the findings to show the benefits of IMAPs on businesses. The FREEVAL based analysis tool, which was provided to NCDOT in a pre-cursor project, can be used to evaluate the impacts of IMAPs in specific corridors. By varying the parameters for value of time, clearly higher for large trucks compared with passenger vehicles, the tool can provide answers about the impacts of IMAPs in specific corridors under consideration. Furthermore, FREEVAL can be applied in better planning of work zones. The Operations branch, as well as Division engineers, can use the findings and the IMAP tool to help review and approve IMAP expansions. The Metropolitan Planning Organizations (MPOs) and the traffic staff within cities and counties who are interested in the initiation or expansion of IMAPs can review the benefits and costs incurred by businesses and whether the IMAP strategy makes sense in their context. The information produced by this research encourages the initiation and expansion of incident congestion mitigation strategies in the appropriate regions of the state. Finally the IMAP tool is simple enough that no particular training on the tool is required. It has already been demonstrated to NCDOT staff in a pre-cursor project.

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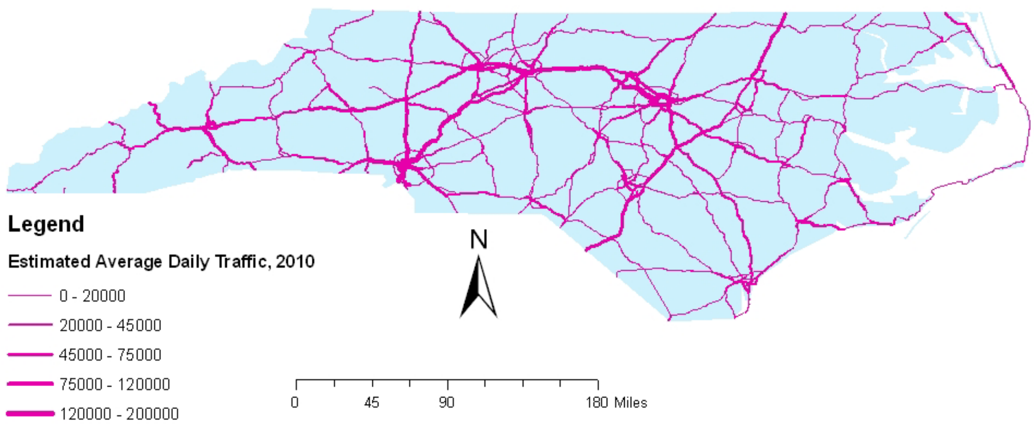
Appendix A – Sample Selection Overview

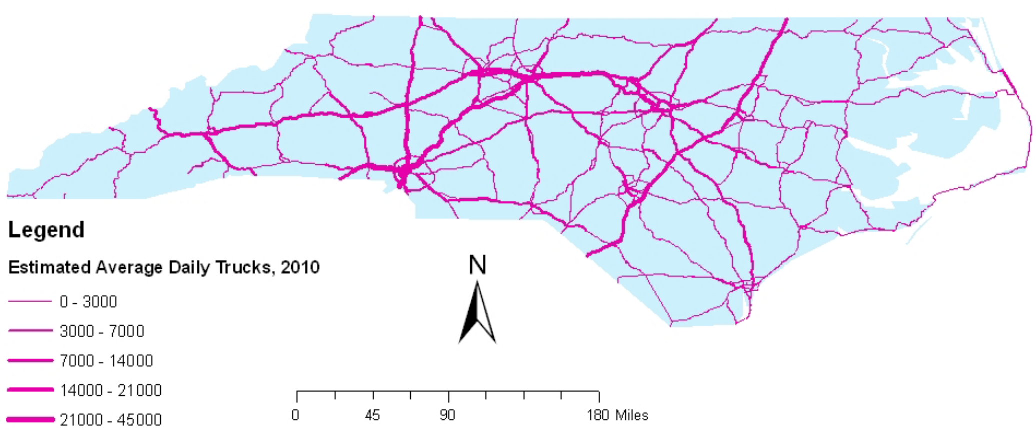
Study Area

The 26 North Carolina counties most impacted by congestion on interstate highways were selected as the study area. Congestion was measured by 2010 volume capacity ratio (V/C) on interstate highways using daily traffic and truck projections from the NCDOT's Highway Safety Information System (HSIS) (Figures A1 and A2). Counties were selected if interstate highways in those counties had a projected 2010 V/C larger than 1.0 (Figure A3). General information about the selected counties is presented in Table A1, including population, employment, average wage, population change from 1990 to 2000, unemployment rate, and educational attainment.



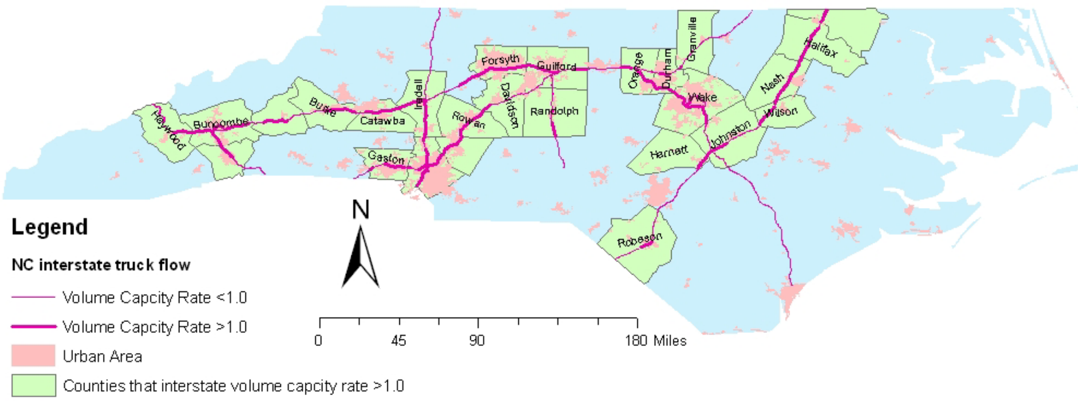
Source: NCDOT HSIS, 1998.

Figure A1: Projected Daily Traffic in North Carolina, 2010



Source: NCDOT HSIS, 1998.

Figure A2: Projected Daily Trucks in North Carolina, 2010



Source: NCDOT HSIS, 1998.

Figure A3: Selected Counties That Have Interstate V/C ratio > 1.0

Table A1. Selected County Profiles										
Name	**Pop. 2005**	**Pop. Rank**	**Jobs 2005**	**Jobs Rank**	**Average Weekly Wage All Industries**	**% Pop. Change 1990 - 2000**	**Unemployed Percent Rate, YTD**	**% High School 2000**	**% Bach or Higher 2000**	**Median HH Income 2000**
Buncombe	217423	7	111405	7	$650	18.3	4	81.9	25.3	$36,666
Burke	89077	30	40636	29	$601	17.7	6	67.6	12.8	$35,629
Cabarrus	150249	13	75229	12	$688	32.5	4.1	78.2	19.1	$46,140
Catawba	149416	14	72961	13	$624	19.7	6.1	74.8	17	$40,536
Davidson	154796	12	75517	11	$582	16.2	5.6	72	12.8	$38,640
Durham	242527	6	123710	5	$1,025	22.8	4.1	83	40.1	$43,337
Forsyth	324361	4	164000	4	$766	15.1	4.4	82	28.7	$42,097
Gaston	192641	8	95577	8	$652	8.9	5.5	71.4	14.2	$39,482
Granville	53977	48	22385	52	$644	26.5	5.8	73	13	$39,965
Guilford	438775	3	228889	3	$739	21.2	4.9	83	30.3	$42,618
Halifax	56344	44	20807	55	$530	3.3	7.8	65.4	11.1	$26,459
Harnett	101737	24	42620	27	$555	34.2	4.9	75	12.8	$35,105
Haywood	57097	43	26483	43	$555	15.1	3.7	77.7	16	$33,922
Henderson	97810	25	44540	24	$624	27.9	4	83.2	24.1	$38,109
Iredell	139135	17	66847	17	$673	31.6	4.8	78.4	17.4	$41,920
Johnston	145968	15	66944	16	$583	50	4.2	75.9	15.9	$40,872
McDowell	43576	57	20150	57	$553	18.1	6.6	70.2	9	$32,396
Mecklenburg	786651	1	412048	1	$948	36	4.6	86.2	37.1	$50,579
Nash	91530	29	40841	28	$668	14	6.2	75.6	17.2	$37,147
Northampton	21507	79	7948	82	$526	5.2	6.5	62.5	10.8	$26,652
Orange	122474	22	63742	20	$792	26.2	3.6	87.6	51.5	$42,372
Randolph	137306	19	71190	14	$603	22.4	4.4	70	11.1	$38,348
Robeson	127506	21	46222	23	$531	17.3	7.1	64.9	11.4	$28,202
Rowan	134094	20	65467	19	$707	17.8	5.1	74.2	14.2	$37,494
Wake	746336	2	380803	2	$817	47.3	3.8	89.3	43.9	$54,988
Wilson	77042	34	33750	33	$650	11.7	9	69.4	15.1	$33,116

Sources: US Census, 2005. US Bureau of Labor Statistics, 2005.

Firm Selection

Industry sectors that best represent NC, significantly contribute to its economy, rely heavily on interstate highways, and contain some element of time-sensitivity were specifically targeted. The following step-by-step process was used to select the firms to be interviewed.

1. Employment data were gathered for the 26 selected counties. The top ten firms in each county were selected as the beginning point for final firm selection. Some counties' lists included more than ten firms, resulting in a total of 317 firms. This was due to the lack of exact employment data, which led to multiple firms falling into the same employment range (i.e., 250 – 500 employees). The firm list was further narrowed by identifying the

three-digit NAICS code for each firm and selecting only those firms from the manufacturing, mining, construction, and trade-transportation-utilities sectors, resulting in 105 firms.

2. NAICS codes were then ranked by the following measures:

    a. 2005 Total Wages (Table A2)
    b. 2001 Gross State Product (GSP) (Table A3)
    c. GSP Growth Rate 1991 – 2001 (Table A3)

Table A2.
Top NC Industry Sectors by Total Wages, 2005

Sector	Industry	NAICS Code	No of Units	Avg Empl for 2005 Qtr	Total Wages	Rank
42	Merchant Wholesalers Durable Goods	423	7371	89826	1164228342	1
23	Specialty Trade Contractors	238	16799	137690	995672527	2
31	Chemical Manufacturing	325	454	44538	788180708	3
31	Computer and Electronic Product Mfg	334	364	38178	766833443	4
42	Merchant Wholesalers Nondurable Goods	424	3680	57292	605549225	5
44	Motor Vehicle and Parts Dealers	441	4302	60106	519178968	6
23	Construction of Buildings	236	8714	52573	499062940	7
31	Textile Mills	313	650	57390	432765371	8
31	Transportation Equipment Manufacturing	336	366	36540	431452949	9
31	Furniture and Related Product Mfg	337	1180	58250	415070604	10
48	Truck Transportation	484	3267	48159	411466439	11

Source: NC Employment Security Commission, 2005.

Table A3. GSP Growth Rates, 1991 – 2001					
Industry Sector	**NAICS Code**	**2001 GSP x000000**	**GSP Rank**	**% Change 1991 – 2001**	**Change Rank**
Construction	23	$14,101	1	154.1	1
Food & Kindred Products	311	$3,055	7	36.4	10
Textile Mill Products	313	$5,024	4	-21.7	20
Apparel & Other Textile	315	$1,140	17	-29.1	21
Lumber & Wood Products	321	$1,800	12	33.8	12
Paper & Allied Products	322	$1,539	15	7.7	15
Printing & Publishing	323	$1,577	14	34.9	11
Chemicals & Allied Products	325	$10,974	2	79.9	4
Rubber & Misc Plastics	326	$2,484	10	64.7	7
Stone, Clay, Glass	327	$1,788	13	77.0	5
Primary Metal Industry	331	$1,178	16	96.3	3
Fabricated Metal	332	$2,551	9	68.8	6
Electronic Equipment	334	$4,682	5	12.1	14
Motor Vehicles/Trans Equip.	336	$2,348	11	142.6	2
Furniture & Fixtures	337	$2,797	8	45.2	9
Wholesale - Durables	423	$96	18	-15.7	18
Wholesale – Non-durables	424	$70	21	-9.9	17
Food Stores	445	$90	19	-17.6	19
General Merchandise	452	$79	20	-2.4	16
Tobacco Products	3122	$9,295	3	47.0	8

Source: US Bureau of Labor Statistics, 2005.

3. Two-digit commodity shipments were then ranked by the following measures (Table A4):

    a. 2002 Two-Digit Commodity Shipments by Value
    b. 2002 Two-Digit Commodity Shipments by Ton-Mile

Table A4. Shipment Characteristics by Two-Digit Commodity with Origin in NC, 2002				
	2002 Value		**2002 Ton-miles**	
Two-Digit Commodity	**(Million$)**	**Rank**	**(Millions)**	**Rank**
05 Meat, fish, seafood, and their preparations	6,751	13	2,532	4
09 Tobacco products	19,366	5	145	28
11 Natural sands	186	31	1,715	9
12 Gravel and crushed stone	504	29	1,668	10
21 Pharmaceutical products	28,167	3	1,571	11
26 Wood products	6,917	12	5,187	1
27 Pulp, newsprint, paper, and paperboard	3,854	18	2,260	5
30 Textiles, leather, and articles	42,237	1	2,941	3
31 Nonmetallic mineral products	8,607	10	3,544	2
35 Electronic and other electrical equipment	20,113	4	913	18
43 Mixed freight	35,466	2	2,125	6

Source: Federal Highway Administration, 2005.

4. Each firm whose NAICS or commodity shipment code ranked in the top five was selected, resulting in 73 remaining firms.

5. The final selection process, outlined below, was then used to ensure adequate industry, commodity shipment, geographical, and time-sensitive variety. The result is 29 firms representing 22 counties, 19 NAICS codes, and 14 commodity shipment codes.

   Final Selection Process:
   a. Those firms that represented the only available choice for an NAICS code were selected first.
   b. Those firms that represented the only available firm remaining in a county yet to be represented were selected next.
   c. Those counties left without representation had a well qualified firm selected.
   d. One firm from the furniture manufacturing, truck transportation, and motor vehicle dealer sectors were added to ensure all top-ranking (total wages) industry sectors were represented.
   e. Two additional firms were selected due to their unique time-sensitivity and existing or potential economic impact in NC.
   f. Several firms were either no longer in operation in NC or declined to participate in the study. New firms were selected based on their similarities to lost firms, including location, industry type, and susceptibility to unexpected travel delays.

Appendix B – Firm Interviews

Firm Telephone Interview

1. Please tell us your name, telephone number, and position in your company.
   Name ____
   Firm Name ____
   Telephone Number ____
   Position ____

2. How would you classify your company?
   - ☐ Manufacturing
   - ☐ Mining
   - ☐ Construction
   - ☐ Trade
   - ☐ Utilities
   - ☐ Other ___________________

3. Does your company hire other companies to ship its primary outgoing product?
   - ☐ Yes
   - ☐ No

4. What are the most-used NC shipment routes (interstates and highways) for your company's incoming and outgoing shipments?
   - ☐ Incoming____
   - ☐ Incoming____
   - ☐ Outgoing____
   - ☐ Outgoing____

5. Did your company experience an unexpected shipment delay (incoming or outgoing) of at least 30 minutes due to a traffic incident (e.g., an accident involving other vehicles) in the past 3 months?
   - ☐ Yes
   - ☐ No

6. If so, how long was the unexpected delay?
   - ☐ ____

7. How was your company made aware of the delay?
   - ☐ ____

8. What were the negative consequences of the unexpected delay due to a traffic incident? (Check all that apply)
   - ☐ Our company incurred higher driver and vehicle costs
   - ☐ Our company incurred production timing costs
   - ☐ Our company incurred inventory costs
   - ☐ Our company's reputation suffered
   - ☐ No negative consequences occurred
   - ☐ Other____

9. How did your company respond to the unexpected delay?
   - ☐ No response
   - ☐ Reroute the shipment
   - ☐ Contact the receiving company
   - ☐ Other____

10. Is this response typical? If not, what is the typical response?
    - ☐ ____

11. How does your company account for expected delays, e.g., during rush hours?
    - ☐ ____

<u>The following questions concern your primary incoming and outgoing products in 2005.</u>

Primary product is defined as the product your company ships or is shipped the most.

12. What were your primary incoming and outgoing products?
    - ☐ Incoming____
    - ☐ Outgoing____

13. How many shipments of that product did your company make/receive?
    - ☐ Incoming____
    - ☐ Outgoing____

14. What was the most common drop-off location for the primary outgoing product (city)?
    - ☐ ____

15. What was the most common route used to ship the primary products?
    - ☐ Incoming____
    - ☐ Outgoing____

16. What was the total shipment weight (tons) of those products?
    - ☐ Incoming____
    - ☐ Outgoing____

17. What was the normal shipping time (hours) of shipments of those products using the primary routes?
    - ☐ Incoming____
    - ☐ Outgoing____

18. Did primary product shipments normally have a delivery window?
    - ☐ Incoming____
    - ☐ Outgoing____

19. If so, what was the typical width (hours) of the delivery window?
    - ☐ Incoming____
    - ☐ Outgoing____

20. Were shipments of those products normally allowed to be unloaded when they arrived earlier than scheduled?
    - ☐ Incoming____
    - ☐ Outgoing____

21. At what time of day did shipments of those products originate?
    - ☐ Incoming____
    - ☐ Outgoing____

22. At what time of day were those shipments normally prescheduled to arrive?
    - ☐ Incoming____
    - ☐ Outgoing____

23. What percentage of on-time performance was expected for shipments of those products?
    - ☐ Incoming____
    - ☐ Outgoing____

24. Does your company value shipment reliability very highly due to a just-in-time manufacturing/inventory system?
    - ☐ Yes
    - ☐ No

Thank you for participating in this phone survey.
We would like to further invite your firm to participate in a NCDOT-sponsored study to help us improve travel time predictability in North Carolina. Your participation can potentially improve your firm's on-time delivery performance and help your employees avoid unpredictability in travel times.

Carrier Firm Telephone Interview

1. Please tell us your name, telephone number, and position in your company?
   Name ____
   Firm Name ____
   Telephone Number ____
   Position ____

2. What specific aspects of your firm make you competitive in the carrier industry? (Check all that apply)
   - ☐ Price of services
   - ☐ Speed of delivery
   - ☐ On-time delivery/pick up (Reliability)
   - ☐ Responsiveness
   - ☐ Use of advanced technology
   - ☐ Other __________________

3. What is the primary industry you serve?
   a. Manufacturing
   b. Mining
   c. Construction
   d. Trade
   e. Utilities
   f. Other __________________

4. What are your company's most-used NC shipment routes (interstates and highways)?
   a. ____
   b. ____
   c. ____

5. Did your company experience an unexpected shipment delay of at least 30 minutes due to a traffic incident (e.g., an accident involving other vehicles) in the past 3 months?
   a. Yes
   b. No

6. If so, how long was the unexpected delay?
   a. ____

7. How did the driver communicate the delay back to your company?
   a. ____

8. How did your company respond to the unexpected delay?
   a. No response
   b. Reroute the shipment
   c. Contact the customer company
   d. Other response

9. Is this response typical? If not, what is the typical response?
    a. ____

10. How does your company account for expected delays, e.g., during rush hours?
    a. ____

<u>**The following questions concern your largest customer in 2005.**</u>

Largest is defined as the customer for whom your company makes the most trips.

11. Who was your largest customer in 2005?
    a. ____

12. What was the primary product shipped for that customer?
    a. ____

13. How many shipments did your company make for that customer?
    a. ____

14. What were the negative consequences when a shipment for that customer was late due to a traffic incident (Check all that apply)?
    a. Our company incurred higher driver and vehicle costs
    b. Our company paid a fee to the customer
    c. Our company was paid less per unit of product shipped
    d. Our company's reputation suffered
    e. No negative consequences occurred
    f. Other____

15. What was the primary pick-up location for that customer (city)?
    a. ____

16. What was the primary drop-off location for that customer (city)?
    a. ____

17. What was the primary route used to make shipments for that customer between these two cities?
    a. ____

18. What was the total shipment weight (tons) for that customer?
    a. ____

19. What were the total freight charges (monthly) for shipments for that customer (thousands of $)?
    a. ____

20. What was the normal shipping time (hours) of shipments for that customer using the primary route?
    a. ______________________________

21. Did that customer value shipment reliability very highly due to a just-in-time manufacturing/inventory system?
    a. Yes
    b. No

22. Did that customer normally give you a delivery window?
    a. Yes
    b. No

23. If so, what was the typical width (hours) of the delivery window?
    a. ______________________________

24. Did that customer normally allow shipments to be unloaded when they arrive earlier than scheduled?
    a. Yes
    b. No

25. At what time of day did you normally pick up freight for that customer?
    a. ______________________________

26. At what time of day were those shipments normally prescheduled to arrive?
    a. ______________________________

27. What percentage of on-time performance were you expected to achieve for shipments for that customer?
    a. ______________________________

Thank you for participating in this phone survey.
We would like to further invite your firm to participate in a NCDOT-sponsored study to help us improve travel time predictability in North Carolina. Your participation can potentially improve your firm's on-time delivery performance and help your employees avoid unpredictability in travel times.

Firm Detailed Interview

Dear _______representative:

Thank you for agreeing to participate in the survey. This project aims to investigate the economic impact of traffic incidents on NC interstate facilities. Your firm's input to this NC Department of Transportation study is very important to our research.

In the following sections we will ask you information about:
A. Your products, shipments, and the impacts of traffic incidents (Question 1-26);
B. How you deal with unexpected delay due to traffic incidents (Question 27-35); and
C. Company attributes (Question 36-40).

We will assemble the information that you provide and provide you a draft copy to review and submit comments before finalizing our results.

Your responses are strictly confidential and will be shared in a manner that will not identify your company. The results of the entire study will be fully shared with yours and other participating companies upon its conclusion.

Thank you again for your time and effort.

START HERE

A. Products, shipments, and the impacts of traffic incidents(Q1-Q26)

Question 1 to Question 7 concern outgoing shipments handled by other companies.

1. Did your company hire other companies to operate outgoing ground shipments in 2005?
   ☐ YES
   ☐ NO (**Go to Question 8**)

2. What percentage of your company's total outgoing ground shipments originated in North Carolina in 2005?
   ☐ _____% Within NC

3. Focusing on the outgoing ground shipments that originated from this facility, please list the percentage of shipments to different destinations in 2005.
   ☐ _____% Within NC
   ☐ _____% States Adjacent to NC
   ☐ _____% Non-adjacent states
   (Total should be 100%)

4. To what extent do you think each of the following attributes of the shipping companies you hired was important to your business? **(Please circle your answer)**

	Not Important ▼				Very Important ▼
a. On-Time Arrival	1	2	3	4	5
b. Shipping Time...	1	2	3	4	5
c. Cost of shipping.	1	2	3	4	5

5. To what extent are you satisfied or dissatisfied with the 2005 shipment performance of those shipping companies you hired? **(Please circle your answer)**

	Very Dissatisfied ▼	Moderately Dissatisfied ▼	Neutral ▼	Moderately Satisfied ▼	Very Satisfied ▼
a. On-Time Arrival	1	2	3	4	5
b. Shipping Time...	1	2	3	4	5
c. Cost of shipping.	1	2	3	4	5

6. Focusing on the outgoing shipments that originated from this facility and were handled by other companies in 2005, please list the product categories, their shipment values, their shipment weights, the companies that handled their shipments, and the total payments to those companies in 2005.

No.	Product Category	Shipment Values (Dollars)	Shipment Weights (Tons)	Companies That Handled Their Shipments	Total Payments to Those Companies in 2005 (Dollars)
P0	*Funiture*	*$20,000,000*	*20,000*	*JBHunt Trucking*	*$50,000*
P1					
P2					
P3					
P4					
P5					

Example ⇨ (row P0)

This column will be used to fill in next question. (Product Category column)

7. In 2005, please describe the negative consequences to your company when each product category listed above is unexpectedly delayed due to traffic incidents on NC interstates, average delay time, costs of the delay, and the willingness to pay.

No.	Product Category	Negative Consequences of Unexpected Delay	Average unexpected delay in 2005 (Minutes)	% of delivery without unexpected delay in 2005	Costs of unexpected delays to your company (Dollars)	Expected % of delivery without unexpected delay	Willingness to pay for the improvement (Dollars)
P0	*Funiture*	*No, shipping company pays the penalty*	*30 mins*	*80%*	*0*		
P1							
P2							
P3							
P4							
P5							

Example ⇨ (row P0)

Question 8 to Question 22 concern outgoing shipments handled by your own company.

8. Did your company operate outgoing shipments internally in 2005?
   - ☐ YES
   - ☐ NO **(Go to Question 23)**

9. How many full-time equivalent drivers did your company hire for operating outgoing shipments in 2005?
   - ☐ _______________ drivers

10. What were the total wages for those full-time equivalent drivers in 2005?
    - ☐ __________________ dollars

11. How many vehicles did your company own or rent for operating shipments in 2005?
    - ☐ __________________ vehicles

12. Where were those vehicles located in 2005? (please provide detailed street address)
    - ☐ __________________

13. What were the total maintenance costs for those vehicles in 2005?
    - ☐ __________________ dollars

14. What were the total fuel costs for those vehicles in 2005?
    - ☐ __________________ dollars

15. To what extent do you think each of the following attributes of your 2005 shipments was important to your business? **(Please circle your answer)**

	Not Important ▼				Very Important ▼
a. On-Time Arrival	1	2	3	4	5
b. Shipping Time...	1	2	3	4	5
c. Cost of shipping.	1	2	3	4	5

16. To what extent are you satisfied or dissatisfied with your 2005 shipment performance. **(Please circle your answer)**

	Very Dissatisfied ▼	Moderately Dissatisfied ▼	Neutral ▼	Moderately Satisfied ▼	Very Satisfied ▼
a. On-Time Arrival	1	2	3	4	5
b. Shipping Time...	1	2	3	4	5
c. Cost of shipping.	1	2	3	4	5

17. What percentage of your company's total ground shipments originated in North Carolina?
    ☐ ______% Within NC

18. Focusing on the ground shipments that originate at this facility, please list the percentage of shipments to different destinations in 2005.
    ☐ ______% Within NC
    ☐ ______% States Adjacent to NC
    ☐ ______% Non-adjacent states
    (Total should be 100%)

19. Focusing on the ground shipments that originated at this facility in 2005, please list the product categories, their shipment values, their shipment weights, and their total shipment distances.

	No.	Product Category	Shipment Values (Dollars)	Shipment Weights (Tons)	Shipment Distances (Miles)
Example ⇨	***P0***	*Funiture*	*$20,000*	*2,000*	*34,000 miles*
	P1				
	P2				
	P3				
	P4				
	P5				

This column will be used to fill in next question.

20. For each product category listed in previous question, please identify the primary customer and the following associated information:
1) The company name;
2) The primary drop-off location;
3) The primary shipping route;
4) The distance of this route
5) The normal shipping time without unexpected delay using this route;
6) The normal pick up time of the day (AM/PM).

Interviewer should fill in this column using the previous question

No	Product Category	Primary customer					
		Company name	Primary drop-off location (City)	Primary shipping route	Route distance (miles)	Normal shipping time without unexpected delay	Normal pick up time of the day (AM/PM)
P0	*Furniture*	*Columbia Carolina Corp.*	*Charlotte, NC*	*I-85s, I-77 S*	*147 miles*	*2 hours and a half*	*7AM*
P1							
P2							
P3							
P4							
P5							

Example ⇨ (row P0)

This column will be used to fill in next question. (Primary shipping route)

21. Please estimate the following items for each shipping route described in the previous question:
   1) The average unexpected delay in 2005 using this route;
   2) The percentage of shipments delivered without unexpected delay using this route in 2005;
   3) The percentage of shipments delivered with less than 30 minutes unexpected delay;
   4) The percentage of shipments delivered with 30 minutes to1 hour unexpected delay
   5) The percentage of shipments delivered with1 hour to 2 hours unexpected delay;
   6) The percentage of shipments delivered with more than 2 hours unexpected delay.

Interviewer should fill in this column using the previous question

No	Primary shipping routes	Average unexpected delay in 2005 (min)	The percentage of shipments delivered					
			without unexpected delay	with less than 30 min. unexpected delay	with 30 min. to 1-hour unexpected delay	With more than 1-hour to 2-hour unexpected delay	with more than 2 hours unexpected delay	Total
P0	*I-85 S, I-77 S*	*40 mins*	*80%*	*5%*	*10%*	*5%*	*0%*	*100%*
P1								100%
P2								100%
P3								100%
P4								100%
P5								100%

Example ⇨ (row P0)

This column will be used to fill in next question. (column "without unexpected delay")

22. Please provide the following information for each shipping route and its associated unexpected delay described in the previous question:
   1. The cost of unexpected delays on that shipping route to your company in 2005—these will typically include higher driver

and vehicle costs, paying a fee to the customer for late deliveries, or lower payments (per unit) for product shipped;

2. Your expected percentage of shipments delivered without unexpected delay: and
3. Your willingness to pay to achieve your expectations.

Interviewer should fill in this column using the previous question

No	Primary shipping route	Current percentage of shipments delivered without unexpected delay	The costs of unexpected delays to your company	Expected percentage of shipments delivered without unexpected delay	Your willingness to pay for the improvement
P0 (Example)	*I 85-S, I-77 S*	*80%*	*$50,000*	*95%*	*$5,000 per year*
P1					
P2					
P3					
P4					
P5					

Interviewer should fill in this column using the previous question

Question 23 to Question 26 concern incoming shipments.

23. For your company's 2005 incoming shipments, please list the product categories, their shipment values, their shipment weights, the supplier companies, and the locations of those suppliers.

Example ⇨

No.	Product Category	Shipment Values (Dollars)	Shipment Weights (Tons)	Supplier Companies	Location of those companies (City or Zip code)
P0	*Wood Products*	*$10,000,000*	*2,000*	*Brown Wood Products Co.*	*Licolnwood, IL*
P1					
P2					
P3					
P4					
P5					

This column will be used to fill in next question.

24. In 2005, please describe the negative consequences to your company when each incoming shipment category is unexpectedly delayed due to traffic incidents on NC interstates, average unexpected delay, and estimate the costs and your willingness to pay.

Example ⇨

No.	Product Category	Negative Consequences of Incoming Shipment Unexpected Delay	Average unexpected delay in 2005 (Minutes)	% of incoming shipments without unexpected delay	Costs of unexpected delays to your company (Dollars)	Expected % of delivery without unexpected delay	Willingness to pay for the improvement (Dollars)
P0	*Funiture*	*Additional inventory keeping costs*	*30 mins*	*80%*	*1000*	*100%*	*500*
P1							
P2							
P3							
P4							
P5							

25. What percentages of incoming shipments were shipped by air, ship, or train before the final truck segment of the shipment?

☐ _______% Air
☐ _______% Ship
☐ _______% Train

26. What would be the approximate cost to your company (if any), in terms of lost revenue, if 10% of your incoming shipments were to arrive late by one day?

☐ ______________

B. Coping Behavior for Traffic Incidents

27. What are the coping strategies used at the business management level when incoming shipments are late due to (unexpected) incidents on NC interstate facilities? Please check those applicable to your company.

☐ Do nothing
☐ Consider changing suppliers
☐ Ask the suppliers to pay a penalty
☐ Other (Please specify) ________________________________

28. What are the coping strategies used at the business management level when outgoing shipments are late due to (unexpected) incidents on NC interstate facilities? Please check those applicable to your company.

☐ Do nothing
☐ Consider company relocation
☐ Adopt new technology in business operations
☐ Attempt to further reduce cost (labor, vehicle, …)
☐ Other (Please specify) ___________________

29. If your company handles outgoing shipments internally, what are the coping strategies used by drivers when shipments are late due to (unexpected) traffic incidents on NC interstate facilities? Please check those applicable to you.

☐ Do nothing
☐ Change route
☐ Change departure time
☐ Other (Please specify) ________________________________

30. Does your company seek pre-trip traffic information on NC interstate facilities?

- ☐ YES, what are the means your company often uses?
- ☐ NO, what are the reasons?

(Open-ended question)

____

____

____

31. Are any route-guidance devices currently installed on delivery vehicles?

- ☐ YES, what are they?
- ☐ NO, what are the reasons?

(Open-ended question)

____

____

____

32. Do you think current traffic information services are sufficient for your business operation?

- ☐ YES
- ☐ NO, what are your concerns and suggestions?

(Open-ended question)

____

____

____

33. To what extent is your company satisfied or dissatisfied with level of service of NC interstate facilities in the following dimensions. **(Please circle your answer.)**

	Very Dissatisfied ▼	**Moderately Dissatisfied** ▼	**Neutral** ▼	**Moderately Satisfied** ▼	**Very Satisfied** ▼
a. Infrastructure	…...1..…..........	.2……….....	3….........	.4...…..…	…5
b. Capacity	…...1..…..........	.2……….....	3….........	.4...…..…	…5
c. Safety	…...1..…..........	.2……….....	3….........	.4...…..…	…5
e. Incident management	…...1..…..........	.2……….....	3….........	.4...…..…	…5
f. Information system	…...1..…..........	.2……….....	3….........	.4...…..…	…5

34. Are you aware of the NCSmartLink.org website, which provides real time traffic information for NC interstate facilities?

☐ YES. If yes, does your company use this service? ________
☐ NO

35. Are you aware of the 511 Toll-Free Number, which provides real time traffic information for NC interstate facilities?
☐ YES. If yes, does your company use this service? ________
☐ NO

C. Company Information

This section asks general information about your company.

36. How many full time equivalent employees work in your company?
☐ _____________

37. What were the annual sales, revenues, and wages of your company for the past five years? **(Unit: Dollars)**

Year	Annual Sales	Total wages
2001		
2002		
2003		
2004		
2005		

38. What is your company's expected annual employment growth rate over the next five years?
☐ _________%

39. What is your company's expected annual growth rate in sales over the next five years?
☐ _________%

40. Is your company considering business expansion in NC in next five years?
☐ YES, what is the plan?
☐ NO, what are the reasons?
(Open-ended question)

____

____

____

Thank you for taking the time to complete this questionnaire. Please feel free to provide any additional information you feel is important but not requested in this questionnaire. Also feel free to make any suggestions about this project.

Carrier Detailed Interview

Dear _______representative:

Thank you for agreeing to participate in the survey. This project aims to investigate the economic impact of traffic incidents on NC interstate facilities. Your firm's input to this NC Department of Transportation study is very important to our research.

In the following sections we will ask you for information about:

D. Your products, shipments, and the impacts of traffic incidents:
E. How you deal with unexpected delay due to traffic incidents: and
F. Company attributes.

We will assemble the information that you provide and give you a draft copy to review and submit comments before finalizing our results.

Your responses are strictly confidential and will be shared in a manner that will not identify your company. The results of the entire study will be fully shared with yours and other participating companies upon its conclusion.

Thank you again for your time and effort.

START HERE

A. Products, shipments, and the impacts of traffic incidents

1. How many full-time equivalent drivers did your company hire for operating shipments in 2005?
   ☐ ________________ drivers

2. What were the total wages for those full-time equivalent drivers in 2005?
   ☐ ____________________ dollars

3. How many vehicles did your company own or rent for operating shipments in 2005?
   ☐ ____________________ vehicles

4. Where were those vehicles located in 2005? (please provide detailed street address)
   ☐ ____________________

5. What were the total maintenance costs for those vehicles in 2005?
   ☐ ____________________ dollars

6. What were the total fuel costs for those vehicles in 2005?
   ☐ ___________________ dollars

7. To what extent do you think each of the following attributes of your 2005 shipments was important to your business? **(Please circle your answer)**

	Not Important ▼				Very Important ▼
a. On-Time Arrival	1	2	3	4	5
b. Shipping Time...	1	2	3	4	5
c. Cost of shipping.	1	2	3	4	5

8. To what extent are you satisfied or dissatisfied with your 2005 shipment performance. **(Please circle your answer)**

	Very Dissatisfied ▼	Moderately Dissatisfied ▼	Neutral ▼	Moderately Satisfied ▼	Very Satisfied ▼
a. On-Time Arrival	1	2	3	4	5
b. Shipping Time...	1	2	3	4	5
c. Cost of shipping.	1	2	3	4	5

9. What is the percentage of your ground shipments originating in North Carolina?
   ☐ _____% Within NC

10. Focusing on the ground shipments that originate in North Carolina, please list the percentage of shipments to different destinations in 2005.
   ☐ _____% Within NC
   ☐ _____% States Adjacent to NC
   ☐ _____% Non-adjacent states
   (Total should be 100%)

11. Focusing on the ground shipments that originated in North Carolina in 2005, please list the product categories, their shipment values, their shipment weights, and their total shipment distances.

No.	Product Category	Shipment Values (Dollars)	Shipment Weights (Tons)	Shipment Distances (Miles)
P0	*Funiture*	*$20,000*	*2,000*	*34,000 miles*
P1				
P2				
P3				
P4				
P5				
P6				

Example ⇨ (row P0)

This column will be used to fill in next question. (Product Category column)

12. For each product category listed in previous question, please identify the primary customer and the following associated information:
   1) The company name;
   2) The primary pick-up location;
   3) The primary drop-off location;
   4) The primary shipping route;
   5) The distance of this route
   6) The normal shipping time without unexpected delay using this route;
   7) The normal pick up time of the day (AM/PM).

Interviewer should fill in this column using the previous question

No	Product Category	Primary customer						
		Company name	Primary pick-up location (City)	Primary drop-off location (City)	Primary shipping route	Route distance (miles)	Normal shipping time without unexpected delay	Normal pick up time of the day (AM/PM)
P0	*Furniture*	*Columbia Carolina Corp.*	*Cary, NC*	*Charlotte, NC*	*I-85s, I-77 S*	*147 miles*	*2 hours and a half*	*7AM*
P1								
P2								
P3								
P4								
P5								
P6								

Example ⇨ (row P0)

This column will be used to fill in next question. (Primary shipping route)

13. Please estimate the following items for each shipping route described in the previous question:

1) The average unexpected delay in 2005 using this route;
2) The percentage of shipments delivered without unexpected delay using this route in 2005;
3) The percentage of shipments delivered with less than 30 minutes unexpected delay;
4) The percentage of shipments delivered with 30 minutes to1 hour unexpected delay
5) The percentage of shipments delivered with1 hour to 2 hours unexpected delay;
6) The percentage of shipments delivered with more than 2 hours unexpected delay.

Interviewer should fill in this column using the previous question

No	Primary shipping routes	Average unexpected delay in 2005 (min)	The percentage of shipments delivered					
			without unexpected delay	with less than 30 min. unexpected delay	with 30 min. to 1-hour unexpected delay	With more than 1-hour to 2-hour unexpected delay	with more than 2 hours unexpected delay	Total
P0 (*Example*)	*I-85 S, I-77 S*	*40 mins*	*80%*	*5%*	*10%*	*5%*	*0%*	*100%*
P1								100%
P2								100%
P3								100%
P4								100%
P5								100%
P6								

This column will be used to fill in next question.

14. Please provide the following information for each shipping route and its associated unexpected delay described in the previous question:
    1) The cost of unexpected delays on that shipping route to your company in 2005—these will typically include higher driver and vehicle costs, paying a fee to the customer for late deliveries, or lower payments (per unit) for product shipped;
    2) Your expected percentage of shipments delivered without unexpected delay: and
    3) Your willingness to pay to achieve your expectations.

Interviewer should fill in this column using the previous question (Primary shipping route)

Interviewer should fill in this column using the previous question (Current percentage of shipments delivered without unexpected delay)

	No	Primary shipping route	Current percentage of shipments delivered without unexpected delay	The costs of unexpected delays to your company	Expected percentage of shipments delivered without unexpected delay	Your willingness to pay for the improvement
Example ⇨	**P0**	*I 85-S, I-77 S*	*80%*	*$50,000*	*95%*	*$5,000 per year*
	P1					
	P2					
	P3					
	P4					
	P5					
	P6					

B. Coping Behavior for Traffic Incidents

15. Does your company seek pre-trip traffic information on NC interstate facilities?

☐ YES, what are the means your company often uses?
☐ NO, what are the reasons?
(Open-ended question)

____
____
____

16. Are any route-guidance devices currently installed on delivery vehicles?

☐ YES, what are they?
☐ NO, what are the reasons?
(Open-ended question)

____
____
____

17. Do you think current traffic information services are sufficient for your business operation?

☐ YES
☐ NO, what are your concerns and suggestions?
(Open-ended question)

____
____
____

18. What are the coping strategies used by drivers when shipments are late due to (unexpected) traffic incidents on NC interstate facilities? Please check those applicable to you.

☐ Do nothing
☐ Change route
☐ Change departure time
☐ Other (Please specify) _________________________________

19. What are the coping strategies used at the business management level when shipments are late due to (unexpected) incidents on NC interstate facilities? Please check those applicable to your company.
☐ Do nothing
☐ Consider company relocation
☐ Adopt new technology in business operations
☐ Attempt to further reduce cost (labor, vehicle, …)
☐ Other (Please specify) ___________________

20. To what extent is your company satisfied or dissatisfied with level of service of NC interstate facilities in the following dimensions. **(Please circle your answer.)**

	Very Dissatisfied	Moderately Dissatisfied	Neutral	Moderately Satisfied	Very Satisfied
a. Infrastructure	1	2	3	4	5
b. Capacity	1	2	3	4	5
c. Safety	1	2	3	4	5
e. Incident management	1	2	3	4	5
f. Information system	1	2	3	4	5

21. Are you aware of the NCSmartLink.org website, which provides real time traffic information for NC interstate facilities?
    - ☐ YES. If yes, does your company use this service? ________
    - ☐ NO

22. Are you aware of the 511 Toll-Free Number, which provides real time traffic information for NC interstate facilities?
    - ☐ YES. If yes, does your company use this service? ________
    - ☐ NO

C. Company Information

This section asks general information about your company.

23. How many full time equivalent employees work in your company?
    - ☐ _____________

24. What were the annual sales, revenues, and wages of your company for the past five years? **(Unit: Dollars)**

Year	Annual Sales	Total wages
2001		
2002		
2003		
2004		
2005		

25. What is your company's expected annual employment growth rate over the next five years?
    - ☐ _________%

26. What is your company's expected annual growth rate in sales over the next five years?
    - ☐ _________%

27. Is your company considering business expansion in NC in next five years?

- ☐ YES, what is the plan?
- ☐ NO, what are the reasons?

(Open-ended question)

____
____
____

Thank you for taking the time to complete this questionnaire. Please feel free to provide any additional information you feel is important but not requested in this questionnaire. Also feel free to make any suggestions about this project.

Appendix C – Descriptive Statistics

Table C1. Firm Phone Interview Descriptive Statistics						
	N	**Avg**	**Med**	**Min**	**Max**	**Std Dev**
Carriers for outgoing shipments*	23	0.78	NA	NA	NA	NA
Experienced recent unexpected delay*	24	0.46	NA	NA	NA	NA
Length of unexpected delay (hrs)	11	2.03	1.50	0.33	7.50	2.04
Incoming shipments per day	22	46.76	22.00	1.00	175.00	67.84
Outgoing shipments per day	21	58.60	40.00	1.00	230.00	61.84
Incoming shipment weight per day (tons)	19	523.77	260.00	12.00	2740.00	761.90
Outgoing shipment weight per day (tons)	19	7876.38	240.00	6.00	125600.0 0	30344.72
Average incoming shipment length (hrs)	21	6.58	4.00	0.50	24.00	7.62
Average outgoing shipment length (hrs)	19	12.79	6.00	0.25	48.00	15.85
Incoming shipment windows*	23	0.39	NA	NA	NA	NA
Outgoing shipment windows*	22	0.36	NA	NA	NA	NA
Incoming window length (hrs)	8	1.75	1.00	0.50	4.00	1.46
Outgoing window length (hrs)	7	1.67	1.25	0.50	4.00	1.25
Can early incoming shipments unload*	12	0.71	NA	NA	NA	NA
Can early outgoing shipments unload*	16	0.53	NA	NA	NA	NA
Expected incoming on-time %	19	96.79	100.00	80.00	100.00	6.15
Expected outgoing on-time %	20	96.74	99.00	80.00	100.00	5.28
Just-in-Time (JIT) operations*	24	0.74	NA	NA	NA	NA

** 1 = Yes, 0 = No*

Table C2. Firm Face-to-Face Interview Descriptive Statistics						
	N	**Avg**	**Med**	**Min**	**Max**	**Std Dev**
Hires carriers for outgoing shipments*	9	0.78	NA	NA	NA	NA
% outgoing shipments origin in NC	8	34.38	25.00	0.00	100.00	31.33
% outgoing shipments to adjacent states	8	21.88	22.50	0.00	40.00	12.52
% outgoing shipments to non-adjacent states	8	43.75	45.00	0.00	90.00	30.21
Importance of on-time arrival**	8	4.88	5.00	4.00	5.00	0.35
Importance of shipping time**	8	4.00	4.00	3.00	5.00	0.76
Importance of shipping cost**	8	4.38	5.00	3.00	5.00	0.92
Satisfaction with on-time arrival***	8	4.25	4.00	3.00	5.00	0.71
Satisfaction with shipping time***	8	4.00	4.00	3.00	5.00	0.76
Satisfaction with shipping cost***	8	3.50	3.00	3.00	5.00	0.76
Average outgoing shipment value	6	NA	NA	NA	NA	NA
Average outgoing shipment weight	7	NA	NA	NA	NA	NA
2005 payments to carriers ($mil)	2	14.70	14.70	4.40	25.00	14.57
Average outgoing unexpected delay (min)	5	93.00	120.00	30.00	150.00	52.39
% outgoing shipments without unexpected delay	6	95.33	96.50	85.00	100.00	5.65
Cost of unexpected outgoing delay	5	24000	0.00	0.00	120000.0 0	53665.63
Expected % of outgoing shipments without unexpected delay	6	98.50	99.50	95.00	100.00	2.07
Annual amount willing to pay for improvement	4	6250.00	0.00	0.00	25000.00	12500

	N	Avg	Med	Min	Max	Std Dev
Internal outgoing shipment operation*	9	0.22	NA	NA	NA	NA
Full-time drivers	2	87.50	87.50	0.00	175.00	123.74
Total driver wages ($mil)	1	11.90	11.90	11.90	11.90	NA
Number of vehicles	1	142.00	142.00	142.00	142.00	NA
On-site vehicle storage*	1	1.00	NA	NA	NA	NA
Total vehicle maintenance cost	1	1.50	1.50	1.50	1.50	NA
Total fuel cost	1	6.50	6.50	6.50	6.50	NA
Importance of on-time arrival**	2	4.50	4.50	4.00	5.00	0.71
Importance of shipping time**	2	3.50	3.50	3.00	4.00	0.71
Importance of shipping cost**	2	5.00	5.00	5.00	5.00	0.00
Satisfaction with on-time arrival***	1	5.00	5.00	5.00	5.00	NA
Satisfaction with shipping time***	1	5.00	5.00	5.00	5.00	NA
Satisfaction with shipping cost***	1	5.00	5.00	5.00	5.00	NA
% outgoing shipments within NC	2	25.00	25.00	0.00	50.00	35.36
% outgoing shipments to adjacent states	2	70.00	70.00	40.00	100.00	42.43
% outgoing shipments to non-adjacent states	2	5.00	5.00	0.00	10.00	7.07
Average outgoing shipment value ($1000)	1	40.00	40.00	40.00	40.00	NA
Average outgoing shipment weight (tons)	1	21.50	21.50	21.50	21.50	NA
Average outgoing shipment distance (mi)	2	164.00	164.00	95.00	233.00	97.58
Average outgoing shipment length (hrs)	2	3.25	3.25	2.50	4.00	1.06
Average outgoing unexpected delay (min)	1	30.00	30.00	30.00	30.00	NA
% outgoing shipments without unexpected delay	1	99.80	99.80	99.80	99.80	NA
% outgoing shipments with unexpected delay < 30 min	1	0.20	0.20	0.20	0.20	NA
% outgoing shipments with unexpected delay 60-120 min	1	0.00	0.00	0.00	0.00	NA
% outgoing shipments with unexpected delay > 120 min	1	0.00	0.00	0.00	0.00	NA
Cost of unexpected outgoing delay	1	NA	NA	NA	NA	NA
Expected % of outgoing shipments without unexpected delay	1	100.00	100.00	100.00	100.00	NA
Annual amount willing to pay for improvement	1	0.00	0.00	0.00	0.00	NA
Average incoming shipment value	6	NA	NA	NA	NA	NA
Average incoming shipment weight	7	NA	NA	NA	NA	NA
Average incoming unexpected delay (min)	8	69.30	45.00	1.50	150.00	62.88
% incoming shipments without unexpected delay	8	97.33	97.50	95.00	100.00	2.25
Cost of unexpected incoming delay	7	26280.00	2400.00	0.00	100000.00	42992.93
Expected % of incoming shipments without unexpected delay	8	98.83	99.50	95.00	100.00	1.94
Annual amount willing to pay for improvement	8	23000.00	0.00	0.00	100000.00	37009.01

	N	Avg	Med	Min	Max	Std Dev
% incoming shipments involving air transportation	9	7.22	5.00	0.00	20.00	7.55
% incoming shipments involving ship transportation	9	32.78	30.00	0.00	95.00	32.51
% incoming shipments involving rail transportation	9	11.44	0.00	0.00	75.00	24.77
Cost of 10% incoming shipments late by 1 day	9	1143.68	300.00	0.24	3000.00	1305.38
Seek pre-trip traffic info*	9	0.44	NA	NA	NA	NA
Use route guidance devices*	9	0.67	NA	NA	NA	NA
Current information services sufficient*	8	0.75	NA	NA	NA	NA
Satisfaction w/interstate infrastructure***	8	3.88	4.00	3.00	5.00	0.64
Satisfaction w/interstate capacity***	8	3.88	4.00	2.00	5.00	0.83
Satisfaction w/interstate safety***	8	3.88	4.00	2.00	5.00	0.99
Satisfaction w/interstate incident management***	8	3.88	4.00	2.00	5.00	0.99
Satisfaction w/interstate info system***	8	3.75	4.00	2.00	5.00	0.89
Aware of www.ncsmartlink.org*	9	0.22	NA	NA	NA	NA
Aware of 511 toll free number*	9	0.22	NA	NA	NA	NA
Full-time employees	8	797.50	750.00	130.00	1500.00	482.75
2005 total sales	1	160.00	160.00	160.00	160.00	160.00
2005 total wages	0	NA	NA	NA	NA	NA
5-yr employment growth rate	7	23.21	10.00	0.00	100.00	35.20
5-yr revenue growth rate	4	14.13	13.75	9.00	20.00	4.63
NC business expansion within 5-yrs*	7	0.57	NA	NA	NA	NA

** 1 = Yes, 0 = No*
*** 1 = Not Important, 5 = Very Important*
**** 1 = Very Dissatisfied, 5 = Very Satisfied*

Table C3.
Carrier Phone Interview Descriptive Statistics

	N	Avg	Med	Min	Max	Std Dev
Experienced recent unexpected delay*	5	1.00	NA	NA	NA	NA
Length of unexpected delay (hrs)	5	1.94	2.00	0.75	3.00	0.92
Outgoing shipments per day	5	34.99	9.86	1.00	136.99	57.44
Total annual outgoing shipment weight (tons)	5	8557.50	3625.00	1980.00	25000.00	11046.26
Total annual charges to customers ($*1000)	5	3675.00	1025.00	650.00	12000.00	5555.85
Average outgoing shipment length (hrs)	5	24.25	11.50	2.00	60.00	26.37
Customers use Just-in-Time (JIT) operations*	5	0.60	NA	NA	NA	NA
Outgoing shipment windows*	5	0.40	NA	NA	NA	NA
Outgoing window length (hrs)	2	2.00	2.00	2.00	2.00	2.00
Can early outgoing shipments unload*	4	0.75	NA	NA	NA	NA
Expected outgoing on-time %	5	98.16	98.50	95.00	100.00	2.04

** 1 = Yes, 0 = No*

Table C4. Carrier Face-to-Face Interview Descriptive Statistics						
	N	**Avg**	**Med**	**Min**	**Max**	**Std Dev**
Full-time drivers	3	122.33	155.00	42.00	170.00	69.97
Total driver wages ($mil)	3	7.10	3.90	2.70	14.70	6.61
Number of vehicles	3	96.67	66.00	55.00	169.00	62.88
On-site vehicle storage*	3	1.00	NA	NA	NA	NA
Total vehicle maintenance cost	3	0.78	0.66	0.07	1.60	0.77
Total fuel cost	3	2.38	2.60	0.04	4.50	2.24
Importance of on-time arrival**	3	5.00	5.00	5.00	5.00	0.00
Importance of shipping time**	3	3.00	3.00	3.00	3.00	0.00
Importance of shipping cost**	3	4.00	4.00	3.00	5.00	1.00
Satisfaction with on-time arrival***	3	4.33	4.00	4.00	5.00	0.58
Satisfaction with shipping time***	3	3.67	4.00	3.00	4.00	0.58
Satisfaction with shipping cost***	3	2.33	2.00	2.00	3.00	0.58
% outgoing shipments within NC	3	22.67	8.00	0.00	60.00	32.58
% outgoing shipments to adjacent states	3	16.67	15.00	0.00	35.00	17.56
% outgoing shipments to non-adjacent states	3	60.67	77.00	5.00	100.00	49.56
Average outgoing shipment value ($1000)	3	92.56	90.00	20.00	175.00	54.50
Average outgoing shipment weight (tons)	3	136.89	21.00	10.00	950.00	306.57
Average outgoing shipment distance (mi)	3	2961.67	2500.00	335.00	12600.00	3702.35
Average outgoing shipment length (hrs)	3	43.43	42.00	24.00	72.00	14.22
Average outgoing unexpected delay (min)	3	56.00	60.00	15.00	90.00	29.45
% outgoing shipments without unexpected delay	3	94.80	95.00	90.00	99.00	3.19
% outgoing shipments with unexpected delay < 30 min	3	3.40	5.00	0.00	5.00	2.30
% outgoing shipments with unexpected delay 30-60 min		10.66	2.00	0	30.00	16.77
% outgoing shipments with unexpected delay 60-120 min	3	6.00	2.00	0.00	25.00	10.70
% outgoing shipments with unexpected delay > 120 min	3	1.53	0.50	0.00	5.00	2.10
Cost of unexpected outgoing delay	3	8000.00	10000.00	4000.00	10000.00	3464.10
Expected % of outgoing shipments without unexpected delay	3	97.03	97.00	96.00	98.10	1.18
Annual amount willing to pay for improvement	3	3333.33	0.00	0.00	10000.00	5773.50
Seek pre-trip traffic info*	3	0.00	NA	NA	NA	NA
Use route guidance devices*	3	0.33	NA	NA	NA	NA
Current information services sufficient*	3	0.33	NA	NA	NA	NA
Satisfaction w/interstate infrastructure***	3	2.33	2.00	1.00	4.00	1.00
Satisfaction w/interstate capacity***	3	3.00	3.00	2.00	4.00	1.00
Satisfaction w/interstate safety***	3	3.67	4.00	3.00	4.00	0.58
Satisfaction w/interstate incident management***	3	3.67	4.00	3.00	4.00	0.58
Satisfaction w/interstate info system***	3	2.67	3.00	2.00	3.00	0.58
Aware of www.ncsmartlink.org*	3	0.00	NA	NA	NA	NA
Aware of 511 toll free number*	3	0.67	NA	NA	NA	NA
Full-time employees	3	220.00	200.00	125.00	335.00	106.42
2005 total revenue	3	24.10	21.20	18.00	33.10	7.96
2005 total wages	3	10.03	6.00	2.90	21.20	9.79
5-yr employment growth rate	3	2.33	2.00	0.00	5.00	2.52
5-yr revenue growth rate	3	7.50	7.50	0.00	15.00	7.50
NC business expansion within 5 yrs*	3	0.67	NA	NA	NA	NA

** 1 = Yes, 0 = No*
*** 1 = Not Important, 5 = Very Important*
**** 1 = Very Dissatisfied, 5 = Very Satisfied*

Appendix D – Case Summaries

Firm #1 Case Summary

Firm Type: Carrier

- Firm #1 employed 155 FTE drivers in 2005 with total wages of $3.9 million;
- On-time arrival and cost of shipping are "Very Important" to Firm #1's business;
- 100% of FIRM #1's outgoing shipments are to non-adjacent states (heavy business on the West coast);
- Firm #1's primary shipment products are filters, auto supplies, chemicals, construction equipment batteries, and foam products;
- The primary pick-up locations for these products are Gastonia, Charlotte, Winston-Salem, and Mount Airy;
- The primary drop-off locations for these products are Los Angeles and Denver;
- Primary shipping routes within NC are I-40 and I-77, each route experiencing unexpected delay on approximately 5% of shipments in 2005;
- These delay resulted in approximately $10,000, due mostly to added fuel costs (fines are only paid to customers when there is driver error);
- Firm #1 would be willing to pay $10,000 to erase those unexpected delays;
- Firm #1 uses GPS tracking devices on its vehicles, but does not seek pre-trip traffic info for NC facilities;
- Firm #1 does NOT consider NC's current traffic services sufficient for their business and suggest that NC install many more traffic cameras, similar to Oregon's camera network;
- Firm #1 responds to unexpected delays in the short-term by rerouting shipments, and in the long-term by adopting new technologies;
- Firm #1 is "Very Dissatisfied" with NC interstate infrastructure and moderately dissatisfied with NC interstate information systems (suggests adding many more digital signs);
- Firm #1 is not aware of the NCSmartLink.org website or the 511 toll free traffic information number;
- Firm #1 expects 0% employment growth, 0% revenue growth, and no business expansion over the next five years and suggest that many long-haul carriers are similar due to the difficulty to find and retain drivers;
- Firm #1 suggests that NCDOT conduct better maintenance planning to avoid high traffic times whenever possible.

Firm #2 Case Summary

Firm Type: Non-Carrier

- Firm #2's primary shipping products are incoming steel coils and outgoing lighting fixtures;
- Firm #2 hires other companies to ship 100% of its incoming and outgoing shipments;
- The most common shipment routes are I-40, I-26, and I-85;
- Ten percent of outgoing shipments are delivered inside NC, twenty percent in adjacent states, and seventy percent in non-adjacent states;
- Firm #2 expects 99% on-time performance for outgoing shipments;

- Unexpected delays are almost always due to weather conditions in the Midwest;
- The most important factor in selecting carriers is on-time arrival, followed by shipping time, and then the cost of shipping;
- Firm #2 paid a premium price for a high quality carrier in 2005;
- The 2005 total outgoing shipment value of lighting fixtures was $105 million, and the total weight was 3 million tons;
- The 2005 total cost of unexpected outgoing shipment delays is estimated at $120,000;
- Timely incoming shipments are vital for the components division to produce parts for assembling in the assembly division;
- The 2005 total incoming shipment value of steel coils was $40 million, and the total weight was 5.5 thousand tons;
- Almost all incoming steel coil shipments come from warehouse in Louisville, KY, via rail from Los Angeles, CA;
- Five percent of incoming shipments finish their last leg by plane, fifteen percent by ship, and eight percent by train;
- The negative consequences of an unexpected outgoing shipment delay would be back-charge from a contractor who needed the fixtures during a specific time window, and the costs of expediting the shipment;
- It would cost this facility $5,500 if 10% of incoming shipments arrived late by one day;
- Incoming and outgoing unexpected shipment delays are addressed through labor rearrangements and changing carriers;
- Firm #2 is moderately-to-very satisfied with NC interstate facilities;
- Firm #2 was not aware of NC Smart Link or the 511 toll free number;
- Firm #2 is "Neutral" to "Moderately Satisfied" with the level of NC interstate facilities and considers the lack of more rest areas along the interstates to be one of the most important issues concerning product shipment;
- Firm #2 stated that the electronic roadway signs that give information on traffic congestion, incidents, and other issues, definitely improved travel conditions.
- Firm #2 suggested better publication of NCDOT services to ensure businesses are made aware and better facilities for carriers at rest areas on the interstates, including informational kiosks.

<u>Firm #3 Case Summary</u>

Firm Type: Non-Carrier

- Firm #3 hires other companies to ship 100% of its incoming and outgoing shipments;
- Twenty percent of outgoing shipments are delivered inside NC, thirty percent in adjacent states, and fifty percent in non-adjacent states;
- On-time arrival, shipping time, cost of shipping, and product protection are all "Very Important" factors in hiring carriers;
- Firm #3's primary shipping products are incoming raw steel and electrical components and outgoing electrical hardware;
- The 2005 total outgoing shipment value of lighting fixtures was $165 million and the total weight was 12,500 tons;
- The majority of incoming electrical component shipments originate in Puerto Rico;
- Firm #3 expects 96% - 98% on-time performance for outgoing shipments;

- Firm #3 expects 100% on-time performance for incoming shipments;
- The 2005 total cost of unexpected outgoing shipment delays is estimated at $0;
- The negative consequences of an unexpected incoming shipment delay would be production timing and labor costs;
- The average length of unexpected incoming shipment delay in 2005 was approximately one hour;
- The total cost of these delays was approximately $150,000;
- Firm #3 may be willing to pay $150,000 to eliminate those unexpected delays;
- Fifteen percent of incoming shipments finish their last leg by plane, thirty percent by ship, and zero percent by train;
- It would cost this facility approximately $200,000 if 10% of incoming shipments arrived late by one day;
- Firm #3 was not aware of NC Smart Link or the 511 toll free number;
- Firm #3 is moderately satisfied with NC interstate facilities;
- Firm #3 stated that the proportion of international shipments is trending upwards, which puts greater importance on the capacities and management of nearby ports (i.e. Charleston, SC);
- Firm #3 suggested that interstate maintenance work only be conducted at night whenever possible to avoid causing shipment delays.

Firm #4 Case Summary

Firm Type: Non-Carrier

- Firm #4's primary shipping products are incoming parts and outgoing computer hardware;
- Firm #4 hires other companies to ship 100% of its incoming and outgoing shipments;
- The most common shipment routes are I-40 and I-85;
- Thirty percent of outgoing shipments are delivered inside NC, thirty percent in adjacent states, and forty percent in non-adjacent states;
- Firm #4 expects 97% on-time performance for incoming shipments and 98% for outgoing;
- Unexpected delays may result in higher driver and vehicle costs and production timing costs;
- Unexpected delays are typically reported by drivers to their dispatchers, who then report them to Firm #4;
- The most important factor in selecting carriers is the cost of shipping, followed closely by on-time arrival and total shipping time;
- The outgoing shipment values ranged from $300,000 per LTL load to $300,000 - $500,000 per parcel load;
- Outgoing shipment weights ranged from 13,000 pounds per LTL load to 15,000 pounds per parcel load;
- All LTL shipments managed by vendor;
- Parcel shipments split between FedEx and UPS;
- Incoming shipments of computer parts valued at $150 million for the three months the facility operated in 2005, which projects out to $600 million per year;
- Total incoming shipments weighed 6,750 tons for the three months the facility operated in 2005, which projects out to 27,000 tons per year;
- Approximately 90% all incoming shipments go to a nearby warehouse managed by APL

Logistics;

- No incoming or outgoing unexpected delays were reported in 2005;
- Lack of unexpected delays due to an internalized warehousing strategy that includes:
  - Leasing of building space within the facility to store parts; and
  - Requirement of vendors to keep a minimum 10-day inventory in stock.
- The primary negative consequences of an unexpected incoming shipment delay would be lost production time and the cost of having employees on the floor longer than expected;
- Incoming and outgoing unexpected shipment delays are addressed through a "Root Cause Analysis;"
- Firm #4 relies on its carriers to adequately deal with congestion issues, which may include using pre-trip traffic info (NC Smart Link, 511 Toll Free, etc.) or route-guidance devices (i.e. GPS units); and
- Firm #4 is "Neutral" to "Moderately Satisfied" with the level of NC interstate facilities and considers the lack of more rest areas along the interstates to be one of the most important issues concerning product shipment.

Firm #6 Case Summary

Firm Type: Non-Carrier

- Firm #6 hires other companies to ship 100% of its incoming and outgoing shipments;
- All overnight packages with destinations west of Memphis, TN, are shipped by air through FedEx or UPS flights;
- Forty-five percent of outgoing shipments are delivered inside NC, twenty-five percent in adjacent states, and thirty percent in non-adjacent states. The majority of non-NC shipments are to other USPS distribution centers;
- On-time arrival, shipping time, and the cost of shipping are all "Very Important" factors in hiring carriers;
- Firm #6's primary incoming and outgoing product is general mail;
- Shipment values vary from $5,000 to $50,000 per shipment, and weights vary from 1.5 to 12.5 tons per shipment, making it difficult to estimate totals for 2005;
- Firm #6 contracts between 22 and 25 carriers at any given time and has an annual transportation budget of approximately $11 million;
- Firm #6 expects 95% on-time performance for incoming and outgoing shipments;
- Firm #6 was the #7 ranked DC in the US in 2005 for on-time delivery percentage;
- The 2005 total cost of unexpected incoming and outgoing shipment delays is estimated at $0;
- Firm #6 may be willing to pay $25,000 to eliminate all unexpected delay;
- The negative consequences of an unexpected outgoing shipment delay would only be reputation due to the nature of the postal service business (systems are much more set than in a private company and there are no shipment guarantees or monetary late-delivery penalties);
- The average length of unexpected incoming and outgoing shipment delay in 2005 was approximately 30 minutes;
- Fifteen percent of incoming shipments finish their last leg by plane, zero percent by ship, and zero percent by train;
- Firm #6 stated that they used to ship some percentage of mail by train and that the mail

would actually be sorted while on the train, but now trains are too slow and unpredictable;

- It would cost this facility approximately $2 to $3 million if 10% of incoming shipments arrived late by one day;
- Firm #6 would most likely “adopt new technologies” at the business management level to cope with unexpected delay;
- Firm #6 uses a blackberry service for weather updates for pre-trip info;
- Ten to fifteen percent of contracted carriers have GPS units installed on their vehicles;
- Firm #6 is moderately satisfied with NC interstate facilities;
- Firm #6 was not aware of NC Smart Link or the 511 toll free number;
- Firm #6 will open a new HASP (Hub and Spoke facility) in Charlotte, NC, in the near future;
- Firm #6 stated that the majority of their unexpected shipment delays are due to equipment failure and not traffic incidents;
- Firm #6 suggested that interstate maintenance work only be conducted at night whenever possible to avoid causing shipment delays.
- Firm #6 had no complaints about NC interstate facilities;

Firm #12 Case Summary

Firm Type: Non-Carrier

- Firm #12 uses its own drivers and vehicles for approximately 90% of its incoming and outgoing shipments. This includes 175 Firm #12 drivers (142 vehicles) and 15 – 30 contracted drivers hired on an as-needed basis;
- Fifty percent of outgoing shipments are delivered inside NC, forty percent in adjacent states, and ten percent in non-adjacent states;
- On-time arrival and cost of shipping are “Very Important” factors in hiring carriers, while shipping time was neutral;
- Firm #12’s primary incoming and outgoing shipping product is general merchandise;
- The 2005 total outgoing shipment value of general merchandise was $208 million and the total weight was 1,118,000 tons;
- The 2005 total incoming shipment value and weight was the same as outgoing;
- Firm #12’s use and payments to contract carriers varies from month to month with the holiday season being the highest rate of use and payments;
- Firm #12 expects 100% on-time performance for outgoing shipments;
- Firm #12 expects 100% on-time performance for incoming shipments;
- Only approximately 0.02% of all outgoing shipments experienced unexpected delay in 2005;
- Firm #12 suspects driver-related reasons to be the main cause of unexpected delay and thus pay their drivers very well (average driver wage = $68,000), which results in an extremely low 4% turnover rate;
- The 2005 total cost of unexpected outgoing shipment delays is estimated between $0 and very minimal;
- Firm #12 already pays for this lack of unexpected delay through increased planning;
- If there was unexpected outgoing shipment delay there would be some amount of labor and inventory cost;
- The average outgoing shipment distance in 2005 was approximately 95 miles;

- The average length of unexpected incoming shipment delay in 2005 was approximately 45 minutes;
- Zero percent of incoming shipments finish their last leg by plane, fifteen percent by ship, and zero percent by train;
- Firm #12 is moderately satisfied with NC interstate facilities;
- Firm #12 was aware of NC Smart Link or the 511 toll free number;
- Firm #12 mentioned the “Sunpass” program in Florida, which keeps drivers from having to stop at weigh stations, as a good program overall;
- Firm #12 stated that NC interstates need more rest areas and more truck parking at existing rest areas. The shortage, as well as safety concerns, results in most Firm #12 drivers parking in Firm #12 store parking lots.

Firm #16 Case Summary

Firm Type: Carrier

- Firm #16 employed 42 FTE drivers in 2005 with total wages of $2.7 million;
- On-time arrival is “Very Important” to Firm #16 ’s business, and cost of shipping ranked a 4 out of 5;
- 60% of Firm #16 ’s outgoing shipments were within NC, 35% to adjacent states, and 5% to non-adjacent states;
- Firm #16’s primary shipment products are furniture, appliances, and flour
- The 2005 total shipment distance for these products was 123,820 miles;
- The primary pick-up locations for these products were High Point and Winston-Salem;
- The primary drop-off locations for these products were Chapel Hill, Statesville, Greensboro, Charlotte, Burlington, Conover, and Asheville;
- Primary shipping routes within NC are I-40, I-85, and multiple highways, each route experiencing unexpected delay on approximately 5% of shipments in 2005;
- These delay resulted in approximately $10,000, due mostly to added fuel costs;
- Firm #16 would not be willing to pay to eliminate those unexpected delays because they expect the tax dollars they currently spend to produce those results;
- Firm #16 does not seek pre-trip traffic info because of existing cell phone and CB communications and a perceived lack of need;
- Firm #16 does not use route-guidance devices on their vehicles due to an unfavorable cost/benefit ratio;
- Firm #16 does consider NC’s current traffic services sufficient for their business;
- Firm #16 responds to unexpected delays in the short-term by rerouting shipments, and would respond to long-term unexpected delay issues by adopting new technologies and seeking more pre-trip info;
- Firm #16 is “Moderately Dissatisfied” with NC interstate infrastructure and capacity (capacity issues only an issue in the Charlotte and Durham metros) and “Neutral” on all other measures;
- Firm #16 is not aware of the NCSmartLink.org website, but is aware of the 511 toll free traffic information number (but they don’t actively use it);
- Firm #16 expects 5% employment growth, 7.5% revenue growth, and plans to open a new facility in Wilmington and possibly Kinston in the near future;
- Firm #16 stated that the majority of its traffic issues, expected or unexpected, occur in the

Charlotte and Triangle metro areas.

Firm #24 Case Summary

Firm Type: Carrier

- Firm #24 employed 170 FTE drivers in 2005, including owner-operators, with total wages of $14.7 million;
- On-time arrival is "Very Important" to Firm #24's business, especially since it's a specialty carrier;
- Eight percent of Firm #24's outgoing shipments are within NC, 15% to adjacent states, and 77% to non-adjacent states (heavy business in New York metro area);
- Firm #24's primary shipment product is furniture;
- The primary customer only constitutes 2.5% of all shipments and is located in Stanleytown, VA;
- There is no primary drop-off location for Firm #24, but they do heavy business in the New York metro area;
- Firm #24 did experience an unexpected delay in the last three months;
- Primary shipping routes within NC are I-85, I-40, Hwy 64, Hwy 220, and Hwy 321;
- One percent of shipments on I-85 experience unexpected delay, 10% on I-40, 3% on Hwy 64, and 0% on Hwys 220 and 321;
- These delay resulted in approximately $3,000 in 2005, due mostly to added fuel costs, driver costs, and loss of driver capacity;
- Firm #24 is not willing to pay to erase those unexpected delays because the amount of taxes they currently pay should be adequate;
- Firm #24 does not use GPS tracking devices on its vehicles because it is not yet cost beneficial;
- Firm #24 does not consider NC's current traffic information services sufficient for their business;
- Firm #24 responds to unexpected delays in the short-term by rerouting shipments or changing departure times, and in the long-term by adopting new technologies;
- Firm #24 is "Neutral" with NC interstate capacity and information systems, and is not "Very Satisfied" with any measure;
- Firm #24 is not aware of the NCSmartLink.org website, but is aware of the 511 toll free traffic information number;
- Firm #24 expects 2% employment growth, 15% revenue growth, and a warehouse expansion in NC over the next five years;
- Firm #24 suggests that NCDOT provide more and better real-time communication to companies in the transportation industry.

Firm #25 Case Summary

Firm Type: Non-Carrier

- Firm #25 uses its own drivers and vehicles for all of its incoming shipments and the vast majority of outgoing shipments. However, all shipments originate from the distribution center, except outgoing inter-store transfers that use parcel service;

- All outgoing shipments are delivered to an adjacent state (VA);
- The cost of shipping is a “Very Important” factor to Firm #25’s business;
- Firm #25’s primary incoming and outgoing shipping product is general merchandise;
- The 2005 total outgoing shipment value and weight of general merchandise varied greatly due to the extreme diversity of products shipped;
- Firm #25 expects 99% on-time performance for incoming shipments;
- Only approximately 1% of outgoing shipments of general merchandise experienced unexpected delay in 2005;
- The average incoming and outgoing shipment distance for general merchandise in 2005 was approximately 233 miles;
- Firm #25 did not experience an unexpected delay of at least thirty minutes in the last three months;
- The average length of unexpected incoming shipment delay in 2005 was approximately one hour for general merchandise, and four hours for food products (shipped from different distribution center in Alabama);
- There were definite costs to Firm #25 in 2005 due to unexpected incoming shipment delays. These include payroll costs, handling costs, and lost sales/revenues;
- Firm #25 considers these costs incalculable, are unwilling to pay for improvements, and would work internally to reduce unexpected delays and/or their costs;
- Zero percent of incoming shipments finish their last leg by plane, ship, or train;
- Firm #25 considered the cost of 10% of incoming shipments arriving late by one day incalculable, but concluded it would be significant;
- Firm #25 does seek pre-trip traffic information;
- Firm #25 was aware of NC Smart Link and the 511 toll free number;
- The major business-level coping strategy for unexpected delays would be to consider changing suppliers (distribution centers), which this facility has already done once.

<u>Firm #26 Case Summary</u>

Firm Type: Non-Carrier

- FIRM #26’s primary shipping products are components and raw materials;
- FIRM #26 hires other companies to ship 100% of its incoming and outgoing shipments;
- The most common shipment routes are I-77 and I-85;
- One-hundred percent of outgoing shipments are delivered inside NC;
- FIRM #26 expects 90% on-time performance for outgoing shipments;
- The most important factors in selecting carriers are on-time arrival and cost, followed by shipping time;
- The 2005 total outgoing shipment value and weight of breaker boxes was not provided;
- The 2005 total cost of unexpected outgoing shipment delays is estimated at $0;
- The 2005 total incoming shipment value and weight of components and raw materials was not provided;
- Most components come from Puerto Rico, resulting in thirty percent of incoming shipments being picked up at ports off ships;
- Five percent of incoming shipments finish their last leg by plane, and none by train;
- The negative consequences of an unexpected outgoing shipment delay would be primarily carrier contracting costs;

- It would cost this facility $300,000 if 10% of incoming shipments arrived late by one day;
- Incoming and outgoing unexpected shipment delays are addressed by attempting to reduce costs and changing suppliers;
- FIRM #26 was not aware of NC Smart Link or the 511 toll free number;
- FIRM #26 is “Neutral” to “Moderately Satisfied” with the level of NC interstate facilities;
- FIRM #26 suggested that NCDOT more adequately prepare for future traffic volumes and the associated congestion.

Firm #27 Case Summary

Firm Type: Non-Carrier

- Firm #27 contracts more than 100 different carriers to ship 100% of its incoming and outgoing shipments;
- No outgoing shipments are delivered inside NC, ten percent are shipped to adjacent states, and ninety percent in non-adjacent states;
- On-time arrival was the only “Very Important” factor in hiring carriers;
- Firm #27’s primary shipping products are incoming raw and synthetic rubber and outgoing automobile tires;
- The 2005 total outgoing shipment value of automobile tires was $1 billion and the total weight was 1.62 million tons;
- The majority of incoming raw rubber originated in Indonesia;
- Firm #27 expects 100% on-time performance for outgoing shipments;
- Firm #27 expects 100% on-time performance for incoming shipments;
- The 2005 total cost of unexpected outgoing shipment delays was not able to be estimated due to the lack of unexpected delays occurring in that year;
- The 2005 total incoming shipment value of raw steel was $120 million, and the total weight was 360,000 tons;
- The negative consequences of an unexpected incoming shipment delay would be production timing costs;
- The average length of unexpected incoming shipment delay in 2005 was not available due to the lack of unexpected delays occurring in that year;
- The total cost of potential delays could not be calculated;
- Firm #27 already pays to avoid these delays through their investments in logistics;
- No incoming shipments finish their last leg by plane, thirty-five percent by ship, and twenty percent by train;
- It would cost this facility approximately $3,000,000 if 10% of incoming shipments arrived late by one day;
- Firm #27 was not aware of NC Smart Link or the 511 toll free number;
- Firm #27 is “Very Satisfied” with NC interstate facilities;
- Firm #27 is generally pleased with all aspects of North Carolina’s interstates and had no additional comments.

Firm #29 Case Summary

Firm Type: Non-Carrier

- Firm #29 hires other companies to ship 100% of its incoming and outgoing shipments;
- Twenty percent of outgoing shipments are delivered inside NC, twenty percent in adjacent states, and sixty percent in non-adjacent states;
- On-time arrival is the only “Very Important” factor in hiring carriers;
- Firm #29’s primary shipping products are incoming equipment parts and outgoing construction equipment;
- The 2005 average outgoing shipment value of construction equipment was $100,000 and the total weight was 20 tons;
- Incoming parts are shipped in from multiple global sister companies;
- Firm #29 has no on-time performance expectations for outgoing shipments because once they leave the facility, individual dealerships are responsible for the shipments;
- Firm #29 expects 100% on-time performance for incoming shipments;
- The 2005 total cost of unexpected outgoing shipment delays is estimated at $0;
- The 2005 total cost of unexpected incoming shipment delays is estimated at $29,000;
- The 2005 average incoming shipment value of equipment parts was $50,000, and the average weight was 8.75 tons;
- The negative consequences of an unexpected incoming shipment delay would be production timing costs;
- The average length of unexpected incoming shipment delay in 2005 was approximately two and a half hours;
- The total cost of these delays was approximately $29,000;
- Firm #29 is not willing to pay to eliminate those unexpected delays, and feels that existing taxes should be sufficient to reduce the delays;
- Five percent of incoming shipments finish their last leg by plane, ninety-five percent by ship, and zero percent by train;
- It would cost this facility approximately $240 if 10% of incoming shipments arrived late by one day;
- Firm #29 was not aware of NC Smart Link or the 511 toll free number;
- Firm #29 is “Moderately Dissatisfied” with NC interstate facilities;
- Firm #29 stated that interstates need more information signs and they should be placed further out from typical congestion areas to give drivers adequate distance to reroute.

Appendix E – Traveler Behavior Model and Sensitivity Analysis in Case Studies with ATIS

Traveler Behavior Model

In this study, we add a traveler behavior model into the traveler information evaluation process, which should better reflect drivers' actual response to traffic congestion information. Such a model would be useful for testing differences in effects of traveler information due to different road user/vehicle behaviors, since different types of road users and vehicles may have distinct traveler behaviors. Therefore, we choose a behavioral model based on a survey of travelers (Khattak 1991). The proposed binary logit model of route choice was estimated using the responses of those who knew about the traffic delays either by observing them or through traffic information. The model parameters can be changed to reflect the local conditions, if behavioral data are available.

Driver attributes were not included in this study, in order to focus on the information effect and simplify the analysis process. The dependent variable (Y) was the decision of staying on the usual route (Y=0) or diverting to an alternate route (Y=1). The independent variables were information source (X_1=1 if delay information received electronically, =0 if delay received via observation) and travel time difference (in minutes) between original and alternate routes (X_2). Table E1 presents β coefficients of the model as well as a sensitivity analysis of parameters. The constant term, β_0, captures the overall tendency of the sample, all else being equal. Its value is negative and statistically significant, indicating that travelers prefer to stay on their usual route in unexpected delay situations, all else being equal. This is possibly due to their inertial tendencies (Khattak 1991). The 90% confidence interval for each β is calculated. For each beta, we compute the diversion probabilities for the four scenarios at its lower and upper interval bound, given that the other two betas are fixed to their point estimates. The four scenarios are represented by the four combinations of different values of X_1 and X_2. It turns out that the probability of diversion is quite sensitive to changes in β s, especially β_0 and β_1. It also can be shown that the probability of diversion increases with β i given all other β s fixed to their point estimates.

Table E1.
Travel Behavior Model and its Parameter Analysis

Variable	β	t-statistics	90% Confidence Interval	Scenario	Probability of diversion
Constant	β_0 = -0.717	-4.27	[-0.993, -0.441]	X_1=0;X_2=0	[0.27, 0.39]
				X_1=0;X_2=10	[0.32, 0.45]
				X_1=1;X_2=0	[0.36, 0.49]
				X_1=1;X_2=10	[0.41, 0.55]
Electronic Information	β_1 = 0.407	1.88	[0.051, 0.763]	X_1=0;X_2=0	[0.33, 0.33]
				X_1=0;X_2=10	[0.38, 0.38]
				X_1=1;X_2=0	[0.34, 0.51]
				X_1=1;X_2=10	[0.39, 0.57]
Travel time difference	β_2 = 0.022	3.48	[0.012, 0.032]	X_1=0;X_2=0	[0.33, 0.33]
				X_1=0;X_2=10	[0.35, 0.40]
				X_1=1;X_2=0	[0.42, 0.42]
				X_1=1;X_2=10	[0.45, 0.50]

Note: Summary statistics – Initial log-likelihood L(0) = -257.85, Convergence log-likelihood L(β) = -246.71, N=372.

We use these coefficients in our study for illustration. Based on the travel behavior model, the probability of road user *n* choosing the alternate route $P_n(alternate)$ could be calculated, where the probability of user *n* choosing the original route $P_n(original) = 1 - P_n(alternate)$. Then, a random number τ is generated between 0 and 1. If τ is not greater than $P_n(alternate)$, then this user is assigned to the alternate route; otherwise this user is assigned to the original route.

What is the extent of ATIS benefits when users can observe traffic congestion?
Two sets of incidents are examined to address this research question. In Set 1 scenarios, nobody can observe the incident-induced queue, while in Set 2 scenarios, they can observe the queue. With a $10 per hour value of time for passenger cars and $50 for large trucks, the analysis of total travel cost is shown in Figure 4, where the vertical axis represents the savings in percentage as compared to the base case (no traffic information is provided and drivers cannot observe the incident), and the horizontal axis represents the percentage of travelers who access and acquire electronic traffic information.

For both sets of scenarios, total travel costs are lower with increasing electronic traveler information. Saving in total travel cost of up to 9% are possible with electronic traveler information as indicated by Set 1 scenarios. The slope of savings is rather steep in these scenarios. However, the results shown for Set 2 scenarios indicate that total travel costs savings from electronic traffic information may be consumed almost entirely by individuals obtaining information by directly observing congestion. One reason for the lower effect of traffic information on the total travel cost in Set 2 scenarios is the restrictions coming from the traveler behavior model, i.e., high value of constant coefficient β_0. This parameter indicates that the probability of drivers choosing the alternate route could be as high as 37%, if they can only observe the incident-induced congestion but not receive any electronic dynamic traffic information, given a travel time difference between two routes equal to 20 minutes (shown in Table 1). Based on existing literature, this rate may be on the high end. The model allows changing these parameters to suit local conditions and considerations. Overall the savings associated with electronic information is highly context dependent, i.e., they can be almost wiped out if drivers are able to observe traffic congestion and divert to alternate routes.

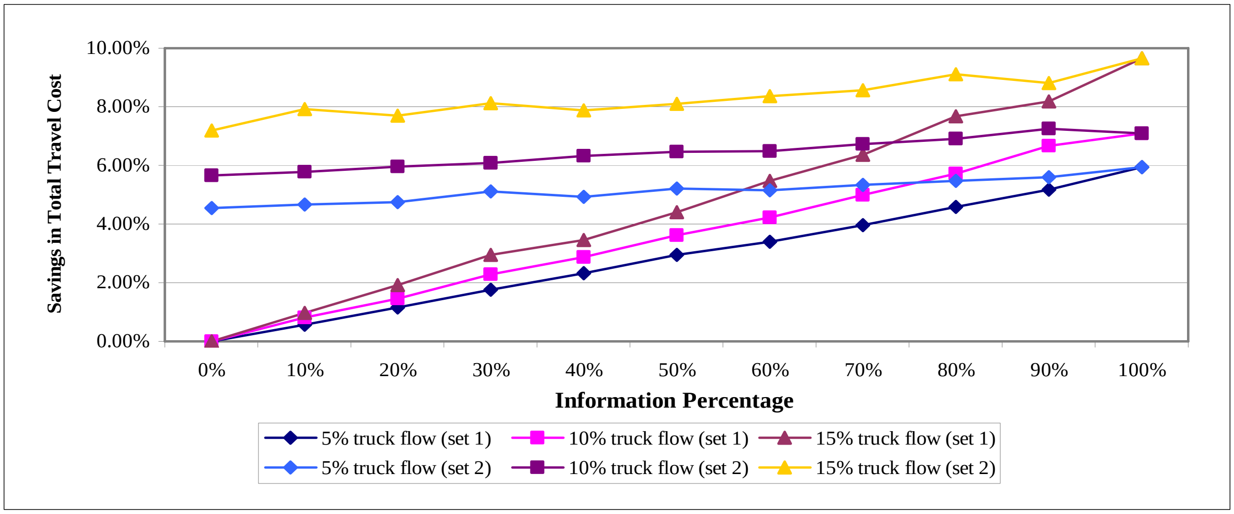


Figure E1. ATIS Impacts on Savings in Total Travel Cost for Two Sets of Scenarios

How might cost savings vary when commercial truck percentages increase in the traffic stream?
The results show that there is an increase in total travel cost (and average travel time) with increasing percentage of truck flows, as expected. The benefit of providing information may be greater when the traffic contains more trucks, because truck traffic usually has greater impacts on the entire traffic flow than regular passenger cars, especially when incidents occur. As shown in Figure 4, if hundred percent of the drivers are provided with information in set 1 scenarios, the total travel cost savings between 15% and 5% truck flow are 3.7% (9.6% – 5.9%). Thus increasing commercial truck percentages are associated with higher potential savings in total travel costs when dynamic traveler information is provided during incident induced congestion. This implies that disseminating information in areas with higher truck volumes should receive special attention.

What are the impacts when commercial truck drivers divert to alternate routes?
To consider the behavioral response of truck drivers, five categories of truck diversion chances were considered compared with passenger car diversion chances. Truck diversion chances were 0%, 25%, 50%, 75%, and 100% of the passenger car diversion chances; 0% means that no truck diverts to the alternate route, and 100% means truck drivers behave exactly like passenger vehicle drivers in terms of diversion to alternate routes. Other parameters in the model are set to their median values, i.e., VOT for trucks was 5 times that for cars, and truck percentage in the traffic flow was 10%.

Figure 5 shows the savings in TTC under different truck diversion probabilities. Note that the percentages on the vertical axis here represent the savings in percentage as compared to the base case (no traffic information is provided and drivers can not observe the incident), and the horizontal axis represents the percentage of travelers who receive traffic information. The interesting, yet expected findings here are two fold. First, the savings in total travel costs due to electronic information are about 6%. If drivers can observe the congestion, then the additional savings in travel cost due to electronic information are relatively small, in the vicinity of 1%. Second, for both scenarios (set 1 & 2), fixing the percentage of traffic information availability, the savings in total travel cost increase with higher truck diversion probability. Clearly, it is more efficient if trucks are able to divert to alternate routes compared to being constrained to stay on the route where incident has occurred. Hence, an important implication here is that guiding commercial carriers' route choice with dynamic traffic information may bring noticeable benefits, especially under incident situation when travelers cannot observe the incident-induced congestion.

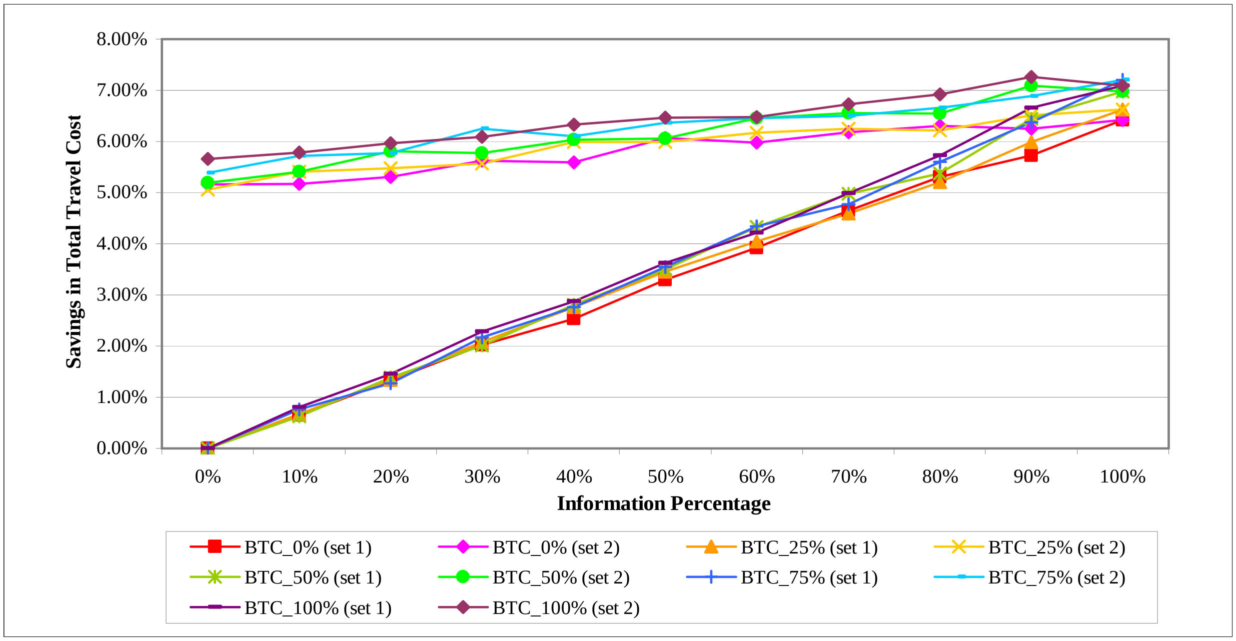


Figure E2. ATIS Impacts on Savings in TTC for Different Truck Diversion Probability

How does the system perform when commercial trucks have a higher value of time?
Truck value of time can vary depending on types of goods, destination constraints, and a host of other factors, but generally commercial carriers usually have a higher value of travel time than motorists. The values of truck VOTs simulated in this study are relatively conservative. Five different commercial truck VOTs are tested in the study, i.e., 1, 3, 5, 7, and 10 times of passenger cars, while holding other parameters at their median value, i.e., truck diversion probability is one-half of cars, and truck percentage in the traffic flow equals to 10%. Recall that the VOT of passenger cars is around $10 per hour per vehicle.

Effects of traveler information on different VOT of trucks are shown in Figure 6, where the vertical axis represents the percentages of savings in total travel cost of different cases compared to the base case (no traffic information is provided and drivers cannot observe the incident, but the truck VOT takes the same value as the case to be compared). The horizontal axis represents the percentage of drivers who receive traffic information. The upper limit of benefits from information is about 7%. Surprisingly, the percentage of savings in total travel cost decreases with increasing truck VOT for both scenarios. For instance, if travelers can observe traffic congestion and 50% of the travelers acquire detailed traffic information (e.g., know the travel time difference between the two options), then the savings are 6.06% of total travel cost, given the truck VOT is $10 per vehicle per hour. However, the savings are 4.93% of total travel cost if truck VOT is $70 per vehicle per hour. This is partly because the total travel costs associated with base cases increase with higher truck VOT and that increase is of a relatively larger magnitude, such that the overall potential for travel cost savings declines.

The benefits of electronic information are limited when users can observe the congestion, as before. Specifically, the percentage of savings in total travel cost when travelers could not observe congestion are relatively smaller than when travelers could, but the gap decreases with greater information availability. The marginal savings in total travel cost by increasing electronic traffic information availability is much smaller than if travelers could not, as indicated by the different slopes of saving curves for cases in the two scenarios, i.e., set 2 slopes are much “smaller” than set 1.

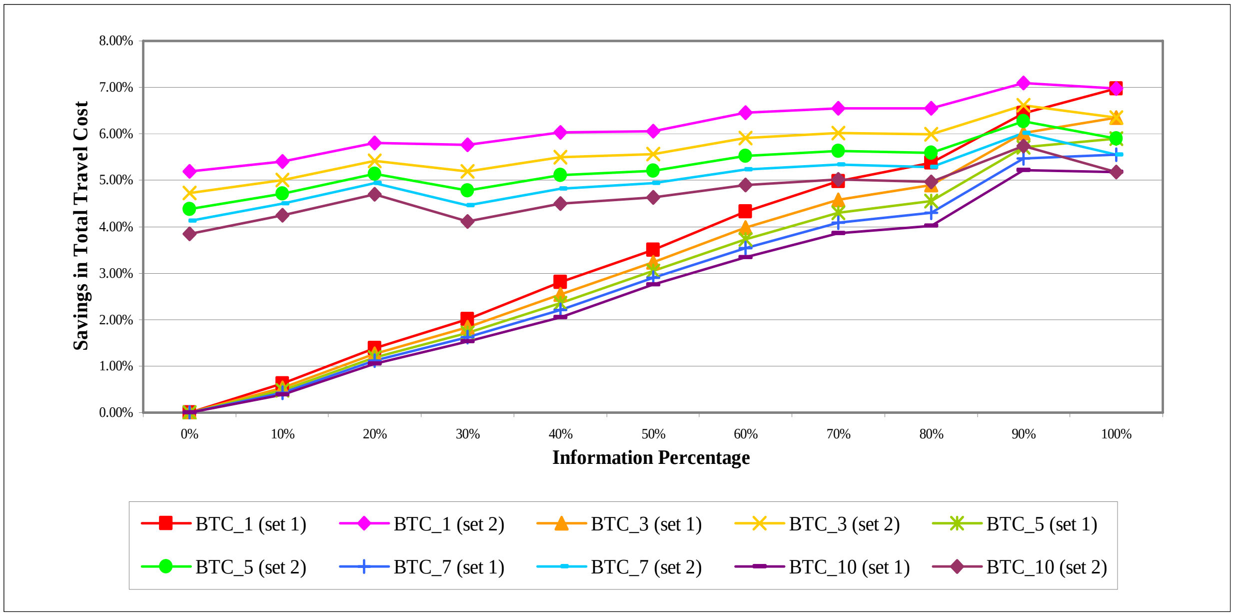


Figure E3. Total Travel Cost for Different Truck VOT