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Speed and Safety in North Carolina

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Final Report

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16. Abstract

With nearly 5000 people losing their lives and many more injured in North Carolina speeding-related crashes over the past decade, more concerted and cooperative action is needed to address speeding as a major safety problem in the State. The project team was tasked with conducting a literature review to identify best practices with regard to speed management, to characterize the problem of speeding in the State, and to come up with recommendations that the State might implement to significantly bring down the numbers of killed and seriously injured due to inappropriate speeds. In addition, a Symposium and workshop were organized to identify effective strategies and policies being used around the world that may help to reduce speeding-related safety problems if implemented in North Carolina. Ultimately, 21 different best practice and evidence-based countermeasure recommendations were developed with potential to reduce speeding and severe crashes. The background information and recommendations developed are described in this report, and the recommendations are also summarized in a separate document, *North Carolina Speed Management: Recommendations for Action*. Several promising innovative strategies were included among the recommendations.

One of the recommendations was to develop approaches to prioritize routes for speed limit and safety review. This report also describes several methods developed, in a second phase of the project, to screen the network to identify and prioritize corridors that may have speeding-related crash problems that could benefit from further problem diagnosis and treatment.

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EXECUTIVE SUMMARY

With nearly 5000 people losing their lives in North Carolina speeding-related crashes over the past decade, more concerted and cooperative action is needed to address speeding as a major safety problem in the State. Although there have been reductions in the numbers of people killed or seriously injured due to speeding in recent years, the long-term trend of fatalities associated with speeding continues at between 30 and 40 percent, which is higher than the fatalities associated with alcohol use or lack of restraint use. Since speeding is so integrally-related to the severity of injuries received in crashes, the State is seeking comprehensive methods to improve compliance with speed limits and reduce fatal and injury crashes associated with exceeding limits or exceeding a safe speed for conditions.

The project team was tasked with conducting a literature review to identify best practices with regard to speed management, to characterize the problem of speeding in the State, and to come up with recommendations that the State could implement to significantly bring down the numbers of killed and seriously injured. To help with the latter effort, a Speed Symposium was held in October of 2011, featuring international experts in speed management to report on successful methods being used to manage speed and reduce fatalities and injuries. The Symposium was followed by a North Carolina-focused workshop that included North Carolina road safety stakeholder agency representatives and the speed management experts. This group of experts identified North Carolina-specific issues and recommendations for improving speed management in the State. Ultimately, 22 different best practice and evidence-based countermeasure recommendations were developed with potential to reduce speeding and severe crashes. The recommendations are described in this report, and are also summarized in a separate document, *North Carolina Speed Management: Recommendations for Action*. Several promising innovative strategies were included among the recommendations.

There are many miles of roadways in North Carolina, and the speeding crash problem is fairly widely dispersed across all types of roads, particularly in rural areas. One of the recommendations was to come up with methods to prioritize roads for speed limit and safety review. The Network Screening section and Appendices III and IV describe several methods developed to screen the network to identify corridors that may have speeding-related crash and injury problems. Of the three primary methods discussed, the first two approaches made use of the state of the art empirical Bayes method to screen six different types of roadways for crashes associated with speeding or with more severe crashes. (Other crash types and combinations of speeding with particular crash types were also tried.)

Corridors were also screened based on proportions of crashes that were speeding-related and/or severe compared to total crashes. Within each method, there are a number of possible ways of ranking the results. One method we used was to combine results from screening based on speeding and screening based on severe crashes.

Although there was significant overlap among the results, the three methods tended to identify somewhat different types of roadways, particularly relating to traffic volumes. Field review by inter-disciplinary teams including experienced traffic engineers may be the best method to identify which approach or combination of approaches best identifies corridors with potentially treatable problems.

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Introduction

This report summarizes results and recommendations of a comprehensive project focused on the nature of the problems and solutions to significantly reduce speeding-related crashes and injuries in North Carolina. This introductory section outlines the need for action, providing an overview of the problems, and an overview of the commitment and types of solutions that are needed.

Need for Action

Nearly 5,000 people lost their lives in speeding-related crashes in North Carolina over the past 10 years. Nearly twice as many individuals suffered disabling injuries. Among those killed were 131 children younger than age 14, 85 teens aged 14 to 15, and 974 young people aged 16 to 20. While crashes, fatalities, and injuries have fallen in North Carolina, as throughout the U.S., over the past decade (Figure 1), more can be done to reduce the risk of serious harm resulting from inappropriate speed. Although these declines are good news, and North Carolina is to be commended on this progress, all of the reasons for these declines are not entirely clear. Engineering safety improvements, graduated driver licensing for young drivers, continuing safety improvements in vehicles, and other policy changes have all contributed. At the same time, some of the decrease in the most recent years is attributable to less driving or changes in the type of driving due to the economic downtown, job losses, and higher fuel prices. In the latter case, the trends may turn upward again as the economy revives, which, in fact, has already been observed in 2011 and early statistics for 2012.

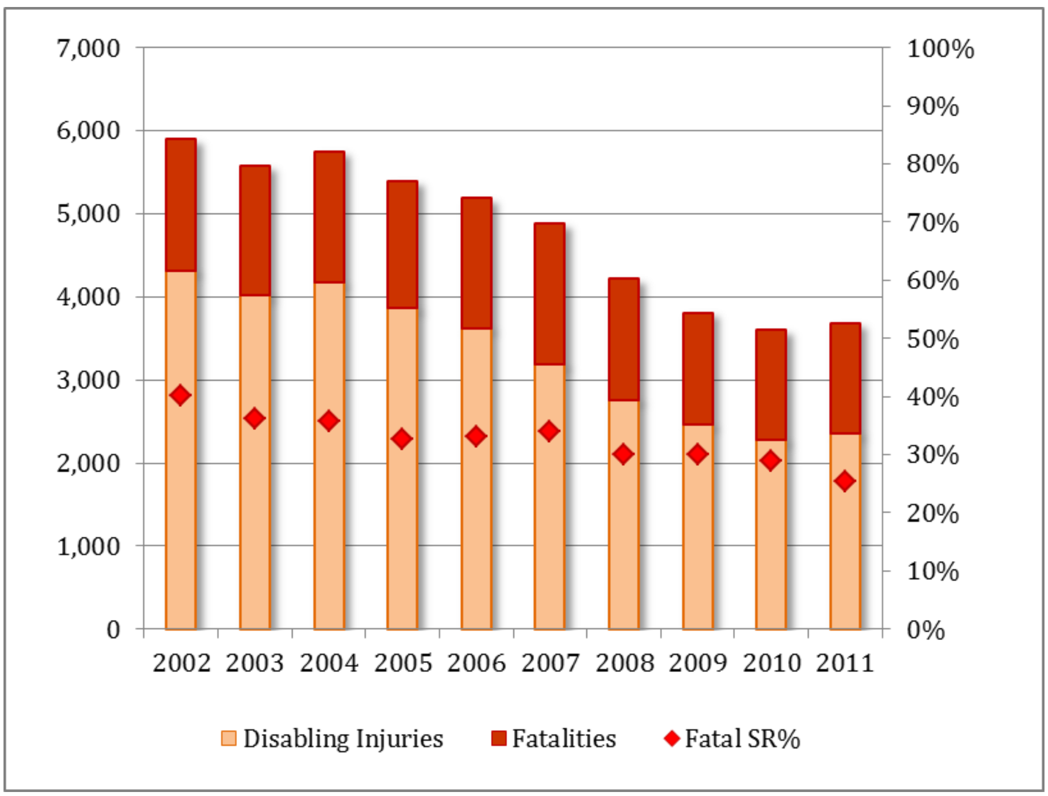

Figure 1. North Carolina 10-year trends in total fatal and disabling type injuries. The red line indicates the percentage of fatal injuries attributed to speeding.

After being among the safest countries during the late 1960s and up to the mid-1970s, the U.S., by several measures of safety, has made less progress than many other developed countries in more recent decades (IRTAD, 2013). North Carolina has ranked 30th safest (per VMT) or lower among the 50 States over each of the most recent five years. Only three states (California, Texas and Florida) had more total traffic fatalities than North Carolina in 2009.

Speeding remains one of the top contributing factors to fatalities and serious injuries in North Carolina and has been cited as a factor in more traffic fatalities than illegal alcohol use and lack of belt use (Figure 2). Yet, over the past several decades, there has also been a relative lack of attention, funding, and progress nationally in addressing speeding compared with restraint use, and, until recent years, compared with progress in reducing drunk-driving-related fatalities (Figure 3).

Speeding includes exceeding speed limits and exceeding a safe speed for conditions. Exceeding limits is cited most often in fatal crashes (about 26%). A majority of North Carolina drivers (85% of those surveyed) admitted to at least occasional speeding by more than 5 mph when driving on *low-speed* (30 mph) roads (Figure 4). Thus, speeding is a population-wide issue, not a problem of the few. Twenty-two percent admitted they speed more than 5 over most of the time on such roads. These numbers, and the proportions admitting to speeding on high speed roads, increased in 2011. Yet, a majority (55%) of the surveyed drivers did not recall having read, seen or heard specific messages or safety information related to speed enforcement programs (NHTSA-GHSA, n.d.).

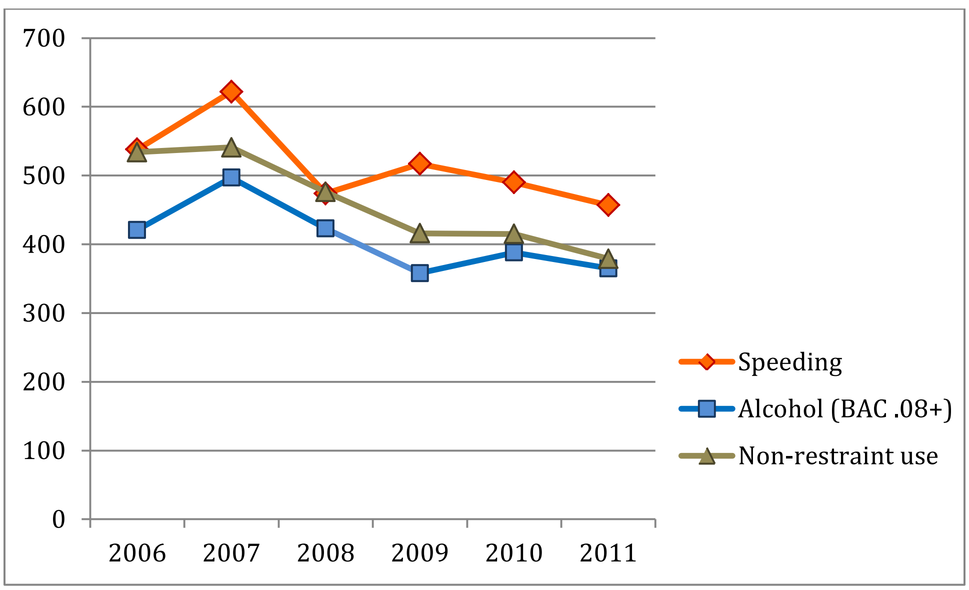

Figure 2. Six-year trend in North Carolina fatalities involving speeding, BAC .08+, and non-restraint use (data from Fatality Analysis and Reporting System).

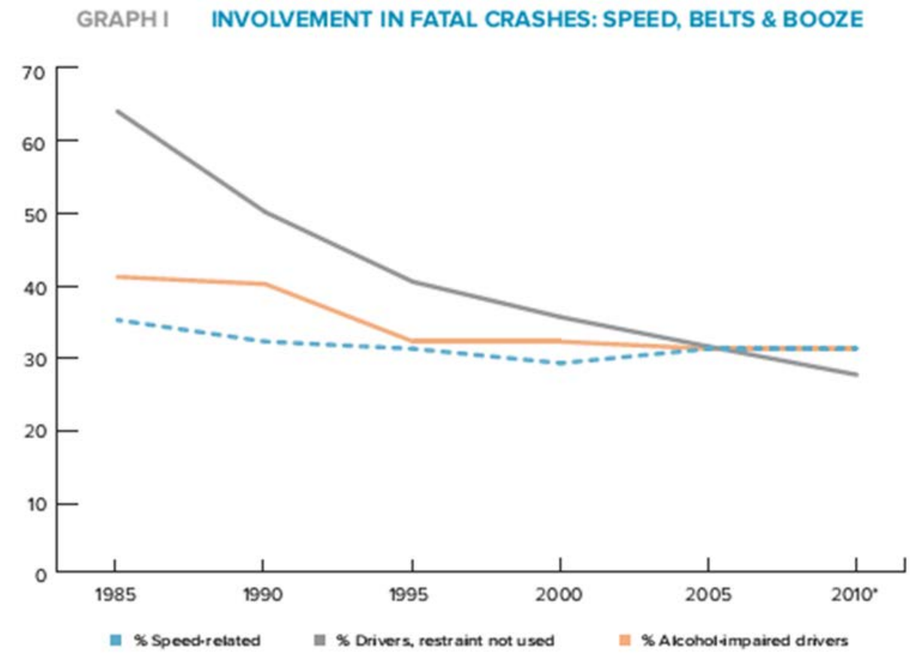

Figure 3. Trends in percentages of speeding-related, alcohol-related, and restraint-not-used fatalities from 1985 to 2010 (U.S. trends).
(from NHTSA-GHSA, 2012.). *Governor's Highway Safety Association, Survey of the States: Speeding and Aggressive Driving*, 2012).

Frequency of Driving More than 5 MPH over the Limit in a 30 MPH Zone

	2011	2010
Most of the time	26%	22%
About half the time	17%	17%
Occasionally	41%	46%
Never	16%	15%
Don't know/Not sure	0%	1%

Figure 4. Frequency of speeding at least 5 mph over the limit in 30 mph zones as reported by North Carolina survey respondents in statewide representative surveys (North Carolina Governor's Highway Safety Program, n.d.)

Speeding-related crashes involve all ages of drivers; 30% of speeding drivers in crashes were 25 or younger and 70% were older than 25. Young driver risks associated with inexperience, time, type and location of driving (exposure), as well as risk-taking tendencies all may explain some of the risk among young drivers. However, given that 70% of crashes involve drivers 25 and older, it is clear that risks of inappropriate speed do not disappear with increasing age and experience.

Speeding and speeding-related crashes, injuries, and fatalities are also a problem on all types of roads in both urban and rural locations. Large percentages of speeding related fatalities (80%) and total fatalities (73%) occur on rural roads where crashes are more than three times as likely to be indicated as speeding-related as in urban areas. However, rural secondary roads also comprise the vast amount of roadway miles in the State, making treatment targeting a challenge.

One fourth of all fatalities and about 46 percent of pedestrian fatalities occur within municipalities where surface street speeds should be low enough to accommodate all modes of travel with a reasonable expectation of safety. Residential and developing, but unincorporated, areas may also account for some of the crashes indicated as rural. These areas may lack adequate transitions to lower speed zones, putting a mix of users at higher risk in such communities. Developed and urban areas also frequently lack adequate infrastructure to separate different weight and speed of users. Pedestrians and bicyclists inherently travel at lower speeds (in most situations) than motorized traffic, need adequate provisions for crossing roads, particularly those with higher speed traffic, and have little protection in the event of a crash. The risk of pedestrian fatalities rises rapidly with higher impact speeds (Figure 5; Richards, 2010; Tefft, 2011).

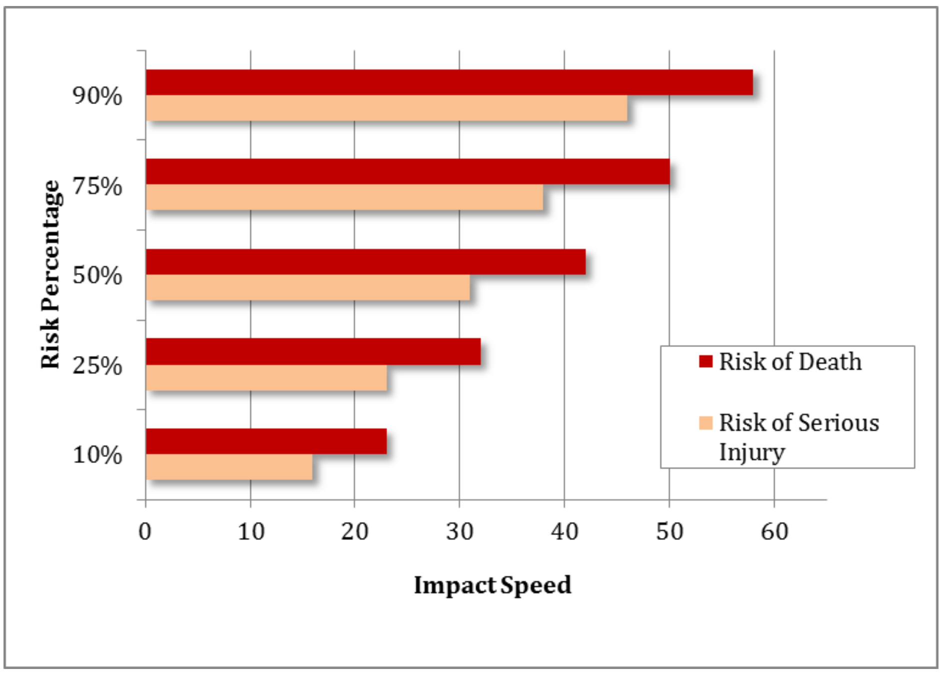

Figure 5. Risk of Serious Pedestrian Injury or Fatality for Different Impact Speeds (results from Tefft, 2011).

Exceeding a safe speed for conditions is cited as a factor more frequently than exceeding limits among all ages of drivers. Conditions such as curves, adverse weather, and nighttime are associated with higher percentages of speeding-related crashes and fatalities, suggesting that drivers often do not perceive or otherwise fail to slow sufficiently in order to maintain control or avoid a crash when conditions warrant. Some crash types that are often speeding-related, such as road or lane departures, are also highly associated with driving too fast for conditions *or* exceeding limits. Some of these crash types are planned to be systematically addressed through implementation of North Carolina's Roadway Departure Safety Plan. However, only the most problematic sections, and most often only roads that also have higher traffic volumes, will be eligible for treatment each year. Speed-reducing measures may also be needed to supplement such treatments. As mentioned, fatal and speeding-related crashes are also dispersed widely over the network, including on many lower-volume roads, and may occur at any time and place. A speed management program can complement and enhance other focused safety efforts such as the Roadway Departure Plan, and help to address a key contributing factor to fatal and serious injury crashes of all types and that may occur anywhere on the network.

Finally, crash numbers do not tell the full story. Determination of speeding involvement is based on an officer's judgment after the crash, not based on scientific investigations. There are no systematic measurements of speeds on our roadways, and little information about the contribution that low-level speeding makes to injuries and fatalities in cities, towns, and rural areas across the State. It is clear that small changes in mean speeds can have a significant impact on the level of injuries and fatalities (AASHTO, 2010 and see Figure 10 in Appendix I – Speed Management Literature Review).

In summary, the nature of the speeding problems in North Carolina includes the following:

- Speeding-related crashes are more severe, resulting in more fatalities and injuries when a crash occurs.
- A majority of all ages and types of North Carolina drivers admit to speeding, often by significant margins, even in low-speed areas.
- Treatment targets are often diffuse.
- There are many miles of roadway; only a small percentage can be treated each year.
- Environments, road designs, and speed limits are often not in close synchrony with each other, and may vary from location to location, sending mixed messages to drivers about safe speeds.
- Enforcement and adjudication tolerances are generally quite high, even in urban, low-speed areas, sending a message to drivers that speed limits are not maximum safe speeds.
- Enforcement resources are stretched; some communities do not put a priority on speed enforcement as exemplified through policies and funding allocations.
- Monies from enforcement are not allowed to cover the costs of enforcement or be returned to the community for other safety programs.
- Use of automated enforcement has been restricted because of legal challenges, and potentially in part due to public perceptions that may not be held by a majority of the public.
- There has been minimal use of publicity to supplement enforcement and increase deterrence of speeding.
- The criminal adjudication system is costly and appears broken with respect to convicting speeders as charged, and treating offenders consistently. Practices also vary across jurisdictions. Deterrence effects of court-administered sanctions also appear questionable based on research evidence. These factors further undermine enforcement effectiveness.
- Planning, design, engineering, enforcement, and public information and educational efforts have not been well-coordinated or sustained.

The result of all of these weaknesses and challenges is that:

- ☐ Drivers are not getting the message – from roadway design, enforcement, adjudication, and public information programs – that speeding is a safety issue and that speed laws are to be obeyed.

The problems are multifaceted and complex and so are the solutions. Effective interventions include changes in policies, laws, planning, road design, vehicles and technologies, enforcement, and public communications. In general, measures that affect structures (road designs, vehicles, etc.), laws, and policies are more effective than those that rely on voluntary changes in human behavior (Preusser et al., 2008). Most drivers know what they should do, but cultural and political acceptance of speeding is widespread. Cost-benefit analysis and feasibility assessment should be used to help prioritize effective countermeasures (NCHRP, 2009).

However, there also may be some costly measures that have a long lifespan or are an important investment for the State to make going forward (such improvements in data and measurement of the problem or implementing policies to prioritize speed-managing designs in new projects). Some strategies may be difficult to evaluate using typical safety cost-benefit analysis or within the overall speed management program, but may be critical to overall program success and to building the infrastructure necessary to continue long term downward trends in fatalities and injuries. Other performance measures can be used for such strategies. Furthermore, traditional cost-benefit analyses *do not* typically include all the future lives that could be saved and injuries prevented with better utilization of existing knowledge, tools and technologies, and the commitment to put these tools to work now.

Many of the countries that have made greater safety progress in recent decades use speeding and injury relationships as a framework to guide policies on speed-limit setting, roadway design decisions, and the use of beneficial technologies to improve the safety performance of the entire system for the people that depend on it (Hauer, 2010). A number of the countries that have had greater success in bringing down fatalities and injuries have sought solutions that acknowledged human nature by attempting to devise a system that reduces the risk of harm that may result from predictable human errors. Safety is a priority (Speed Management, 2008). For example, speed management to reduce the risk of harm is a one of the organizing principles of road design and operations in some of those countries such as the Netherlands and Sweden (Wegman, Aarts, and Bax, 2008). The “Sustainable Safety” approach in the Netherlands incorporates an “injury minimization” approach to speed limit setting is credited with a 9.7% reduction in the number of road fatalities and 4.1% in injury crashes (Wegman et al.). In addition, the Netherlands assesses and determine the network function of roads (from high access, multi-use roads which require low speeds to access-controlled, high throughput roads for motor vehicles which are designed to safely operate at high speeds, similar to the Interstate system in the U.S.). These principles are used to determine desired speed limit and operating speed and to make decisions about appropriate design. Specific treatments or countermeasures are selected and prioritized based on cost-effectiveness of alternates. Enforcement is generally used to reinforce and supplement engineering treatments and includes automated means. Many European countries are using similar practices; Australia is also moving in this direction and has also long used automated enforcement as a tool to manage speeds.

Similar reductions in North Carolina’s road trauma would save 50 lives and prevent 370 injuries in the first year alone. If the State develops ambitious speed management safety targets and implements more effective speed management measures to achieve these targets, these strategies would improve safety for all types of road users and help to set North Carolina on a path to minimize future fatalities and injuries. Effective speed management strategies may also be expected to help improve the livability of the State’s cities and towns, and provide more balanced access to the network for people who drive, walk, bike, or use transit to meet their mobility needs. The will and the commitment to wisely and effectively implement new laws, policies, and practices and to sustain and improve effective strategies is paramount to success. This commitment and will is needed at all decision-making and practice levels for implementation to be successful.

Among the strategies recommended in this report are to adopt more proactive and systematic approaches to identify roads that may be priorities for speed management improvements. This essential first step helps to begin the process of prioritizing existing roads where focused efforts may have greater safety benefits. In the second phase of this project, the research team developed and compared a number of preliminary approaches towards that effort. Other recommendations are to apply more foresight to planning and design of new projects so that they are in keeping with the principles of credible and safe limits. Since many more roads need improvement than will be re-designed each year, spot safety treatments will continue to be needed. Very importantly, improvements in enforcement and publicity, and more reliable and consistent penalties for offenders are needed to help increase the deterrence effects of enforcement and reinforce established limits.

The remaining chapters in this report provide the following:

- Results of literature reviews, expert and stakeholder input to identify potential policies, strategies and countermeasures the State could use to address speeding and reduce fatalities and serious injuries
- More information on the speeding-related crash problems and other speed management issues
- Speed management recommendations
- Results of development and comparison of a network screening approaches to identify corridors that may benefit from speed limit and safety assessment
- A summary of finding and conclusions
- Suggestions for implementation

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Literature Review

An extensive literature review was performed during phase 1 of the project to characterize the nature of the challenges in managing speed, and to identify effective speed management strategies and countermeasures. The results of this review were used to help inform the recommendations made in the Speed Management Recommendations section. Many of the references from the literature review are cited in support of the strategies recommended in that chapter, and in an independent summary of recommendations provided as a stand-alone document to NCDOT.

The complete literature review, which was provided as part of an earlier deliverable to NCDOT, is included as Appendix I – Speed Management Literature Review. Since managing speed is a complex endeavor, there is considerable discussion of strategies and considerations for managing speed for the interested reader.

Additional literature relevant to specific other sections of this report is cited and referenced following the appropriate sections.

Problem Description

This chapter characterizes North Carolina's speeding-related crash problems from crash analyses, and other speed management issues, challenges and needs identified through stakeholder input. Data analysis was undertaken as part of phase 1 (year one) of this project. At that time, 2009 was the most recent year for which complete crash data were available. The introduction to this report updates the general trends through 2011.

The other speed management issues and challenges emerged through discussions and meetings with stakeholders, including a Speed Symposium held in October 2011, and a follow-up day-long workshop that brought together North Carolina stakeholders with international speed management experts. A later section describes recommendations for speed management strategies that the North Carolina Department of Transportation and partner agencies might implement as part of a comprehensive and proactive speed management program, and to systematically target severe injuries and fatalities resulting from inappropriate speed.

Speeding-Related Crash Factors

General crash trends and major results are summarized in the following sections. More detailed results from crash analyses are provided in Appendix II – Problem Description: Speeding Crash Relationships and NC Speed Management Issues**Error! Reference source not found.**

General Trends

From 2004-2009, an average of 11.5% of NC's more than 220,000 crashes per year had at least one driver who was indicated to contribute to the crash by improper speed (Table 1). Reported crashes in general decreased in number since 2007, and the number of speeding-related crashes also declined. The proportion of crashes that were speeding-related decreased from an average of 12.2% for the first three years (2004-06) to 10.6% for the latter three (2007-09). However, the 23,896 crashes that were speeding-related in 2009, the latest year currently available, constituted a rise in both number and proportion from 2008 as well as a rise in the speeding-related crash rate per VMT.

Table 1. Six year trend of North Carolina's crash history by speeding-related (Spd-Rel in table) or not.

	2004	2005	2006	2007	2008	2009	Total
Not Spd-Rel	198,715	195,524	196,167	201,296	192,713	185,799	1,170,214
Not Spd-Rel %	85.9	87.9	89.0	89.7	89.9	88.6	88.5
Spd-Rel	32,527	26,921	24,140	23,011	21,645	23,896	152,140
Spd-Rel %	14.1	12.1	11.0	10.3	10.1	11.4	11.5
Total	231,242	222,445	220,307	224,307	214,358	209,695	1,322,354
100 MVMT	956.27	1008.61	1016.48	1036	1015	1026	
Spd-Rel Rates /100 MVMT	34.0	26.7	22.6	22.2	21.3	23.3	
Total crash rate/100 MVMT	241.8	220.5	216.7	216.5	211.2	204.4	

Speeding-related crashes have decreased in rural areas but remained relatively flat in urban areas over the six year period (Figure 6). These trends may reflect increasing urbanization and other changes in driving patterns.

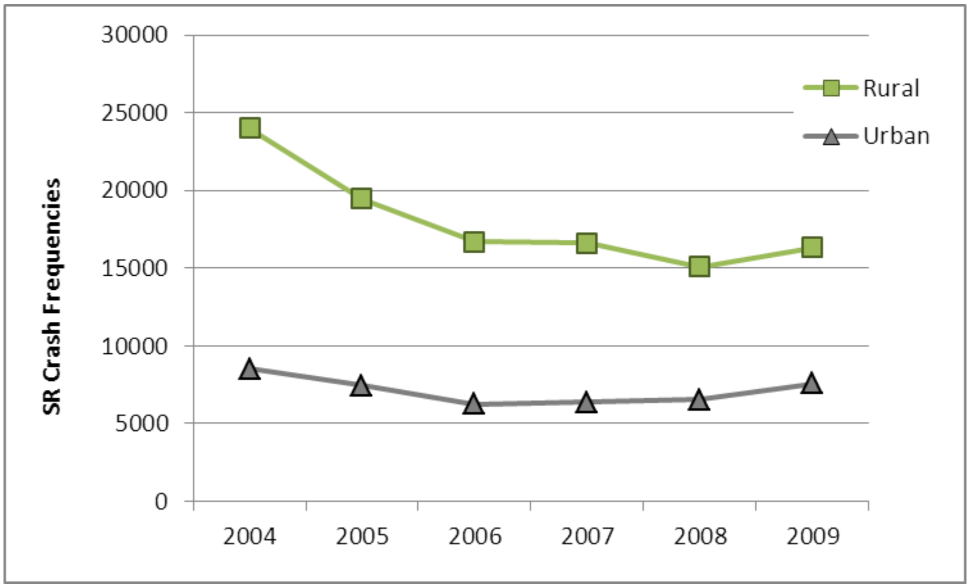

Figure 6. NC rural and urban speeding-related crash trends.

Crash severity

The proportion of fatalities and disabling-injury type crashes associated with speeding remains high. Although there have been decreases in the number and percentage of fatal crashes in the later two years of this period, it is not known how long these trends will continue or whether they are due mostly to decreases in amount of driving, and perhaps other trends (whom is driving and where, etc.).

- On average, about 33% of fatal crashes (Figure 7) and about 26% of disabling-injury crashes involved speeding according to NC's definition of speeding; about 39% of 2009 fatalities involved speeding according to FARS data (not shown).
- Close to 1000 additional fatal crashes per year were not clearly indicated in crash reports to involve speeding. Due to the inherent relationship between speed and severity of injuries received in a crash, it may be important to consider the role that inappropriate speed may play in some of these fatalities as well.

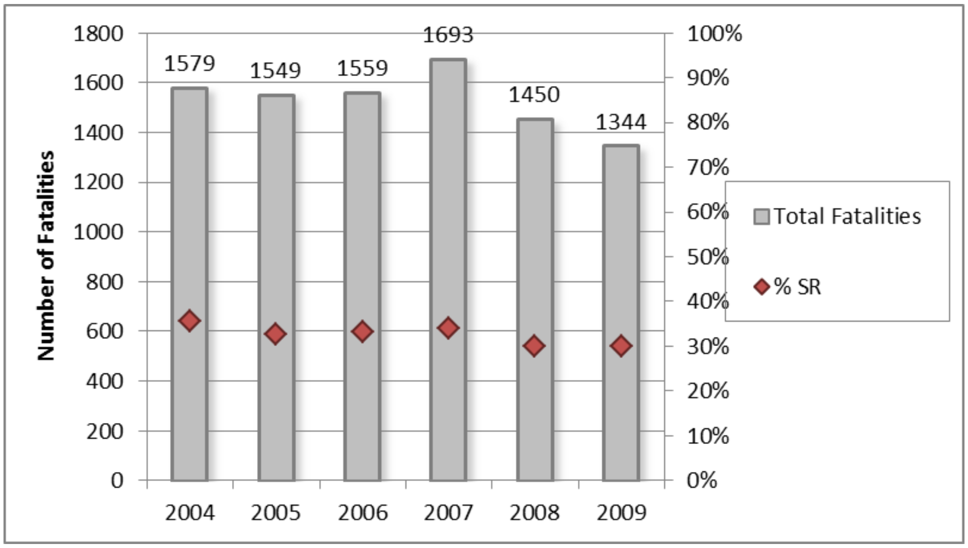

Figure 7. Six-year NC fatality trends and percentages speeding-related.

Crash types

- The highest numbers of speeding-related crashes are fixed object (about 50% of the total), run-off-road, overturn, rear-end, and angle crash types.
- 72% of speeding-related crashes are rural, but still over 7,000/year occur in urban areas.
- 70% of speeding-related crashes occur on weekdays, but there is a higher speeding-related percentage on weekends (14.8% speeding-related vs. 10.5%).
- 58% during daylight, but higher speeding-related percent at night; 44% of NC's fatal speeding related crashes and 33% of all fatal crashes occurred at night.

Locations

- The largest numbers and the highest percentage of speeding-related crashes (24%) occur on state secondary routes (predominantly rural). Due to the extensive mileage of this system, these numbers represent the lowest number of speeding-related crashes on a per roadway mile basis.
- The largest number of speeding-related fatalities (52%), and of total fatalities (37%) also occur on state secondary roads (predominantly rural), but these are also spread across many miles of highways.
- The top 12 counties for high percentages of speeding-related crashes only account for 6% of NC's total speeding-related crashes.
- The top 12 counties by number of speeding-related crashes account for 38% of NC's total speeding-related crashes, but averaged only 9% speeding-related.
- The largest number of speeding-related crashes (47% of the total speeding-related) occurs on some type of curve (curve- level, curve with grade, etc.).
- The largest number (58%) and percentage of speeding-related fatalities also occurs on curves and curves with grades.

- Less than 2% of total speeding-related crashes are in work zones, and the percentage speeding-related in work zones is lower than for total crashes.

Times

- The largest numbers of speeding-related crashes occur during morning and evening peak travel times.
- The highest proportions of speeding-related crashes occur during off-peak travel times (late night and early morning hours – 16 to 21%) compared to daytime hours (9 to 12%).
- Higher proportions of speeding-related crashes occur on weekends (15 percent) (from midnight Friday to midnight Sunday) compared with weekdays (10.5% speeding-related). Nearly 31 percent of speeding-related crashes occur during the weekend time period.
- A disproportionate number of fatal, speeding-related crashes also occur at night (52%).

Drivers

- 16-20 year-old driver group has highest number (28% of total speeding-related crashes) and percent of crashes (12%) that are speeding-related. Conversely, 72% of speeding-related crashes involve drivers of other ages.
- The 21-25 driver age group accounts for the second highest percentage (20%) of speeding-related crashes), with 9% being speeding-related.
- Males have more speeding-related crashes and a slightly higher percent of their crashes are speeding-related.
- Motorcyclists have the highest percent speeding-related among vehicle types (20%), but only account for 3% of total speeding-related crashes.
- Although drivers involved in speeding-related crashes are somewhat more likely to have another speeding-related crash within five years, the vast majority (98%) of drivers involved in speeding-related crashes had no prior speeding-related crashes in North Carolina the previous five years.

Many other variables and factors were examined with respect to speeding. These results are detailed in Appendix II – Problem Description: Speeding Crash Relationships and NC Speed Management Issues

Perhaps, the most important message is that speeding is a population and system-wide issue. As noted, the vast majority of drivers involved in speeding-related crashes had not been involved as a speeder in a crash within the five prior years. The risk of a speeding-related crash for each individual and trip may be low, but a majority of NC drivers acknowledge significant speeding, even on very low-speed roads. The increased risk multiplied by large numbers of drivers exceeding limits by small to large margins, during only portions of some trips up to nearly every mile driven adds up to a significant road toll and higher severity of injuries due, at least in part, to speeding.

Measuring the Costs and Benefits

Speeding, and the consequent crashes and injuries continue to burden the State and its citizens with significant economic, social and personal costs. The estimated monetary cost of one year's speeding-related crashes is nearly $880 million using crash cost estimates for different severity of injuries within crashes (Table 2). When amounts are included for pain and suffering and other quality of life lost, the comprehensive cost is $2.255 billion. When children and youth are involved, costs are even higher in terms of life-years lost. These cost estimates *do not* include all the future lives that could be saved with better utilization of existing knowledge, tools and technologies, and the willingness to manage speeds and reduce serious crashes and injuries on the State's roadways.

Table 2. Crash Cost Estimates for 2009 speeding-related Crashes (using 2008 crash cost estimates).

Maximum Crash Injury Severity	No. Spd-Rel Crashes	Total Crashes	Estimated Monetary Cost	Comprehensive Crash Cost	Total Monetary Cost of Spd-Rel Crashes	Total Comprehensive Cost Spd-Rel Crashes
Fatal	371	1234	$1,600,000	$4,400,000	$593,600,000	$1,632,400,000
A Injury	495	1995	$79,000	$250,000	$39,105,000	$123,750,000
B Injury	3280	18149	$30,000	$74,000	$98,400,000	$242,720,000
C Injury	5283	49250	$17,000	$36,000	$89,811,000	$190,188,000
PDO	13371	132828	$4,300	$5,000	$57,495,300	$66,855,000
Unknown	1096	6239				
Total	23896	209695			$878,411,300	$2,255,913,000

Although no one would wish to assign a dollar value to a lost life or traumatic injury, using estimates of economic costs of treatment, loss of health, lost work, economic costs to the injured and survivors, and other pain and suffering may help to prioritize treatments that reduce more severe crashes. Since speed directly relates to energies expended in crashes, it is directly related to the severity of injuries received. Treatments that reduce or control speed through design are among such effective treatments.

The US DOT has adopted a Toward Zero Deaths, National Strategy on Highway Safety that aims to develop strategies that minimize death and serious injury by strengthening traffic safety culture, and building a safety foundation (FHWA, Toward Zero Deaths web-page, n.d.). Speed management measures are an integral part of such an overall Toward Zero Deaths approach that considers the roadway and user context and develops appropriate strategies to minimize the potential for severe injuries. A Toward Zero Deaths approach or other policy strategy could provide a vision in support of decisions, that while consistent with costs and benefits analyses, doesn't rely only on such analyses, which may not fully capture society's values or adequately consider future lives. Such vision-based strategies have been used by several, but not all of the countries with among the lowest fatality and injury rates (Hauer, 2010).

Speed-management countermeasures may also sometimes require balancing tradeoffs of measures that may reduce more traumatic, life-altering crashes but potentially increase less severe crashes. Speed management measures may require other real and perceived trade-offs such as with mobility. There is certainly an expectation that such trade-offs are accurately measured and tracked at the very least, to ensure, for example, that strategies used to improve mobility really accomplish those objectives, and do so without unacceptable detriments to safety.

Given that close to 1000 fatalities per year occurred in crashes that were not clearly indicated as involving inappropriate speed, it may also bear fruit to think more broadly about what constitutes a problem of speed. Given the limits of crash data estimates of pre-crash speed, we have incomplete information about the role of traveling above speed limits, including by moderate amounts, in contributing to serious injury crashes. Higher speeds are clearly related to increasing crash severity as illustrated by the data and discussed in the literature review. Even small changes in speed can have a large impact on the severity of outcomes (AASHTO, 2010).

Thus, one of the recommendations is to consider severity when screening for problems that may relate to speeding or a mismatch between operating speeds, the environment, and road designs that may contribute to the occurrence of severe crashes.

More details of analysis results are provided in Appendix 3 for the interested reader.

Major Speed Management Issues

Interviews with stakeholders and a stakeholder workshop held in October 2011 identified the following issues and problems that could be addressed through more proactive, coordinated and systematic approaches and new policies for in support of speed management.

<u>Key Design and Engineering Issues</u>

The following important issues were identified through review of current practice with stakeholders and workshop discussions:

- The treatment targets (crash locations) are often dispersed widely around the roadway network. Only a small percentage of the roadway network can be reviewed each year and even less can be treated each year.
- The most effective speed managing designs such as roundabout intersection design, fewer lanes (reductions in number of lanes), narrower lanes, separation of users, and traffic calming have not been widely implemented yet. Some of the measures may be more expensive initially, or controversial among different stakeholders. Thus an extensive public process is a key to utilizing effective speed managing designs.
- Speed limits may be set in many ways, with most state-owned roads falling under rural or urban statutory maximums. Limits may also be set through engineering studies, for political reasons (but which may have a safety component), and through varied practices across the many towns and cities across the State. Municipalities may set limits on locally-owned streets, while the State and towns must concur on any changes for State-owned roads within municipalities.
- As urban areas expand, or other changes occur to a roadway or travel patterns over time, speed limits and road designs may no longer fit area context and needs. Concurrency agreements between the State and cities to change limits on State-owned roads may be difficult to achieve as the State and local governments may not be in agreement about what constitutes safe maximum speed limits for the varied designs, purposes and users of the streets.
- Statutory limits are also not required to be posted (and are usually not posted in rural areas), leading to the question of whether drivers always know what the limits are.
- The primary triggers for review of speed limits and safety have been public complaints about speeding as opposed to a systematic safety process. NCDOT guidance and recent national guidance (USLimits tool) gives strong consideration to prevailing operating speeds (85^{th} percentile), with engineering judgment used to qualitatively consider safety issues. Engineering judgment and differences in speeding culture and speed choice by drivers in different parts of the State may also lead to different speed limit decisions in practice. North Carolina is not unique in this regard. The current prevailing speeds also reflect high enforcement tolerances and (generally) low levels of enforcement, and not necessarily safe driving speeds.

- Speed limits have often been determined after a new road is designed and built. Therefore designing for an intended, safe operating speed for the area type, purposes and users of the road may not be as intentional or effective as it could be. Speed and safety reviews may not have been routinely performed as part of the overall process.
- Designers have been urged by past guidance to use high design speeds, often significantly higher than the intended operating speed of the roadway, particularly in urban areas. Such roads may contribute to sending to mixed messages to drivers about safe operating speeds, resulting in many drivers speeding on such roads and a difficult enforcement situation.

As a result of many of the foregoing issues, road designs, speed limits and environments are often not in good agreement with each other. The lack of consistent outcomes from the varied limit setting methods and roadway and land use evolution, and the shortage of resources to conduct speed and safety reviews and implement changes, increases driver confusion about the importance of limits, frequently violates driver expectation about safe travel speed, undermines safe operations and creates challenges for enforcement.

Enforcement Challenges

Resource and policy challenges include the following:

- Enforcement has not kept pace with vehicle miles traveled; resources are stretched; only the top few crash corridors tend to be targeted for speed enforcement (by the NC SHP).
- Many counties do not have rural enforcement by their Sheriff's offices. These are political decisions.
- Some smaller communities lack law enforcement resources as well.
- There has been minimal use of publicity and education to supplement and enhance enforcement efforts.
- Automated enforcement for speeding was tried, found to be effective, but has been restricted because of legal challenges, and potentially other public perceptions.
- Somewhat surprisingly, most drivers think it is at least somewhat likely that they may receive a ticket for speeding (NC GHSP, n.d.), but this may be in part because so many routinely do speed. However, drivers may also know where enforcement is likely (since only a few corridors tend to be targeted) and avoid speeding in those areas, but feel able to speed in others.
- High law enforcement tolerances above speed limits are also fairly common among agencies before officers are likely to issue a citation, or the courts to convict as charged. Drivers also perceive that there are high enforcement tolerances before a citation will be issued (even if detected). Research shows that driver speed selection is affected by the speed at which they think they will get a ticket. Large percentages of drivers admit to speeding at least 5 mph above limits.
- Some enforcement officials deem that tracking enforcement allocation and outcomes may be insufficient, due in part, to outmoded technologies.
- The criminal justice system is costly and broken with respect to adjudicating speeding violations. Many drivers contest their citations so the courts have had to develop strategies for plea agreements, reduced charges and other strategies in order to process large numbers of violators through the system. Practices may vary by districts across the State. There is a long history of trying to close legal loopholes to little apparent avail, and research findings are providing little

evidence that court adjudication of traffic cases (under present systems) works to deter further speeding.

- Drivers therefore perceive, accurately, that if they contest their tickets in court, they are not likely to be convicted as charged, even if caught and issued a citation for speeding. A generally low expectation of serious penalties and inconsistent treatment of offenders across the State or among those who challenge their citations in court may further weaken respect for speed laws and the effectiveness of enforcement efforts.
- Development, funding, and evaluation of anti-speeding campaigns have been limited. Those programs that do exist (such as the Statewide No Need to Speed) are of limited duration, and may target only a small proportion of the network. Deterrent effects at other times or locations are therefore limited. Publicity or visibility of the programs may also be inadequate to increase general deterrence of speeding.
- Engineering, enforcement, and public information and education efforts have not been well-coordinated or sustained.

The result of all of these weaknesses and challenges is that:

- ☐ Drivers are not getting the message that speeding is a safety issue and that speed laws are to be obeyed. In fact, the message sent by the infrastructure (sometimes), high enforcement tolerances, policies that limit or suspend effective programs, media reports and other cultural messages suggests that, in fact, speeding is widely accepted.

The next chapter describes recommendations developed from review of the literature, expert recommendations, and understanding of North Carolina-specific speed management problems that are needed to change these perceptions and bring about lasting reductions in fatal and injury crashes.

References for Problem Description section

AASHTO (2010). *Highway Safety Manual*, 1st edition. American Association of State Highway and Transportation Officials: Washington, D.C.

FHWA (n.d.). Toward Zero Deaths web-page. http://safety.fhwa.dot.gov/tzd/

Hauer, E. (2010). White paper No. 9. Lessons learned from other countries. “White Papers for: Toward Zero Deaths: A National Strategy on Highway Safety.” Draft prepared under subcontract to Vanasse, Hangen, Brustlin, Inc.

Speed Management Recommendations

The speed management strategies and policies recommended in this section were identified as a result of the various problem identification processes (data analyses and stakeholder input), identification of best practices and solutions (the literature review and expert input), and the identification of strategies that should help to address North Carolina's crash and injury problem and speed-management needs (NC stakeholders – expert workshop and research team expertise).

The strategies recommended also aim to strengthen a comprehensive and cooperative public health approach to speed management that has achieved improvements in belt use, reductions in young driver-related crashes, and helped advance safety in a number of countries that aim to minimize injury and death from road crashes. A comprehensive approach entails developing interdisciplinary speed management teams to administer and implement all types of solutions as well as efforts to garner the public and political will to implement effective actions.

A benefit of a comprehensive approach, first championed by William Haddon in the traffic safety field, is that multiple causes for speeding and crashes are acknowledged. Risk factors or causes (driver, roadway, vehicle, and environment) are not studied in isolation, but in a comprehensive way so that the most effective points of intervention may be selected (World Health Organization & Indian Institute of Technology, Delhi (2006). Successful traffic injury prevention efforts such as safer vehicles and occupant protection, and young driver graduated licensing programs exemplify how strategies that target issues at a population and infrastructure level (laws, policies, design) are effective at saving individual lives. Multiple private and public partners also support and implement mutually effective strategies.

Fifteen potential strategies are organized by:

- Management strategies: those that are deemed crucial for establishing a sustainable and credible speed management framework
- Engineering
- Enforcement
- Education and public information
- Information technologies
- Innovative strategies

Six unproven, innovative strategies with potential are described last. These strategies lack a clear track record of effectiveness, but are promising in terms of preliminary data or fitting speed management principles that aim to create a safe system for road users. Planning and innovation may be keys to providing a safe network that continues to respond to changes in vehicles, driving patterns, law enforcement needs, and other issues.

Just as problems and crash causes do not occur in isolation, strategies should be selected as part of a package of strategies, several of which may depend on others, in a comprehensive approach to speed management. To provide further guidance in countermeasure selection, the strategies are also categorized according to whether they are proven measures, tried (and promising), or experimental. "Tried" or "experimental" strategies that have little chance of working were not included. However, some of the experimental treatments seem very promising and should be considered for a longer-term plan. As always, the implementation affects chances and degree of success. Finally, funding sources and costs will vary for engineering versus enforcement and other measures. Some enforcement strategies could be set up to pay for themselves and potentially other safety programs.

Further discussion and work by stakeholders, including further data analysis, is needed to help elaborate the expected costs and benefits, and to prioritize strategies to be pursued first or at all. A number of these strategies will require extensive stakeholder involvement and coordination.

Management Strategies

The following measures are important to set a Speed Management Framework and provide the basis for effectiveness and coordination of all the other strategies:

- ☐ **Re-establish an on-going speed monitoring program.**

  The Goals of a system-wide speed monitoring program include:

  - Track speeding and injury risk and trends over time
  - Measure progress of the speed management program
  - Adjust targets and program elements
  - Use data gathered for communicating about the risks to build support for effective strategies

  Tried/Proven – Speed monitoring was carried out in the past, prior to repeal of the National Maximum Speed Limit (although for non-safety reasons) and is carried out in other countries as one of the risk performance measures. Monitoring is currently used for restraint use and driver impairment to track trends and progress for these traffic safety risks. The data and knowledge gained have likely contributed to raising the profile of these other safety issues.

Operating speeds have been shown to be a relevant safety measure, reflecting injury and fatality risk (AASHTO, 2010). The more routinely such data are collected, the better the estimates of relative risks in different environments that will be available. Speed data may provide an early indication of program effects before effects on crashes and injuries can be detected. Potentially, speed data collected for safety reasons might also be used in mobility performance metrics. Collecting and using speed data can help raise awareness of the risks involved in speeding, increase support for developing and implementing effective measures, and may have helped to develop a political champion at the highest political level in France (Hauer, 2010). Speed monitoring in France is also used to track road safety progress, make and refine policies, and benchmark performance (Chapelon and Lassarre, 2010).

- ☐ **Frame the speeding safety problem in terms of injury prevention. Develop coordinated internal and external communications about the issue.**

  Goal: Increase public and political input and support for effective speed management strategies.

  Experimental (for speeding)/Proven – in other traffic safety areas and public health contexts. For example, framing the young driver crash problem in a public health context and communicating effectively with stakeholders and decision-makers has led to new and effective policy solutions including the Graduated Driver Licensing program. The history of occupant restraint use shows a similar trajectory, with changes in laws driving behavior change.

Transportation consumers are important stakeholders in speed management processes and should be informed about the risks of speeding and engaged in policies and decision-making (Speed Management, 2008). However, it is important to communicate about injury in ways that frame the problem as one that can be solved as a society with cost-effective solutions that improve the quality of life for all (National Center for Injury Prevention and Control, 2010).

Speeding is one of the more difficult to solve road safety problems (Elvik, 2010). Framing the problem so that individuals are not seen as solely responsible is a challenge in all injury prevention fields (National Center for Injury Prevention and Control, 2010). Safety approaches that focus on altering individual driver behavior or blaming individual road users for their mistakes will not be successful. Greater progress is made when laws are passed and enforced, road infrastructure is improved, and policies and practices focus on identifying the most cost-effective solutions that acknowledge human error and frailty (Speed Management, 2008). Even the laws and practices currently in place may not be as effective as they could potentially be with stronger support and the commitment to pursue and utilize effective strategies in the speed management toolbox. For a successful speed and safety program, there must be the know-how, the ability (resources and capacity available), *and* the willingness to implement the appropriate measures. The latter may be the most limiting (Wegman, 2007). Framing the problem as one to be solved as a society may increase support for effective solutions, and potentially, help to also generate innovative and effective solutions.

Engineering Strategies

The following engineering strategies are recommended to develop more proactive, consistent and safer approaches to speed limit setting and road design, and identification and treatment of existing safety problems.

- ☐ **Increase standardization of speed limit setting methods across the State using an injury minimization approach to establish limits.**

  Goal: Increase safety, credibility and consistency of established speed limits for different types of roads.

  Tried/Proven – Setting safer speed limits based on the injury minimization approach is tried and proven as a key component of a safe systems coordinated strategy as used in the Netherlands and other countries (Hauer, 2010; Wegman et al., 2008).

  Target – The targets would be primarily state-managed roads, with outreach to cities, developers, and other road developers and safety managers to extend the target. This strategy could take advantage of an opportunity to coordinate with Complete Streets Planning and Design Guidelines to plan and design for context-appropriate speed limits.

Speed limit setting, enforcement, engineering and other communications must work together to convey safe speed messages to drivers (NCHRP, 2009; NHTSA, 2011; Speed Management, 2008; TRB 1998). There is a need for safe and credible speed limits that are more consistent across roads and areas of similar types.

Different speed limit setting methods are described by Forbes et al. (2012). Operational methods of speed limit setting rely heavily on prevailing operating speed distributions (primarily the 85th percentile speed), with consideration given to other factors such as driveway density, crash history, alignment, pedestrian use, and other factors (Fitzpatrick et al., 2003). Operating speed methods assume that a majority of drivers know and choose a safe speed. Significant evidence suggests that this is frequently not the case (Åberg et al., 1997; Fitzpatrick et al., 2003; Goldenbeld, and Schagen, 2007; Mannering, 2009), and clearly the higher 85th percentile speeds are associated with greater injury risk than are 50th percentile speeds (AASHTO, 2010). Current speed distributions are also shaped by the relatively low levels of enforcement and high enforcement thresholds that have developed over time. As noted previously, NC drivers report speeding at a higher rate in the most recent GHSP survey than they did even two years ago.

Speed limit setting incorporating expert judgment (such as the U.S. Limits Tool, FHWA, Office of Safety website) is available to provide a somewhat more quantified way to consider various roadway, traffic, crash, and user factors in what has been termed a rational speed limit setting approach to speed zoning, but this method also heavily weights the 85th percentile operating speed. Furthermore, several evaluations of so-called rational speed limit setting, followed by various levels of enhanced enforcement of the new limits, have thus far found that crashes are not affected very much, positively or negatively (Fontaine, Park, and Son, 2007; Freedman et al., 2007; Harder and Bloomfield, 2007). In each trial thus far, speed limits were raised, based predominantly on the 85th percentile, with no changes made to the roadway. Average speeds and sometimes speed variance have typically increased (although in one case speed variance decreased) with the higher limits. Although crash-based assessments have been fairly short-term and not well-controlled from an analysis stand-point, the evidence of increases in average operating speeds suggests the potential for long-term increases in fatal and injury crashes (Hauer, 2009). Hauer also cautions against speed creep if limits continue to be raised with no changes to the roadway or other controls of speed. Relying on enforcement to rein in speeds at a higher limit carries risks as several of the rational limit trials found that, although enforcement was intended to be increased, there was little evidence that this was done, or the increases were of very short duration.

Statutory limits may provide a generally uniform message for urban or rural environments (if these limits are appropriate and well-known), but statutory limits are not appropriate for safety reasons in all situations. Many miles of roadway must be reviewed for potential speed zone changes each year due to increasing traffic, changes in development type or extent, or other issues that may have changed the safety of operations under the statutory limit.

An Injury Minimization (or Safe System) method for establishing speed limits has been used in countries that are at the forefront of global road safety improvement (e.g., Sweden, Netherlands, more recently, Australia). Using this approach, speed limits are set according to the crash types that are likely to occur given the main physical features of the road design (amount of access, presence of median, roadside, etc.), the type of users that can be expected, the impact forces that result, and the human body's tolerance to withstand those forces (Aarts et al., 2009; Forbes et al., 2012). Data collection to establish the road type is fairly minimal, as the critical factors are fairly easily distinguished (Aarts et al.)

Low limits are established for urban and local full access roads, while higher speeds are appropriate for limited access roads that serve primarily through motorized traffic and have high design standards. Greater separation (signals, crossings, space) by mass and speed of user would guide design decisions on the intermediate road types that serve multiple purposes and users and distribute traffic, but where higher speed limits may be desirable. Once appropriate limits are established for the type of roadway and basic design, other design and infrastructure changes are made to the roadway to achieve operating speeds in line with established speed limits. Enforcement is used to encourage compliance until the road design can be changed and to reinforce established limits (Letty Aarts presentation to NC Speed and Safety symposium, Aarts et al., 2009).

Speed limit setting using an injury minimization approach, as implemented in the Netherlands, requires first assessing the network function (or purposes) of all roads to establish roads that serve primarily a mobility function (higher speeds), distributor functions (transition traffic between access and mobility), or access functions (lower speeds; see Figure 8). The roads that serve transition between access and mobility type roads are the most challenging. Speed limits should be low on distributor types of roads if different weight and speed of users cannot be separated by the design, facilities, and operations.

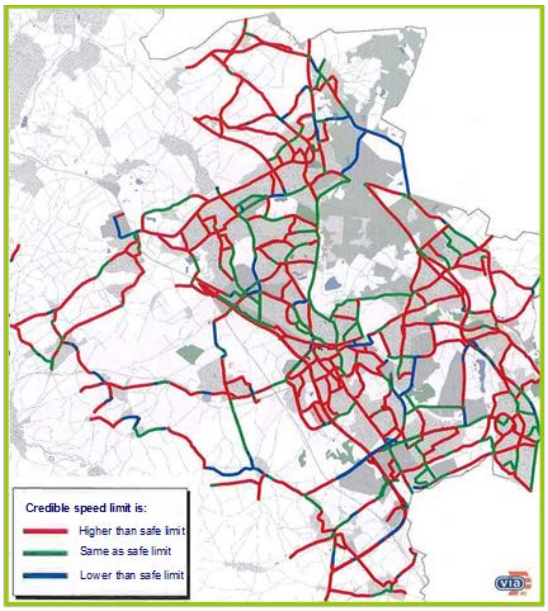

Figure 8. Network and speed limit assessment outcomes in the Netherlands (from Aarts et al., 2009)

In conjunction with improved efforts to standardize speed limit setting practices, all the other supporting structures, including planning, design and engineering, enforcement, and penalty systems, must fully support the limits established. Along with an injury minimization approach to setting limits, the Safe Systems approach in the Netherlands is exploring the use of fewer different speed limits and consistent and distinctive designs for roads performing similar functions (Stelling-Konczak, Aarts, Duivenvoorden, and Goldenbeld, 2011; See under Innovative Recommendations).

- ☐ **Prioritize use of design features that limit or manage speeds to the appropriate level.**

  Goal – Design improvements so that roads are self-enforcing to the extent feasible to prevent future speeding and speeding-related crashes.

  Proven – A number of design and engineering measures, including roundabouts are proven to significantly reduce fatal and injury crashes and control speeds particularly in lieu of signalized intersections and intersections with stop-control on only the minor approaches. Other speed managing measures include reductions in the number of travel lanes (road diets), lane narrowing, shifting alignments, and other traffic calming measures to manage speeds in appropriate contexts.

  Target – Target roads should be all those undergoing upgrades, new roads, or roads where safety improvements may be targeted (identified and prioritized through screening and diagnosis methods).

Roadway design and environmental context are the most proximal cues to the driver as he/she drives, and of paramount importance in supporting the perception that speed limits are appropriate and reasonable (NCHRP, 2009; Speed Management, 2008). Many design and operational features also influence speed choice, or are speed limiting; Goldenbeld and Schagen, 2007; Stelling-Konczak, et al., 2011. In addition, appropriate design may improve enforceability by law enforcement (NCHRP). Many of these factors have been highlighted in the literature review for this document.

At the present time, speed prediction and safety performance methods for alternative designs are relatively limited to rural highways (see for instance the Interactive Highway Safety Design Model available at https://www.fhwa.dot.gov/research/tfhrc/projects/safety/comprehensive/ihsdm/).But specific design elements that have expected operating speeds and crash-reducing effects include roundabouts, road diets from undivided four-lane to three or fewer lanes, traffic calming measures, some lane narrowing treatments, gateway treatments, and others (Elvik, 2004; Engineering countermeasures for Reducing Speeds, 2009; Ray et al., 2008). Roundabouts are estimated to reduce injury and fatal crashes by about 90% when implemented at rural, two-way stop-controlled, high-speed intersections (Isebrands, 2012). Converting signalized intersections to roundabouts can be expected to reduce injury and fatal crashes by about 66% in urban and suburban areas with traffic volumes up to 43,000 ADT (Srinivasan, et al., 2011). Roundabouts have been found to operate well with unbalanced traffic flows, have been successfully used along school corridors with child pedestrians, and can be adapted/designed to fit within the community context (Isebrands, 2012). Maryland estimated a 13:1 benefit to cost ratio (20 year service life) for converting five rural, two-way stop-controlled intersections to roundabout (Roundabouts, the Maryland Experience, n.d.).

Road diets are another cost-effective way to reduce speeds and significantly reduce crashes and injuries while maintaining capacity for a wide range of traffic volume and operational characteristics. Reducing the number of lanes on four-lane undivided roads to two-lanes plus a center two-way left turn lane, is estimated to reduce crashes by from 19% (larger suburban areas) to 47% (State highways passing through smaller towns where speed reductions were likely greater) (Harkey et al., 2008).

Other lower-cost measures are also available to help reduce speeds in transition areas, in advance of junctions and in neighborhoods and communities (Engineering Countermeasures for Reducing Speeds, 2009). For roads that serve multiple types of functions at higher speeds, it is important to provide separated facilities and crossings for different type and mass of users to reduce the risk of serious injuries (Aarts et al., 2009).

- ☐ **Implement methods for triggering and prioritizing roads for review of speed limits and conducting safety assessments. (Supporting strategy)**

  Goal – Develop effective methods to identify roads that may benefit most from speed limit review, potential speed limit change, roadway improvements or enhanced enforcement.

  Experimental to Proven – Although somewhat experimental with respect to identifying roads warranting speed limit and associated safety and design review, network screening, diagnosis and prioritization of cost-effective solutions is state-of the practice with respect to safety treatment of existing roads (AASHTO, 2010; NCHRP, 2008).

  Target – Existing road network, particularly State-managed roads, but ideally all roads.

The Netherlands uses a cost-benefit approach to prioritize design changes and other countermeasures within the country's Sustainable Safety framework. These measures are credited with a 10% reduction in fatalities (Wegman, Aarts, and Bax, 2008). However, as already mentioned, the Dutch first assess the road network for an initial determination of whether speed limits are set appropriately from a safety standpoint, and credibly with respect to the current design (Aarts et al., 2009). The Dutch then determine whether changes to limits, changes to the roadway, or to enforcement are needed to improve credibility and to safely operate the roadway close to the limits established.

Because of the variety of speed limit setting methods and changes that can occur to and around roadways and their use over time, there is a need for North Carolina to develop and validate network screening and other proactive methods to prioritize roads for speed limit and road safety assessment. The Manual for Uniform Traffic Control Devices suggests that at least once every 5 years, State and local agencies should reevaluate non-statutory speed limits on segments of their roadway that have undergone significant change in roadway characteristics or surrounding land use since the last review (NCHRP, 2009). However, as mentioned, statutory limits may become less appropriate over time as well. Other priorities for reviewing speed limits and road safety could include ensuring safe routes to school and other areas where children, the elderly, or vulnerable users are found. Implementation of new roadways that may alter the use or traffic patterns of other roads could also trigger a speed limit and safety review for those roads. Safety performance, especially evidence of a significant speeding-related crash problem could also be used to prioritize speed limit reviews and safety assessment.

- ☐ **Determine desired operating speed and speed limit before designing new projects and upgrades, and design to support that limit. Conduct speed and safety reviews of all new designs and at key stages throughout the implementation process.**

  Goal – Ensure new roads are designed in accordance with best practices and in keeping with intended operating speed and limit to reduce the opportunities of future speeding and other speed-related safety problems.

  Tried/Proven – Consideration of speed limit and intended operating speed should be a key aspect of planning, design, and safety review.

  Target – All new and improved roads.

Design inconsistencies violate driver expectation, with the result that drivers may fail to slow sufficiently for the lower design features (Donnell et al., 2009a; 2009b). Consistent design may be a better safety approach than the frequent use of signs and other spot safety devices (AASHTO, 2010). Using higher design speeds than the intended speed limit/ operating speed may counteract intended safety benefits by inducing drivers to adopt higher speeds (Donnell et al., 2009b), and create enforcement challenges due to many drivers exceeding limits.

Urban streets and streets that provide access to all users and destinations in particular may warrant different design approaches and use of features that lower speeds (see above) than roads intended primarily for throughput and with limited access. Also, pedestrians and bicyclists may be able to safely share low-speed streets with motorized traffic, but should have separate facilities and protected crossing opportunities on higher-speed roads according to an injury minimization approach.

- ☐ **Lower maximum default rural speed limits from 55 mph to 45 mph.**

  Goal – Lower the baseline risk of rural roads that provide access and distributor functions to all modes of traffic and do not meet modern design standards for 55 mph roadways.

  Tried/Proven – Lowering statutory speed limits, when supported by automated enforcement and publicity, works to reduce speeds and crashes.

  Target – Largely, rural, state secondary highways.

Speed limits provide the foundation for managing speeds, but must be made credible to drivers through all possible means (Speed Management, 2008; TRB, 1998). Lower limits in urban areas and on access roads have been widely used in Europe, backed up by designs and enforcement. Evaluations in Australia have also found that lower urban limits backed up by publicity and automated enforcement have helped to lower fatalities and serious injuries (Archer, et al., 2008; Hoareau, Newstead, and Cameron, 2006; Shinar, 2007). As mentioned earlier, changing limits without changing enforcement or the road design may have minimal impact on operating speeds, but average speed reductions of about 25% of the change in limit have been achieved with no changes to enforcement or the road (Speed Management, 2008). Remember that small reductions in average operating speeds can have a sizable impact on injury and fatality crashes (AASHTO, 2010). Cross-sectional models (not before and after) also suggest that limits have an effect on travel speeds (Fitzpatrick et al., 2000; 2003). The strategy of lowering default limits is also being tried in rural areas of Australia (Dr. Bruce Corben, personal communication). The limits may be posted more extensively in these trials than in North Carolina, and the limits are also supported by the presence of automated enforcement and media campaigns.

Although speeding-related crashes occur on all types of roads in North Carolina, 37 percent of all fatalities and about 52 percent of speeding-related fatalities occur on the State's secondary road system. About 24% of pedestrians struck on rural (< 30 percent developed) 55 mph roads in NC were killed, compared with 13% of those struck on rural 45 mph roads.

An average of more than 500 fatalities and 18,000 injury crashes per year have occurred on the state secondary system. Reductions of 12 – 23% in injury crashes, and 21 – 42% in fatal crashes could be achieved if average operating speeds drop by only 2 to 4 mph (assuming average initial operating speeds of 50 mph, and using estimates from the Highway Safety Manual (AASHTO, 2010). Using the more conservative estimate, more than 100 lives could potentially be saved if drivers are convinced through changes in limits, enforcement, publicity, and other measures to lower their speeds on these roads.

Statutory limits provide general consistency across rural or urban roadways, but it is important that statutory limits be set with consideration of safety, since they affect a large portion of the road network. Most of the rural, two-lane roads were not designed and have not been improved to modern standards for 55 mph roads. Although many are low-volume roads, development extent, numbers of access points, along with traffic volumes may have changed significantly for some of these roads since the rural statutory limit was enacted. These factors, and many others, may affect the safety and suitability of the 55 mph limit.

According to estimates provided by the State DOT, approximately 10% of the rural secondary mileage has already been zoned to 45 mph limits, with smaller percentages being zoned to 50 and other less than 45 limits. About 2% has been zoned to higher limits. Currently, each section of roadway operating under the statutory maximum must undergo an engineering review to develop a special speed zone ordinance (alter the limit from the default limit and post the limit). State traffic safety engineers have suggested that 45 mph would be a more appropriate and safer default maximum, given statewide mobility, safety, and implementation considerations.

Enforcement Strategies

The recommended enforcement strategies are intended to address the challenges of increasing enforcement presence and effectiveness on North Carolina's 100,000 miles of streets and highways.

- ☐ **Develop random allocation enforcement strategies using regular marked, parked patrol vehicles (all agencies and divisions) and other overt and covert enforcement methods to cover a larger portion of the network where serious crashes occur.**

  Goal – The goal is to maximize deterrence through visible, but sustainable levels of enforcement and increase the perception that enforcement may be encountered anytime and anywhere.

  Proven – Adding quality publicity or media coverage would be expected to enhance effectiveness.

  Targets – Targets would include a large portion of serious (fatal and injury) crashes occurring on the entire network, depending on how extensively the strategy might be implemented.

Enforcement that is randomized and highly visible tends to be more effective at extending effects to a larger area than enforcement that concentrates on high-violation locations, perhaps by conveying the message that enforcement could be detected anywhere, anytime (Shinar, 2007). Current enforcement may tend to focus on the top few crash locations in each county according to input received from SHP personnel. Drivers may come to anticipate where enforcement is targeted and thus deterrence of speeding at other locations may be minimal. It is therefore unlikely that a large portion of crashes or potential crashes are targeted by this approach, especially in the face of limited publicity. However, there may be challenges to traditionally enforcing some roads, including many low-volume, secondary routes. Various deployment strategies and technologies should be considered as part of the plan to increase the perception and reality of wider enforcement coverage with greater deterrent effects.

Elvik (2004) reviewed studies of both stationary and patrol type enforcement, and performed meta-analyses to obtain estimates of effects. For stationary enforcement, fatal and injury crashes were reduced by 14% and 6% respectively. For patrol enforcement, injury crashes were reduced by 16%, with no estimate possible for fatal crashes due to a smaller number of studies and sample size. However, distance halo effects may be greater for patrol enforcement (Shinar, 2007) and for mobile covert automated enforcement compared to fixed (stationary) enforcement (Thomas et al., 2008). A good mix of fixed, conspicuous, and mobile, covert enforcement, supported by publicity, seems necessary to maximize the perception that enforcement is widespread.

An effort, known as Random Road Watch, was undertaken in the State of Queensland, Australia around the mid-1990s specifically to achieve a sustainable and widespread enforcement strategy that targeted a large set of the crash problem in that rural state. The program combined randomly targeting high crash zones or road sections for enforcement for two hour periods between 6 am and midnight with marked and parked police vehicles, and issuing tickets when offenses were detected (Newstead, Cameron and Leggett, 2001). Regular levels of enforcement capability were used to determine deployments. The program was estimated to reduce fatal crashes by 31% and provide a significant savings of 12% of the entire State's crashes by the third year of the program's implementation. The program is considered a successful and continuing safety effort according to a 2006 Queensland road safety plan update. States that are reported to use sustained belt use enforcement (as opposed to blitzes) also report belt use rates significantly higher than the national average. Sustained enforcement is also not associated with abrupt drops in belt use such as may occur after a blitz type enforcement (NHTSA, 2011).

Drone radar, also targeted randomly, and speed display devices (especially if accompanied by visible law enforcement) are other methods that may help to manage speeds by taking advantage of the use of radar-detecting devices and increase the perception that enforcement is present among drivers using such devices or in communication with others who are (NHTSA, 2011).

- ☐ **Lower enforcement tolerances and publicize the enforcement.**

  Goal – The goal is to reduce the number of vehicles exceeding the limit by significant amounts but which are less than typical enforcement tolerances. Mannering (2009) found that drivers' expectation of what threshold above the speed limit would trigger a ticket affected their perception of safe driving speeds. Low-level speeding is a serious safety problem due to the large numbers of vehicles involved (Gavin, et al., 2010; Kloeden, McLean, and Glonek, 2002). This strategy may help to shift the distribution of higher speeds down as well.

  Tried/Proven – Estimates from the Highway Safety manual show that risk of fatal and injury crashes decrease significantly with small changes in average operating speeds. Effects are most pronounced on lower speed roads (AASHTO, 2010).

  Target – All types of roads where the measure could be feasibly implemented. Urban streets and freeways could be more feasible for implementing and publicizing the enforcement initially (pilot).

Input from law enforcement suggests that speeding above the limit is most excessive on interstate highways. However, driver themselves report speeding more frequently in lower speed zones (Figure 9). Only 16 percent of drivers indicated they never speed in low-speed zones while 30 percent indicated they never speed on 65 mph roads.

The proportions of drivers admitting speeding on both types of locations also increased from 2010 to 2011 (North Carolina Governor's Highway Safety Program, n.d.). Note that 5 miles above the limit on a 30 mph road is 17 percent above the limit, while 5 miles above the limit on a 65 mph road is about 8 percent above the limit. Also, as mentioned and shown in estimates of fatal and injury crash reductions in the Highway Safety Manual (AASHTO, 2010), relatively small changes in average operating speeds may have a potentially greater proportional impact on fatal and serious injuries on lower speed roads.

This approach has been tried and proven when used with automated enforcement systems and publicity. The State of Victoria, Australia implemented a comprehensive effort to reduce marginal speeding and crashes through a program that included a reduced camera speed detection threshold, media campaign, and enhanced hours of covert, mobile speed operations, and penalty restructuring. Over the same time period, there was also a reduction in urban speed limits from 60 kph to 50 kph (from 37 mph to 31mph). An evaluation estimated that this comprehensive effort reduced injury crashes by 10% and fatal crashes by 27% (D'Elia, Newstead and Cameron, 2007). In another test of adopting and publicizing a lower threshold, mean speeds were reduced by 2.5 km/h (1.6 mph), the standard deviation of speed by 1.1 km/h (0.7 mph), and the proportion of vehicles exceeding the limit decreased by 11.8

percentage points when an automated speed enforcement threshold was lowered from 20 (12.4 mph) to 4 km/h (2.5 mph) on a two-lane, rural Finland highway (Luoma, Rajamaki, and Malmivuo, 2012).

If well-publicized, compliance may increase enough that the number of violations (and consequent administrative burden) may not increase (Luoma et al., Shinar, 2007). If backed up by stringent prosecutions, the burden on the courts may not increase either as was found in a North Carolina speed enforcement pilot (Hunter, Thomas, and Stewart, 2001).

Frequency of Driving More than 5 MPH over the Limit in a 30 MPH Zone

	2011	2010
Most of the time	26%	22%
About half the time	17%	17%
Occasionally	41%	46%
Never	16%	15%
Don't know/Not sure	0%	1%

Frequency of Driving More than 5 MPH over the Limit in a 65 MPH Zone

	2011	2010
Most of the time	17%	14%
About half the time	13%	17%
Occasionally	39%	38%
Never	30%	31%
Don't know/Not sure	0%	0%

Figure 9. North Carolina driver self-reports of speeding behavior in low speed (top) and high speed zones. (From North Carolina Governor's Highway Safety Program, 2012 FY Annual Report.)

- ☐ **Use automated speed enforcement to supplement traditional enforcement.**

  Goal – Increase the perceived and actual risk of being detected speeding to improve individual and population level deterrence of speeding.

  Proven – Automated speed enforcement systems (both mobile and fixed camera systems) are proven to reduce speeds and injury crashes. Media coverage and publicity associated with the campaigns have also been found to add to crash reductions.

  Target – The target includes potentially all crashes involving vehicles exceeding speed limits, depending on the type and extent of implementation. The target group depends on the types of roads or situations where implemented, the type of implementation, and supporting publicity (which may affect how wide-spread deterrence may be).

For example, Australia uses mostly covert, mobile automated enforcement to increase the perception that enforcement may be encountered anytime, anywhere. Other countries use the strategy of targeting high crash locations with highly visible automated enforcement which may effectively reduce crashes at those locations, but may have less deterrent or crash reduction effect elsewhere, and may have greater potential to shift speeding or crashes to other locations (Thomas et al., 2008). Automated enforcement may also be used in locations and at times that are difficult to cover with traditional enforcement alone (Eccles et al., 2012).

Significant international evidence suggests that injury crashes may be reduced on the order of 25% by well-implemented automated speed enforcement programs (Thomas, et al., 2008). A mobile camera enforcement program in Charlotte, NC achieved significant crash reduction benefits (Moon and Hummer, 2010). Fatal and injury crash reductions of 17 to 21%, and total crash reductions of 15 to 18% were estimated to result during the intervention, increased in the post-intervention phase, and continued for some months after the program was discontinued before gradually returning to pre-intervention levels. A fixed speed camera enforcement program implemented on a principal arterial beltway in Arizona was estimated to reduce serious and minor injury crashes by 48% in a well-controlled study (Shin, Washington, and van Schalkwyk, 2009).

Motives must be perceived as legitimately about safety for the public to support enforcement programs (Eccles et al., 2012). The safety focus should be well-communicated to the public and decision-makers. Clearly communicated and well-established speed limits backed up by good road designs also form a strong basis for automated enforcement, as the public may also be skeptical of automated enforcement where tolerances are not perceived as reasonable (Eccles et al., 2012). Characteristics of effective programs are described in Eccles et al., 2012 and in earlier guides by NHTSA and FHWA.

Cost recovery (recovery of operating costs from camera revenues) in conjunction with a fixed camera program is a proven concept in the United Kingdom. The U.K. cost recovery program established warrants for application and clear procedures for accountability (Gains, et al., 2004). The programs were, however, deemed to be limited by the inability to use additional revenues for safety or to expand the programs to target additional crashes (Delaney et al., 2005). Revenues that exceed operating costs should be allocated for roadway safety functions in the local community (Eccles et al., 2012).

- ☐ **Shift most speeding violations to a civil and uniform penalty system.**

  Goal – Increase the actual and perceived expectation of receiving appropriate and consistent penalties when caught speeding to improve deterrence effects of enforcement.

  Tried – with respect to automated enforcement. Automated enforcement systems around the world (highly effective) use a civil penalty system.

  Target – The target group would be all speeding or would-be speeding drivers. The program would be expected to deter most drivers from speeding. If more low-level violations can be shifted to a civil system, it may better-enable improvements in tracking and prosecution of flagrant and repeat violators that are serious enough to remain in the court system.

There is plenty of evidence suggesting that penalties and threat of severe sanctions can affect driver speeding and future crashes. However, for penalties to work effectively on both an individual or population-deterrence level, they must be predictable (expected) and administered uniformly (Shinar, 2007). Although Masten and Peck (2004) reported that effects increased with obtrusiveness of sanctions, such effects are by no means guaranteed for strict penalties. The certainty of punishment may be more important than the intensity (Shinar, 2007). In fact, Masten and Peck also noted that court-administered sanctions tended to be less effective than those administered through licensing bureaus. In addition, civil penalties would help to increase the consistency of penalties. All driver ages, including young drivers, should be treated similarly with respect to enforcement and penalty measures to maximize effectiveness of deterrence measures and respect for traffic laws, and to have the greatest impact on reducing population-wide injuries and fatalities (Child Fatality Task Force, 2012).

There is significant evidence that the judicially-administered penalty system in North Carolina (and those in other States) is failing the basic deterrence principles of high expectation of being caught *and punished* for speeding. Researchers reporting on Maryland speeding citation dispositions, for example, found the following:

- 54 percent of drivers who received a speeding citation showed up in court to contest their tickets rather than accept the penalty and pay the fine by mail. This fact alone places a huge burden on the courts.
- Those who accepted guilty verdicts and paid fines by mail had a longer time to future violations and crashes than those who contested their charges, even after adjusting for other risk factors.
- Among those whose cases were decided judicially, various legal consequences from having charges dismissed to guilty verdicts had little effect on future crashes or citations.
- Only drivers receiving suspended sentences, such as prayer before judgment, had a somewhat reduced risk of subsequent speeding tickets. These results could have been due both to driving less due to other license restrictions, and partly to the deterrent effect of threat of reinstatement of charges with an additional citation (Lawpoolsri, Li, and Braver, 2007; Li, et al., 2011).

Given the challenges and expense of operating courts to administer justice to speeding violators, the possibility that many drivers, and indeed the general public, do not perceive speeding as a crime, and the breakdown in the judicial system caused by a flood of drivers contesting their tickets, Speed Workshop participants suggested the possibility of shifting much of the penalty side of enforcement to a civil system. More consistent, swiftly administered, and fair penalties could be meted out for most violations through a standardized, civil penalty system. Similar to effective automated enforcement systems, the system should be established so that fees pay for the costs of operating it, with the potential for additional fine revenues going to improve roadway safety.

The evidence is somewhat mixed about the importance of penalty size, but penalties could also be scaled to the offence as they are in many automated enforcement programs around the world. Penalties scaled to the infraction that are certain to be enacted may have a larger effect than harsh penalties that are inconsistently administered.

Education and Public Information Strategies

Educational and informational strategies should be used to support and increase the effectiveness of other strategies, particularly to enhance deterrent effects of enforcement.

- ☐ **Utilize earned, paid, and social media campaigns to enhance the deterrent effects of all enforcement efforts. Campaigns should reinforce the type of enforcement undertaken.**

  Goal – Enhance the perceived risks of being caught speeding and consequently the population-level deterrence of speeding. The objective should be to educate drivers about the program, and most importantly persuade them that detection and sanctions are likely.

Proven – About 8 to 10% of the crash reduction effects of Charlotte's automated speed enforcement program were attributed to media coverage of the program (Moon and Hummer, 2010) and effects lingered for some months after the program was discontinued. Persuasive communications are an essential part of successful speed enforcement programs (NHTSA, 2011). Additionally, media may be used to publicize new laws or enforcement strategies.

Target - The target depends on the enforcement efforts undertaken, and how the campaign might widen the deterrent effect.

In conjunction with .08 BAC laws and primary belt enforcement laws, high visibility enforcement through sobriety checkpoints and saturation patrols, and belt enforcement blitzes, backed up by publicity about those efforts have been effective tools to reduce impaired driving collisions and increase restraint use to about 90% in NC. High-visibility anti-speeding campaigns have not received as much attention or funding in the U.S. as restraint use and alcohol enforcement, but some high visibility speed enforcement programs have achieved success (NHTSA, 2011). Australia has also used media campaigns extensively to support enforcement efforts and even to challenge the social norm of speeding.

- ☐ **Educate courts officials about the importance of their role in traffic safety.**

  Goal – Improve consistency and certainty of prosecution of speeding violations that are prosecuted through the court system.

  Experimental/Tried for alcohol impairment – Measures to educate and influence courts officials through advocacy organizations, court monitoring and publicity may have helped raise the profile and success in effectively prosecuting DUI offenders and altering the social norm of drink-driving. It is unknown if this strategy has been tried with regard to speed enforcement (except in a NC pilot study in Iredell County) (Hunter, Thomas, and Stewart, 2001), but there are no known evaluations of effectiveness. Progress in reducing DUI crashes has also slowed in recent years. Since courts officials (judges and prosecutors) turn over frequently, such a strategy would have to be continued/repeated or made self-sustaining through institutionalized training or courts monitoring.

  Target – Speeding violators that contest their citations in court.

Attempts to close loopholes legislatively have thus far failed to work. It is not clear if attempts to make adjudication more sustainably consistent through the courts can be done by providing outreach to judges and prosecutors.

Information Technologies

- ☐ **Make wider use of variable speed limits (VSLs) on freeways or other roads with conditions where a single posted speed limit may frequently be inappropriate.**

  Goal – Provide a safer and more credible indication of appropriate travel speed for varying conditions.

  Proven/Tried – European countries have been using variable speed limits for managing speeds during peak hours for over two decades on freeway types of roads. Several U.S. states have conducted trials of VSL related to weather conditions with promising speed reductions (NHTSA, 2011). VSLs fit with a principle of communicating a more accurate message about safe speed, especially when maximum limits are likely to be often inappropriate.

Targets – In addition to school areas where VSLs are already frequently used during school travel times, other prime targets include freeways with intermittent congestion due to peak flows, crashes, or adverse weather, or roads where nighttime safe speeds may be very different from daytime limits.

Interstate highways in North Carolina account for 6% of fatal speeding-related crashes and 8% of all fatal crashes but had the highest fatal crash rate per mile of highway. Since these roads also carry large flows and provide important mobility functions, maintaining smooth flows and improving safety are important goals. A pilot study of a Wyoming freeway VSL system found speed reductions of 0.47 to 0.75 mph for every mph reduction in speed limit (NHTSA, 2011). Continue to monitor research from other states.

VSL systems have been used much more widely for more than 40 years in European countries including the Netherlands, Germany, and Sweden, particularly on motorways in the Netherlands and autobahns in Germany. According to an FHWA study tour, improvements in travel time and significant crash reductions were reported from the systems.

Forty-four percent of NC's fatal speeding related crashes and 33% of all fatal crashes occurred at night on unlighted roads of all types. A variable day-night speed limit could be considered if further research suggests it may be an appropriate and effective solution. Prior evidence is somewhat mixed with respect to day/night variable limits.

Coupling VSLs with publicity or signing about the reasons for VSL, and, perhaps with automated enforcement could enhance effectiveness.

- ☐ **Improve ready availability of complete and accurate driver history data to enforcement officers and the courts.**

  Goal – Improve knowledge of violators' prior histories by courts officials and improve outcomes of prosecution of speeding violations.

  Experimental – It is unknown if any States have tried this measure but improving driver records and prosecution is an often-recommended strategy (NCHRP, 2009) and one identified by the stakeholders work group. There is some evidence that court outcomes have little deterrent effect on future speeding behavior and crashes under current systems, (Lawpoolsri, Li, and Braver, 2007; Li et al., 2011) but deterrence could improve if the court practices were widely known and consistently implemented.

  Targets – Drivers who contest their citations in court, and particularly repeat and egregious violators are the primary focus of this strategy. The contribution of this group is difficult to track due to present plea agreements and challenges in tracking complete records of violations, not just convictions.

The ability to effectively prosecute or treat repeat and flagrant speeding violators is hampered by challenges in obtaining accurate and complete driver history data in a timely and efficient manner. Citation data as well as conviction histories should be available. Improvements in normal procedures and communications as well as through technological improvements may be tried. This strategy may be an alternate or additional strategy to shifting most speeding citations to a civil and automatic penalty system. Over the longer term, Intelligent Speed Adaptation (see next section), and other strategies may be available to assist with managing repeat offenders.

Innovative (Unproven) Strategies

The strategies that follow are not yet proven, and may require additional research and interagency discussion to verify their efficacy and appropriateness for North Carolina. In the authors' opinion, North Carolina should begin long-term planning and consideration of several of these strategies. Several, including the first, would enhance or fit within a safe systems approach to speed management, helping to create a road network that supports and communicates safe driving speeds and providing a sound basis for effective enforcement strategies as well as supporting safe travel choices by varying modes.

- ☐ **Improve recognizability and consistency among roads of the same type and speed limit.**

  Another core principle of the Dutch road safety vision includes the principle of predictability. Related to this principle, is the principle "functionality of roads," and that road layouts facilitate homogeneous use in "speed, mass, and direction." One of the objectives is to create design consistency within the same functional class of roads, or what is more widely known as "self-explaining roads (Stelling-Konczak et al., 2011)." Establishing fewer different speed limits is also a strategy of the Dutch safe systems approach.

  Europe is carrying out a research program to develop a self-enforcing, self-explaining road system. North Carolina could consider a similar program to develop a system of design standards, markings and signing to clearly distinguish the type of roadway, with its associated speed limit, that one is traveling on.

- ☐ **Implement a driver reward approach to encourage safe speeds.**

  A number of recent studies suggest that rewards may work to improve compliance with speed limits, at least for some drivers (NHTSA, 2011). Lease car drivers exemplified compliance with speed limits and improved following behavior more of the time when driving was monitored and monetary incentives were offered with the lease agreement. A pay-as-you drive plan to save young drivers' insurance costs also reduced the percentage of miles that young drivers exceeded the limit by 14%. We are not aware of any studies reporting crash effects of such systems.

- ☐ **Implement Intelligent Speed Adaptation**

  Intelligent Speed Adaptation involves on-board systems that "know" the speed limit through accurate digital mapping of speed limits and that warn when the limit is being exceeded, apply active controls to slow the vehicle, or limit the vehicle to no more than the posted speed. The system architecture as currently conceived in Europe does not require special roadside infrastructure (European Transport Safety Council, [ETSC] n.d.), but requires only accurate digital mapping of roadway speed limits (currently underway in NC) and use of in-car global positioning systems that interact with the map. Advisory limits could be included; variable limits would require live interaction with the variable limit devices.

  Intelligent Speed Adaptation (ISA) trials have been conducted in at least 10 European countries (Carsten and Tate, 2005). Several Australian states are currently conducting trials and exploring the use of ISA, such as potentially requiring it for repeat speeding offenders. Significant crash and injury reductions have been predicted from a full roll-out, given certain assumptions about operating speeds and expected reductions in mean speeds. The ETSC addressed barriers to implementation ("myths") and concluded that ISA works, is reliable, is technically simple (more so than other automatic devices such as collision avoidance systems), and that the expected crash reductions far outweigh the costs, particularly if the devices are required by law (ETSC, n.d.).

- ☐ **Create guidelines and conduct training and outreach to cities and other local planning agencies to help ensure that new developments and local roads also follow best design practices for speed management and safety.**

  Conducting outreach and developing inter-agency agreements has also been practiced in the Netherlands Sustainable Safety approach, which required 24 inter-agency agreements with provincial, municipal, and local road managers.

  Many roads result from new development where design principles to achieve self-enforcing roads may not be known, followed or mandated through local ordinances. Ultimately many of these roads end up in the State system. For example, wide (straight) residential streets with large building setbacks from the road may encourage higher speeds than intended if the space is not needed for on-street parking. The State could facilitate discussion and agreement on implementation of good design principles to manage speeds in new developments and connector roads.

- ☐ **Maximize use of existing capacity by improving and increasing use of transit, and demand management strategies such as HOV and managed lanes, flex-time work arrangements, and compact development patterns to minimize the need for adding traffic lanes.**

  This measure could reduce exposure to driving and speeding in general, and potentially the risk of speeding. As a proportion of crashes, speeding-related crashes, and especially fatal crashes, are higher on weekends and during other non-peak hours. Excess capacity during non-peak hours may increase opportunities to speed during hours when fewer vehicles are on the road.

  Kononov, Bailey and Allery (2008), in an analysis of safety, congestion, and the number of lanes on freeways, also found that, while practitioners generally believe that additional capacity afforded by additional lanes is associated with more safety, their findings suggest that adding lanes to multilane freeways may initially result in a temporary safety improvement that disappears as congestion increases. As ADT increased, crashes in the Kononov et al. models increased at a faster rate on freeways with more lanes than on freeways with fewer lanes. In turn, increases in crashes can be expected to contribute to additional congestion since back-ups related to crashes are slow to clear, particularly during peak periods (Kononov et al.).

Based on 2005 data for 85 U.S. metro areas, the societal costs of crashes in urban areas of all sizes were more than 2.4 times the costs of delay (time) and fuel related to congestion. For small and medium sized cities, the crash costs were 7.2 times and 4.4 times, respectively, the costs of congestion (Cambridge Systematics, Inc., 2011).

Congestion and delay are a serious concern for workers, travelers, energy consumption, air quality and the economy. But, enhancing capacity by building more lane miles is also costly and may be further constrained by existing development, right-of-way availability, and environmental concerns. The State and other stakeholders could seek solutions that address congestion but that do not lead to inappropriately high speeds when traffic volumes are light. TTI's 2012 Urban Mobility report highlights the contributions to congestion reduction made by investment in public transport and operational measures, and the potential for other measures such as increased walking and biking, more diverse and denser development patterns, and changes in usage patterns that encourage shorter trips (flexible work hours, telecommuting) (Schrank, Eisele, and Lomax, 2012).

- ☐ **Discourage the use of car advertising that glamorizes speed.**

  Although the State has no direct control over advertising, the State and partners could encourage such a national measure. Such a measure would support the safe systems approach to speed management that addresses risks for speeding at the level of driver attitudes and beliefs and intention to speed. As part of a systemic approach to break the culture of speeding, Australia has enacted an advertisers' "Code of Practice," whereby vehicles cannot be depicted speeding or driving recklessly in commercials. It is a voluntary code, but people are reportedly quick to call in and get the ad off air if it breaks the code, so it can be costly for little gain (Senserrick, personal communication, 2012).

Managing speed, because of its indisputable role in the severity of injuries received in crashes, should be a cornerstone of the State's plans to ensure that participating in a daily and necessary activity does not continue to be a major cause of death for children and young people and a major cause of death for all ages (NC Vital Statistics Volume 2). It is important that cooperative efforts be strengthened, sustained and improved over time, both for improved safety results and to maintain a focus on the safety consequences of inappropriate speed. Small gains may be quickly lost. Consequently, in addition to speed monitoring, safety evaluation of the program and individual strategies or countermeasures are critical components of renewing and improving a sustainable program. Furthermore, traditional cost-benefit analyses *do not* include all the future lives that could be saved with better utilization of existing knowledge, tools and technologies, and the commitment to put these tools to work now.

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Network Screening

One of the recommendations to emerge from the problem identification process was to develop a proactive and systematic approach to identify corridors that may benefit from speed limit and safety review. Phase 2 of this project therefore focused on developing several approaches to network screening that might be used to prioritize routes for review. Other potential triggers include:

- Changes in roadway function or uses,
- Significant changes in traffic volume,
- Changes in development extent or type,
- Changes in use of the roadway due to implementation of other roads (alternate routes or nearby corridors).

In collaboration with NCDOT, it was determined to adopt a corridor-focused network screening approach using crash and roadway inventory data to identify routes with potential speeding-related crash and injury problems. The following variables were used to determine when a corridor would end and a new corridor would begin:

- County route
- Area type (rural versus urban)
- Mile-posting gap of more than 0.005 miles
- Access control (partial versus no access control). These two categories were ultimately combined due to low numbers of partially-controlled roads.
- Route subcategory (two-lane, multi-lane but not physically divided, four or more lane divided roadway, service road, ramp, or 'other')
- Average Annual Daily Traffic category (AADT) (Unknown, ≤1499, 1500 – 4999, 5000 – 14999, 15000 – 23999, ≥24000)

Corridors shorter than 0.1 mile were not included in the network screening. Since sufficient data were not available for service roads and ramps, the screening was conducted for corridors that belonged to the following six roadway types:

- Rural 2 lane
- Rural multilane undivided
- Rural divided
- Urban 2 lane
- Urban multilane undivided
- Urban divided

Roads with full access control were, however, not included because NCDOT indicated that they were not high priority for screening for speeding related crashes. Wholly federally-owned roads (such as National Park roads) also were not included.

Screening was conducted using the following methods:

- Empirical Bayes methods – this method is considered state of the art in the recently published Highway Safety Manual (HSM)
- Trends in crashes
- Proportion of crashes of specific types

Further discussion of the methods used in the network screening and the findings is available in Appendix III. These results are of most interest to NCDOT safety and mobility engineers and local agencies such as law enforcement that may also be involved in the diagnosis and treatment of speeding-related safety problems. Safety Performance Functions developed for the different roadway types are provided in APPENDIX IV - Safety Performance Functions.

Findings and Conclusions

Speeding contributes to an average of nearly 40 percent of North Carolina's fatalities and a significant portion of other injury crashes each year. Managing speed is an integral aspect of developing a transportation network that minimizes the risk of fatal or severe injury to all users. Safer countries have used these relationships to develop policies, set speed limits, and prioritize design, engineering, and enforcement improvements to minimize the risk of harm to the people using the transportation system.

With the legacy road network that has resulted from outdated design practices that encourages drivers to adopt high speeds, high enforcement tolerances above the limit and generally low levels of enforcement, and many other policy and cultural factors, drivers receive (and contribute to) the message that they should be able to drive fast just about all the time and everywhere. The most recent NC driver survey shows that even more drivers reported speeding in both low-speed and high-speed environments in 2011 compared with 2010.

Recommendations for speed management were described in this report and summarized in a companion document, North Carolina Speed Management, Recommendations for Action. Commitment and engagement is needed by all stakeholders to review, prioritize, select, fund, and implement the most appropriate combination of management, design and engineering, enforcement, and public information strategies in the short term, and to consider long term plans for implementation of infrastructure and innovative strategies. Some of the strategies require significant policy change but are important for the State to adopt to catch up to a 21st century approach to managing speeds on the State's highways and streets.

A systematic approach to identify and prioritize existing roads for speed limit and safety review may be adopted as one of the strategies. Methods for network screening were developed in the second phase of this project and may undergo further refinement. The next steps will be to select and test a few of the approaches to determine which methods may be most effective at identifying corridors where inappropriate speed is contributing to safety problems that might be treated. At the same time, it may be important to establish how speed limits will be reviewed and set.

History (as in prevailing speeds) in this case, may not be the best guide to the way forward for setting limits to improve safety. The State should consider that an injury minimization approach to set speed limits and make design and enforcement decisions may be a way to increase the priority on safety, and perhaps improve the credibility and consistency of messages to drivers about safe speeds on different types of roads.

Unfortunately, using any type of cooperative and evidence-based speed limit setting approach may be (somewhat) easier to do, although by no means easy, with regard to rural (outside municipalities) roads since the addition of municipal jurisdictions adds even more complexity to the speed limit setting processes on urban roads (State or local). Outreach to local communities may be an important part of the speed management program with regard to speed limit setting as well as local planning, development, and speed management practices. NCDOT's Complete Streets policy and Design Guidelines, which NCDOT already encourages local jurisdictions to follow, could potentially be a common tool for establishing safer speed limits and designing to help achieve similar operating speeds.

Applying the same concept, that speed limits form the basis for design and enforcement strategies to new projects, and, in principle, should come before designing new roads, should help to reduce future road design and speed limit incompatibilities and minimize the chances of severe harm. This is also key area that will require cooperation among State and local stakeholders, and the planning and commitment to seek mutually acceptable solutions.

Even if all roads could be made at any point in time to be as "self-enforcing" as possible, bringing speed limits, road designs, and operating speeds into closer agreement will be a never-ending process since transportation needs and development are ever-changing. Speeding *is* also a matter of driver intent, and one that engineering cannot solve alone. Speed enforcement will likely be needed as long as people are behind the wheel of vehicles (and perhaps longer).

Cooperation between engineering (State and local), policy-makers, (State and local), law enforcement agencies and courts officials, and media and injury prevention experts is therefore needed to implement a comprehensive balance of solutions. For example, Cities, Counties and the State make important funding and policy decisions about the amount of enforcement to implement. Automated enforcement is currently restricted from use by State law. Innovation of new practices, designs and other strategies also requires encouragement and cooperation among decision-makers, designers, engineers, researchers, and funding agencies.

In some instances, enforcement may be one of the few solutions that can be implemented right away. This fact should also strengthen partnerships between NCDOT divisions and law enforcement agencies to work together to identify routes where serious crashes relating to speeding are occurring, and to test methods for enhancing enforcement presence and effectiveness. Some potential strategies recommended in this document include lower enforcement tolerances, automated enforcement, improvements in penalty systems or adjudication, and enhanced publicity. Other experimental treatments may be tried and evaluated.

Finally, and perhaps most importantly, measuring the problem and developing a framework for communicating about the risks of speeding may guide all the stakeholders and help to raise the profile of the issue to achieve the public support needed to implement new policies and other improvements.

Implementation and Technology Transfer

This project has developed the following products:

- A literature review about best practices in speed management – included as Appendix I
- Planned and convened the first North Carolina Speed and Safety Symposium. (Separate program) and a full day NC speed management workshop.
- A NC speeding and safety problem summary – Appendix II
- A set of 21 speed management recommendations for actions the State highway safety agencies and other partners could take to reduce speeding-related crashes and injuries. The document is entitled "North Carolina Speed Management, Recommendations for Action" a separate document. Recommendations are also described in greater detail in Chapter 4.
- Network screening methods for identifying and prioritizing corridors for speed and safety review – described in this report (Chapter 5 and Appendix III); with Excel spreadsheets included separately.

The first three products were used to develop the fourth, "North Carolina Speed Management, Recommendations for Action." The recommendations may be used to promote understanding of the issues and solutions among stakeholders, especially among decision-makers. The background materials such as the literature review may also prove useful to some stakeholders that need more detail.

The NC Speed and Safety Symposium was video-recorded and is available on the UNC-HSRC website (at http://www.hsrc.unc.edu/news_room/events_speed_video.cfm). The symposium recordings could potentially be used to educate policy-makers and practitioners about the issues.

The State might consider soliciting additional products in further projects, such as white papers, fact sheets, or presentations to be developed in support of individual strategies and recommendations in this report.

For implementation of network screening, HSRC will provide documentation for the screening results to NCDOT. NCDOT will need to undergo additional discussion and review, with field validation and other work to select or modify the most appropriate screening methods and determine how these may be integrated within existing programs.

Each of the recommended strategies has significant implementation considerations and NCDOT and its partner agencies will need significant further work to prioritize, develop, and coordinate on implementing selected strategies. A strategic speed management team may provide administration and policy guidance for such efforts.

Appendix I – Speed Management Literature Review

Culture is best modified through changes in social practice. In general, risk management literature suggests that the most productive points of leverage are material in nature, advocating a focus on modifying structures, policies, and controls over attempting to change beliefs, values, and attitudes (Preusser et al., 2008 and others). Behaviors may change before attitudes change.

General Characteristics and Problem of Speeding

As discussed in a comprehensive review of speeding, speed management and safety, there are generally agreed-upon reasons for setting speed limits and regulating driving speeds. If left to their own devices, drivers may make both inappropriate judgements and intentional choices about safe driving speed that cost others as well as themselves in the form of increased crashes and injuries (TRB, 1998). The aim of roadway design and speed limit setting should be to minimize the unintentional misperceptions and choices, while enforcement and other communications are needed to ensure that drivers respect the information communicated. Speeding increases the severity of injuries and the numbers of fatal and serious injury crashes (Hauer 2004; and AASHTO, 2010).

It is a common belief that "everyone speeds" and, based on what drivers report about their own behavior, that belief seems to be vindicated. Respondents in a national survey of driver attitudes and behaviors performed for NHTSA (2004) indicated that 78% of drivers reported speeding on interstates, 83% on other multi-lane roads, 78% on two-lane roads, and 73% on city streets during the past month. One-fourth to one-third reported speeding on the date of the interview, and 34% reported that they sometimes drive 10 or more mph faster than other vehicles (NHTSA, 2011). Research has documented that drivers speed for many reasons including from general habit, from habituation to high-speed roads (AASHTO, 2010), from a lack of proper information on speed limits, from perception of safe speeds that differ from limits (Mannering, 2009; Goldenbeld and Schagen, 2007), due to sensation-seeking tendencies (Goldenbeld and Schagen, and others), from perceptions about speeds that others are driving and the desire to conform (Åberg et al., 1997), driving while angry (Arnett, Offer, & Fine, 1997) and due to other reasons including being in a hurry or late. Mannering (2009) found, for example, that drivers' expectation of what threshold above the speed limit would trigger a ticket affected their perception of safe driving speeds (not to mention what speed they adopted). Drivers also tend to over-estimate their own abilities and underestimate the risk of activities they perform every day (Preusser et al., 2008). Thus, addressing speeding in all its forms may require multi-pronged approaches. To significantly lower the distribution of average speeds, **it may not be enough to simply increase enforcement, if that is even an option, if the amount of increase is not enough to be noticed by drivers, or if the perception and reality is that speeds being enforced are actually far above the limits.** There is also the question of whether limits are set appropriately. So, in some cases, drivers may be traveling at or even under limits, but still be "exceeding safe speed for conditions." Of course, there may be cases where limits are set too low or at least perceived to be too low by drivers. There will be more discussion of these issues under the section Setting and Enforcing Speed Limits below.

Williams, Krychenko, and Retting (2006) investigated characteristics of serious speeders, that is those exceeding the limit by at least 15 mph and driving at least 5 mph faster than surrounding vehicles. These drivers were compared with drivers, traveling in proximity to the speeding drivers and who were therefore perceived to be good controls for exposure, who were either not speeding or were only mildly speeding (by 5 mph or less). Observed serious speeders had worse traffic records with more than twice as many total traffic violations and speeding violations and 60% more crashes on their records than the other drivers. The (excessively) speeding drivers also tended to be younger, male, and were more likely to drive newer vehicles and sport utility vehicles compared to the slower drivers. This study therefore suggests that excessive speeders contribute to more than their “share” of crashes, compared to slower drivers observed at the same time and location. However, excessive speeders would be expected to account for a relatively small proportion of the total speeding-crash problem since they are a small portion of speeding drivers, although such data were not reported in the study.

We also know that speeding can be dangerous on all types of roads and in rural and urban locations. Data from FARS indicate that 48% of speeding-related traffic fatalities occurred on roads posted at 50 mph or less and *nearly one-fourth of speeding-related fatalities (24%)* occurred roads posted at 35 mph or less (NHTSA, 2010, Table 121). In North Carolina, 29% of speeding-related crashes over the past six years (as identified through data-based definitions of speeding) occurred in urban areas with 71% in rural locations (defined as outside municipal boundaries).

Fatal and injury crashes increase with increases in speed and decrease when operating speeds are reduced (AASHTO, 2010; Aarts and van Schagen, 2006; Shinar, 1998). Speeding plays a complex role in crash causation by increasing the distance and time needed to perceive a hazard, process the information, and react to avoid a crash, *in the event that a conflict or triggering event that could result in a collision* occurs (Shinar, 2007).

The well-documented and accepted effects of speed on crash and injury severity mean that changing speed distributions will affect the severity and consequently “reportability” of crashes, and thereby the total reported crash frequencies, even if the “real” total number of crashes does not change (Hauer, 2009). For this and other reasons, much of the prior research into the relationship between travel speeds and crash frequencies has been called into question, yet there remain widely held beliefs based on conclusions from some of the earlier research (AASHTO, 2010). These conceptions may be difficult to change.

The Highway Safety Manual (HSM) adopts Hauer’s rationale that we must examine safety outcomes by the effects on distribution of fatal and injury crashes and forego attempting to predict changes in total crash numbers since we cannot (AASHTO, 2010). Crash modification factors (CMFs) for changes in average operating speeds on a roadway were developed for the recently released HSM, and show that small changes in average operating speeds may be expected to reduce fatal and injury crashes by substantial amounts (Figure 10).

In general, for a given average reduction or increase in speed, proportional effects are more pronounced for lower initial speeds than higher speeds (AASHTO, 2010). However, the expected reduction in fatal crashes from reducing average travel speeds by only 3 mph from 70 mph is 20% (Crash modification factor of 0.80) and 13% for injury crashes (AASHTO, Table 3E2, p. 3-57). If the number of fatal and injury crashes is significant on a roadway, then measures to reduce average operating speeds should certainly be considered.

Injury Crashes	$\overline{v}_0$ [mph]					
$\overline{v}_1$ - $\overline{v}_0$[mph]	30	40	50	60	70	80
-5	0.57	0.66	0.71	0.75	0.78	0.81
-4	0.64	0.72	0.77	0.8	0.83	0.85
-3	0.73	0.79	0.83	0.85	0.87	0.88
-2	0.81	0.86	0.88	0.9	0.91	0.92
-1	0.9	0.93	0.94	0.95	0.96	0.96
0	1	1	1	1	1	1
1	1.1	1.07	1.06	1.05	1.04	1.04
2	1.2	1.15	1.12	1.1	1.09	1.08
3	1.31	1.22	1.18	1.15	1.13	1.12
4	1.43	1.3	1.24	1.2	1.18	1.16
5	1.54	1.38	1.3	1.26	1.22	1.2

Fatal Crashes	$\overline{v}_0$ **[mph]**					
$\overline{v}_1$ - $\overline{v}_0$[mph]	30	40	50	60	70	80
-5	0.22	0.36	0.48	0.58	0.67	0.75
-4	0.36	0.48	0.58	0.66	0.73	0.8
-3	0.51	0.61	0.68	0.74	0.8	0.85
-2	0.66	0.73	0.79	0.83	0.86	0.9
-1	0.83	0.86	0.89	0.91	0.93	0.95
0	1	1	1	1	1	1
1	1.18	1.14	1.11	1.09	1.07	1.05
2	1.38	1.28	1.22	1.18	1.14	1.1
3	1.59	1.43	1.34	1.27	1.21	1.16
4	1.81	1.59	1.46	1.36	1.28	1.21
5	2.04	1.75	1.58	1.46	1.36	1.27

Figure 10. Injury (top) and fatal (bottom table) crash modifications expected from changes in average operating speeds (Reproduced from the Highway Safety Manual, AASHTO, 2010).
Effects are stated as multipliers, so effects less than 1 would reduce crashes.

While future research may lead to model adjustments in the predictions of safety effects of changing speed distributions for various types of roads, according to Hauer (2010), we currently we have less knowledge about how to design roads to achieve reductions in speeds that will in turn lead to reductions in severe injury crashes. These issues are not trivial, and may, in addition to other issues described in the next section, affect communications about the problem of speeding and the perceptions of drivers and road safety decision-makers and stakeholders themselves.

Countermeasures for Speed-related Crashes

The Haddon Matrix has been widely used as a framework for identifying pre-crash, crash event, and post-crash factors affecting safety outcomes (Shinar, 2007). Road user, vehicle, and environmental factors are the types of measures (columns) considered for each phase. A modified Haddon Matrix is adapted (slightly) from Shinar with general types of measures that affect road safety (with some additional speed-related factors added in italics). As Shinar shows surrounding his matrix (but Table 3 doesn't), these measures are further set within organizational structures, policies, norms and values and the prevailing culture(s). The context is important in selecting and designing the most-effective countermeasures, and implementing them successfully.

Table 3. Adapted from Table 18-1 (Shinar, 2007). A modified Haddon Matrix for traffic safety. Additional speeding-related crash-related examples were added in italic text.

		FACTORS AFFECTING SYSTEM COMPONENT		
PHASE	**GOAL**	**Road User**	**Vehicle**	**Environment**
Pre-Crash	Crash Prevention	Licensing, education, enforcement; *driver states*	Inspection of brakes, lights, tires, Crash avoidance/alerting systems, *other vehicle-based speed control (cruise control)*	Road design and layout, *speed limits,* high-friction pavement, speed calming, ,safety policy and goals, *built environment*
Crash	Injury prevention and reduction of injury severity	Use of restraints, impairment, driver *reaction*	Occupant restraints, air-bags, crash absorption, safety glass, padded interiors, *ABS, elec. stability control*	Crash absorption barriers, breakaway poles, elimination of roadside objects, hard shoulders, *Safety edge*
Post-Crash	Injury treatment, life preservation	Medical treatment and evaluation	Ease of extraction, fire prevention	Rescue facilities, evaluation lanes and recognized traffic control procedures in congestion, treatment procedures

In developing a strategic framework to help NC more effectively manage speeds and reduce trauma, we could adapt a Haddon Matrix concept to think about the causes of speeding (pre-crash), and other factors associated with speeding crashes and post-crash outcomes in order to help determine where along the causal chain from institutional practices to specific crash triggers, measures may be most effective. In general, measures that affect structures, laws and policies are more effective than those that rely only on voluntary compliance (Preusser et al., 2008). Additionally, if we want to target speeding and the trauma and severity of injuries as well as crashes that may result from inappropriate speed, then our focus will be largely on pre-crash user, vehicle, and environmental factors. The focus of this review is also on measures relating to crash-prevention.

In this review, a broad view of "speeding" that encompasses "too fast for conditions" as well as "exceeding limits" is used, following discussions with NCDOT. "Speeding" may result when there is a mismatch between the environment and the driver's speed choice that contributes to a crash due to any number of reasons that may be local or temporal in nature, or related to a broader mismatch between prevailing speed choice and conditions and context including inappropriate limits.

Setting Speed Limits

As noted already, there is substantial body of evidence that higher speeds lead to higher fatal and severe injury crashes. What is less well-known is how to achieve reductions in average speeds under different contexts. At a minimum, speed limits should be set to account for the function and environment of the road and the volume and mix of users (NCHRP, 2009; Speed Management, 2008). Although changing limits alone may sometimes have little impact, speed limits are known from a U.S. study to have the highest correlation with driver speed choice among a variety of roadway and environmental cues (Fitzpatrick et al., 2003a). Established limits ideally form the basis for roadway design and safe operations, although we could wish for tighter relationships than we currently know how to achieve. Speed limits also form the basis for enforcement of (ideally safe) speeds, and, for identifying treatments that may be needed to remedy discord between operating speeds and safety.

Speed limit review and adjustment

The common experiences of many drivers who exceed limits but do not crash, reinforces the perception that exceeding limits does not always lead to crashes. According to Harsha and Hedlund (2007), a survey by the Governor's Highway Safety Association (2005) confirmed that many police agencies also have enforcement tolerances considerably above posted limits. In addition, road designs have become much more tolerant, especially on higher-speed, higher-function roads so that higher speeds are more easily adopted, and "seldom" have unfortunate consequences. Thus, over time, the belief that most drivers are reasonable and do not want to increase their crash risk in choosing their speeds (and other probably historical issues) has affected practice and belief among law enforcement agencies, engineers, courts, and the public that, speed limits are not maximum safe limits/not to be believed (Harsha and Hedlund). Those driving within the 85th percentile of free-flow speeds are deemed to be reasonable drivers, even if those drivers exceed current limits by significant margins. Observational data from NCHRP 15-18 and many other studies confirms that only between 23 and 64 percent of drivers operated at or below the posted limit on non-freeway facilities. Unfortunately, we have some, but too little information on how the crash risk of those traveling above limits is affected, particularly with respect to NC roads, and when, where and for whom crash risk is increased.

A recommended measure to increase the perception that speed limits are set appropriately (or "rationally") has been to conduct a speed limit review and to adjust – that is most often, to raise - the speed limit to fit the prevailing travel speed distribution, generally using the 85th percentile as the norm (NCHRP, 2009). The expectation is that if drivers perceive limits to be reasonable they are more likely to obey those limits. In addition to guidelines offered in the NCHRP Guide for reducing speeding-related crashes, the US Limits tool (www.ustlimits.org) was developed to offer more specific guidance and a quantitative way to assess speed limit by developing a model that incorporates other factors such as the 50th percentile speed, level of pedestrian/bicycle activity, presence and usage of on-street parking, number of driveways and traffic signals, presence of roadside hazards, presence of median, terrain, number of interchanges (in freeways), and crash statistics. In fact a national study found that agencies were often considering a number of these other factors prior to US Limits, although perhaps not in a structured or quantitative way, and set a majority of sites 5 mph or more lower than the 85th percentile speed (Fitzpatrick et al., 2003a). States were adjusting for contexts such as pedestrian volumes, number of intersections, crash history, and so forth. Political pressures also play a role in selecting limits.

Research is underway to provide evaluations on setting and enforcing rational limits in the U.S., but at the present, only a preliminary study from Minnesota is available. Thus, while it seems reasonable to expect that reviewing, adjusting if appropriate, and *enforcing* what are often called “credible” or “rational” speed limits can actually tighten or even shift travel speeds downward, and improve safety in the short term, it is not clear what the long term effects of this approach are, especially if enhanced enforcement is not maintained over time. It is clear that raising limits on a system-wide basis, at least, results in higher speeds and more severe crashes. We should give careful consideration to the fact that raising speed limits may contribute to “speed creep” (Hauer, 2009), especially if enforcement measures and publicity are not sustained to maintain speeds relative to the new limit. [Note in that several recent trials of rational speed limit setting have found that enhanced enforcement is very rarely maintained and speeds nor crashes have changed much.] A careful assessment should be made of which roads, and whether the system as a whole, will have safety benefits. System-wide monitoring of travel speeds does not currently occur in NC, so it is impossible to track trends in speeds along with changes in safety.

If there is a lack of synchrony between speed limits and a majority of drivers’ operating speeds, in actuality, there are also other choices available besides raising limits. The roadway can also be modified to bring it more in line with the context, users and safe operations (Goldenbeld and Schagen, 2007). In addition, enforcement of the current limits (and supporting publicity) might be increased. We are only aware, however, of examples where speed limit review has been followed by raising the limit, combined with planned enhanced enforcement of the new limit, *at least for the short term.*

What triggers a speed limit review is not, however clear. According to NCHRP (2009), *A Guide for Reducing Speeding-Related Crashes*, MUTCD offers limited guidance on what triggers a review of posted limits, suggesting a review of non-statutory speed limits on roadway segments that have undergone significant changes in roadway characteristics or surrounding land use since the last review. Agencies might also consider a review based on crash experience, particularly a prevalence of high-severity crashes.

Variable speed limits

There are currently promising evaluations underway, particularly with the use of variable limits on urban freeways, but as yet, these countermeasures are not yet considered proven. But such a measure is in line with efforts to improve credibility of speed limits and communicate with drivers about the “reasonableness” of limits as conditions change.

Differential speed limits

Generally, there is greater speed variation on uncongested and higher-speed roadways and less variability on lower-speed roads (Preusser et al., 2008). Speed dispersion on a roadway has been linked to higher crash risk in some studies. When large trucks have different speed limits and speed limiters, (and some do not) greater speed variation may result under higher-speed, free-flowing conditions. We are uncertain at present whether research shows that such variation does increase and has positive or negative safety effects.

Lower speed limits

Reducing speed limits on higher speed roads reduces traffic fatalities (NHTSA 2011) at least on a system-wide level. Reduced travel, and slower and more uniform speeds resulting from lowering of the National Maximum Speed Limit in 1974 were judged to have saved between 3,000 and 5,000 lives, nationally. Although reductions in speeds are generally a fraction of the change in speed limit, the shifting downward by a slight amount by many drivers has a large effect on crash reductions. When the NMSL was repealed in 1995 and States began raising limits on higher-speed roads, increases of about 4 mph in average and 85^{th} percentile speeds and statistically significant increases in fatalities resulted on these roads (NHTSA, 2011).

According to Preusser et al (2008), reduced speed limits in urban areas results in a 25% reduction in pedestrian injury and significant cost savings, but there is some debate overall about effectiveness of lowering limits in urban areas. In a case-comparison study, Australian researchers concluded that speeds only 5 km/h (3.1 mph) above average speed in an urban setting (Adelaide, Australia) and 10 km/h (6.2 mph) in rural areas were enough to double the risk of a casualty crash (Kloeden, et al 2002). In addition, models show that most speeding vehicles are traveling within ranges that are within enforcement tolerances. Depending on the specific assumptions, a 25 to 70% reduction in free speed injury crashes was estimated for a 10 km/h (6 mph) reduction in the speed limit. Hauer (2004) critically reviewed this study and made two observations: (1) Results from case control studies can be biased because of the possibility of confounding. To reduce this bias, controls are selected to match the cases. However, in this study, "there was no matching between the Controls and Cases on the potential confounders of age, gender, car mass, and number of occupants", and hence the results "are vulnerable to plausible confounding." (2) Relative risk was calculated based on two speed estimates: one was based on speeds measured by a laser speed meter, and the other was based on crash reconstruction approaches. This difference in precision introduces a large systematic bias in the results and "tends to produce a U shaped relationship between estimated relative risk and speed even when the true relationship is entirely flat." A 2006 evaluation of a default 50 km/h (31 mph) limit in place since 2001 suggested that urban injury crashes had a sustained reduction of around 12% compared with 60 km/h limit (37 mph), although the effect was longer lasting for more minor injury crashes (Hoareau, Newstead, & Cameron, 2006).

The State of Victoria, Australia also implemented a comprehensive effort to reduce speeding and crashes that enhanced hours of covert, mobile speed operations, a reduced camera speed detection threshold, a media campaign, and penalty restructuring, and over the same time period, included a reduction in urban speed limits from 60 kph to 50 kph (from 37.3 mph to 31.1 mph). An evaluation estimated that this comprehensive effort reduced injury crashes by 10% and fatal crashes by 27% (D'Elia, Newstead, & Cameron, 2007 and NHTSA, 2011). However, note that Victoria enhanced *enforcement and reduced enforcement tolerances, which may be a key to ensuring "credibility" of the new speed limits.*

Enforcement

Enforcement of speed limits works to reduce speeds and crashes (TRB, 1998; NHTSA, 2011). Unfortunately, both the time and distance halos of enforcement are relatively small and effectiveness extent depends on the level of enforcement, supporting publicity, and potentially other factors (Hauer, 2010). To reduce the chances of traffic and crash spillover onto other roads, provide crash reductions, and provide system-wide deterrence of speeding, some combination of mobile, covert, and conspicuous, or highly visible enforcement, with publicity seems essential. Thus, enforcement must be frequent and wide-spread and somewhat random, or at least be perceived by most drivers as being so, to have the population-wide effects needed to reduce average speeds and have a large effect on crashes. How to achieve the perception of widespread enforcement may vary. Studies prior to the 1990s concluded that the most successful programs were those deployed at specific locations and times when speeding or speeding crashes were most likely to occur, were made highly visible to the public, and were maintained for more than a year (TRB, 1998). How to accomplish a sustained impression of widespread enforcement under current traffic, roadway, and enforcement capacity is a challenge.

An effort was undertaken in the State of Queensland, Australia specifically to achieve a sustainable and widespread implementation that targeted a large set of the crash problem. The program combined randomly targeting high crash zones or road sections for enforcement for two hour periods between 6 am and midnight with marked and parked police vehicles, and issuing tickets when offenses were detected (Newstead, Cameron, & Leggett, 2001). The program was estimated to reduce fatal crashes by 31% and provide a significant savings of 12% of the entire State's crashes by the third year of the program's implementation. Thus, in addition to the crash reduction, there seems to have been a sustainable effort as well.

Automated enforcement

In these days of government austerity measures and decreased budgets in the face of rising travel and traffic, the ability to sustain enforcement at a level needed to deter speeding on a wide scale is seriously undermined. Automated enforcement should be considered as a supplement to regular traffic enforcement that may be applied widely, increasing the perception of widespread enforcement, or targeted to high-speeding crash zones. Automated speed enforcement works to reduce speeds, crashes, and injuries (Decina, Thomas, Srinivasan, and Staplin, 2007; Pilkington and Kinra, 2005; Wilson, Willis, Hendrikz, and Bellamy, 2006). In a critical review of the safety effects of automated speed enforcement programs, Thomas, Srinivasan, Decina, and Staplin (2008) concluded that application of conspicuous, fixed camera, speed enforcement yielded injury crash reductions in the range of 20 to 25% around camera speed-enforced sites relative to comparison areas (and controlling for other confounders). Mobile, covert jurisdiction-wide programs were also found to be effective at reducing injury crashes by around 20 to 25 percent area-wide, particularly in urban areas (Thomas, et al., 2008). A wide range of site-specific reductions have also been reported for mobile, but conspicuous speed camera enforcement programs, and results may vary according to intensity, publicity, signing, and other program parameters.

Automated speed enforcement (ASE) may enhance regular speed enforcement efforts by officers in that it may be used at times and in locations that are difficult to enforce by regular traffic enforcement methods. In addition, automated methods are efficient and cost-effective – ASE programs may pay for themselves and other desirable public programs as well as the direct crash savings (Hauer, 2010). In addition cameras are inherently objective (as long as properly calibrated and maintained) in that a pre-set speed triggers the camera and ticket, although some opponents object to not being aware of the ticket immediately (Delaney, Ward, Cameron, and Williams, 2005). As hinted, automated enforcement methods suffer from being controversial, a prime complaint being that they are about revenue, and not safety. Although a survey by the Insurance Institute of Highway Safety suggests that a majority of U.S. drivers support the use of speed cameras (32% strongly in favor, 22% somewhat in favor), an apparently vocal minority of about 28 percent of drivers are strongly opposed, with 15% somewhat opposed (Delaney et al.). There has been very limited success at implementing and sustaining programs in the U.S., although several national guides on establishing and operating automated enforcement programs have been developed.

A finding in Great Britain was that the way the programs were initially structured - the fine revenues went to general government funds rather than to the police agencies that operated them – was a disincentive to further implementation and improvements. There was little incentive to increase camera use to an optimal level because the greater costs of increased implementations were borne by the police agencies and courts (Delaney et al., 2005). We have heard similar comments from Charlotte, NC officials – that if the program costs for a now defunct mobile, speed-camera program could not be recovered – they would not pay for such a program out of scarce, local policing funds. A cost-recovery scheme was put into place in Great Britain that allowed the local agencies involved in the automated enforcement process to have program operating costs covered by a portion of fine revenues. Partnerships and program guidelines were put into place. Guidelines included: placing cameras at locations with a history of speed-related crashes, programs must include a strategy on education and communications, enforced zones must meet camera conspicuity requirements and enforced locations must be identified with signs, publicity and other measures. Great Britain's program has been highly successful at reducing speeding-related crashes at camera sites (Thomas et al, 2008) and the government maintains a clear position that speed cameras are operating to reduce crashes as a benefit to society. Apparently the percentage of drivers that support speed camera use has remained relatively unchanged over time at about 75 – 80% of the country's drivers. In addition to the costs saved through crash reductions, France's widespread automated speed enforcement program also pays for itself and is not a burden on the public coffers (Hauer*,* 2010).

A recent U.S. evaluation of a fixed-camera speed enforcement demonstration project on a 6.5 mile Scottsdale, AZ freeway found that average speeding detections increased by a factor of 10 after the program had been implemented and was temporarily suspended (Shin, Washington, and van Schalkwyk, 2009). This high-quality study also used three methods (with varying levels of control for confounders) to evaluate crash effects. The range of effect estimates were from 44 to 54% reductions in total target crashes with estimates of 28 to 48% in injury crash reductions. Shin et al. also provided detailed estimates of the safety benefits to Arizona of approximately $17 million, accounting for specific changes in crash types, and expected costs of these crashes adjusted to Arizona specific costs. The costs included comprehensive medical; other direct costs (police, fire, rescue, lost wages, legal, property damage); and comprehensive quality of life valuations.

Two pilot automated enforcement programs have been evaluated in North Carolina. A three-year mobile, automated speed enforcement program was legislatively approved for 14 corridors in Charlotte, NC in 2003. The "Safe Speed" program began issuing tickets on August 1, 2004 and continued until 2006 (Cunningham, Hummer, & Moon, 2008). A variety of media including radio, television, and flyers disseminated by the City were used prior to the ticketing phase to make the public aware of the pending speed enforcement effort. Cunningham, et al. estimated that the program was responsible for a reduction in total collisions of around 14% on the enforced corridors. The five most heavily enforced corridors, which accounted for about 90% of all citations issued by the program, yielded reductions in the higher range. In addition the analysis found reductions in mean and median speeds of from 0.67 to 0.8 mph, and reductions in 85th percentile speeds of from 0.77 to 0.91 mph. The proportion of vehicles traveling greater than 10 mph above the speed limit was 55% lower at one year after operation and 23% lower at two years after. The speed reductions documented provide additional support for the crash reductions found.

A pilot, automated speed enforcement program utilizing warning letters only was previously implemented in Iredell County, NC (Hunter, Thomas, and Stewart, 2001). Iredell was selected for the pilot effort because it had an extensive rural, speeding crash problem relative to other counties in the state. The program included use of conspicuous, mobile camera-radar enforcement and issuance of warning letters; enhanced, highly conspicuous, cooperative targeted speed enforcement efforts; print ads, billboards, public service announcements and earned media as well as efforts to implement stricter court punishments for speeding citations, particularly repeat offenders. Downward trends in the proportions of excessive speeders and reductions in mean speeds were observed for some road types in Iredell County, while no downward trend was observed for similar roads in a neighboring comparison county over the same time period. In addition, a convenience survey found that drivers in the community were well-aware of the program, and 77% of those surveyed in a convenience sample were supportive of automated speed enforcement. No crash-based evaluation was possible.

Both the Charlotte program and the Scottsdale, AZ program, although effective, have been dismantled for non-safety reasons. The continuing political and public relations challenges to establishing and maintaining effective speed enforcement programs (by automated or traditional means) are a key barrier for many states to overcome. A sustained, strategic research and implementation effort in Australia (with a culture, perhaps, fairly comparable to that in the U.S.) into the effectiveness of automated speed enforcement programs and the components of those programs (e.g. publicity, overt and covert deployment strategies, enforcement thresholds, and sanctions) has also led to important lessons that may be applicable here (Delaney, Ward, Cameron, and Williams, 2005). Australia, for example, has used a mix of administrative and judicial-based penalties for infractions detected through photo-enforcement, based on the severity of infractions. A current NCHRP study (Project 3-93) seeks to elucidate operational and program characteristics associated with successful implementations of automated enforcement programs in the U.S (Eccles, lead investigator, personal communication).

If the barriers to implementation of speed enforcement initiatives could be overcome, and the costs of effective safety programs could be recovered or used to enhance other safety efforts (which could include additional enforcement, infrastructure, education, or other public value programs), the political will to address this public safety issue could rise in NC as it has in other countries (Hauer, 2010). While perceptions often exist that the public does not support automated enforcement, surveys have shown that a majority often do support automated speed enforcement (IIHS, 2009). We, however, lack data specifically from North Carolina except the small study from Iredell County. Publicity and communications strategies that address concerns and keep the focus about safety may help improve acceptance among those on the fence. A current program operating in Portland, Oregon school zones has adapted such strategies to sustain an ASE program (Eccles, personal communication).

Tighten enforcement tolerances

The safety effects of the sort of sanctioned, and largely undetected speeding from 1 to 11 - 15 mph above the limit, cannot be assessed at the moment in the U.S., since crash data lack good information on pre-crash travel speeds, few agencies are collecting such data at a roadway level, and there are few prior clinical or case-controlled studies that have good pre-crash travel speed estimates. As mentioned above, Victoria, Australia has been successful with a program that included tightened enforcement tolerances as part of an overall speed management package that includes and various forms of enforcement, publicity, and penalty restructuring (D'Elia, Newstead, & Cameron, 2007).

Driver licensing and sanctions

Driver licensing control and sanctions are part of the overall enforcement "package." And consistent treatment of infractions is considered by most experts to be important to upholding and reinforcing a public perception that speed limits are sensible, and that limits are to be obeyed. However, there is uncertainty regarding the effectiveness of particular sanctions for particular situations or indeed whether differing penalty outcomes actually affect future speeding and crashes. The certainty of punishment may be more important than the intensity (Shinar, 2007)

Masten and Peck (2004) reviewed the evidence for effectiveness of a wide variety of driver improvement and driver control actions, including various penalty levels and types all the way to warning letters, from 35 high-quality studies. They found that, taken together, all actions and penalties reduced subsequent crashes by 6% and violations by 8%, with effectiveness increasing as "obtrusiveness" of the action increased, but this might be expected since suspensions and revocations cause at least some suspended drivers to actually stop driving. However, even warning letters had some effect, presumably based on the threat of more severe sanctions. In a study of North Carolina Fatal and A-type crashes, having a suspended license at the time of the crash actually was associated with an increased risk of a driver being at fault in a crash (Thomas, Masten, and Martell, 2008). Additionally, there are no studies showing that diversion programs that allow the offender to escape sentencing or begin with a clean slate are effective, and substantial evidence that such programs may work to increase crashes or increase recidivism, as with alcohol use (NHTSA, 2011; Masten and Peck).

Other research evidence is more mixed, however, regarding the effect of increasing sanctions or level of penalties on drivers' choice to speed and subsequent crashes (NHTSA, 2011). Certainly some drivers, including repeat offenders may be difficult to deter. Improved traffic records systems (so law enforcement may immediately access driver records), enhanced penalties, and provision of alternate transportation are among the strategies recommended to deter repeat offenders (NHTSA, 2011; NCHRP 2003), but effectiveness evidence for these measures is lacking.

Engineering - Modify the Roadway

Traffic calming measures are effective at reducing driver speeds and crashes. As discussed in the HSM (Tables 14-3 and 14-4), ***roundabouts*** (replacing signalized and stop control) are associated with a significant reduction in crashes (especially injury and fatal crashes). The reduction is more pronounced at rural locations where speeds are typically higher before the roundabouts are implemented. For example, the conversion of a minor-road stop controlled intersection in a rural area can be expected to reduce total crashes by 71% and injury and fatal crashes by 87%. When a similar conversion is done in an urban area, the expected reduction in is 39% in total crashes and 78% in injury crashes if the outcome is a single lane roundabout (the reductions were not significant for two lane roundabouts possibly because of the limited sample of sites that were included in the evaluation). When signalized intersections are converted to roundabouts in urban areas, the expected reduction in injury crashes is 60% with no expected reduction in total crashes. When a similar conversion is done in suburban areas, the expected reduction in total crashes is 77% (results were not available on the expected reduction in injury and fatal crashes for suburban sites). More recent work using a larger sample of sites where signalized intersections were converted to roundabouts confirms that suburban sites are expected to experience a larger reduction in crashes compared to urban sites (Srinivasan et al., 2011). Roundabouts are considered by FHWA (2008) to be a proven safety measure.

Other vertical and horizontal traffic calming devices (chicanes, bulb-outs, mini-traffic circles; speed humps, tables) also reduce speeds, crashes and injuries on low-speed streets (Mountain, Hirst and Maher, 2005; Elvik and Vaa, 2004) although the Cochrane Collaboration found that there is significant heterogeneity of results and that more research is needed (Bunn et al., 2003).

Recently, Srinivasan et al. (2010a) found that transverse rumble strips on approaches to stop controlled intersections in rural areas can result in fewer severe injury and fatal crashes (i.e., KAB and KA crashes). Considering that some other studies (e.g., Harder et al., 2001; Harder et al., 2006; Fitzpatrick et al., 2003b) had found reductions in speeds due to transverse rumble strips, it could be argued that the reductions in KA and KAB crashes may be due to reduced speeds.

Harkey et al., (2008) evaluated the safety of converting four lane, undivided roads to three lane roads with a two way left turn lane (TWLTL) (also called road diet). Data from 15 locations in Iowa and 30 locations in Washington and California were utilized. The locations in Iowa experienced a 47 percent reduction in total crashes, whereas the locations in California and Washington experienced a 19 percent reduction in total crashes. When the data from all these locations were combined, the reduction was estimated as 29 percent. Speed data were not available for this study, but there is significant evidence to indicate that road diets have a calming effect leading to lower speeds (Knapp and Giese, 1999; Gates, Noyce, Talada, and Hill,2007) particularly more excessive speeds (Knapp and Giese, 2001). The extent of speed reductions may depend on operational conditions, extent of turning movements and other factors, but road diets generally mean that the lead vehicle or more moderate drivers set the pace helping to reduce the percent exceeding by a high margin once the other lane in each direction have been eliminated.

The locations in Iowa were predominantly US and State routes passing through small urban areas (average population of 17000), whereas the locations in Washington and California were predominantly in suburban areas surrounding large cities (average population of 269,000). Regarding the reasons for the different estimates, the authors speculated that while there could have been significant differences in speeds between the rural U.S. or State highway approaching a small town and the road diet section, this calming effect would likely be less in the larger cities in the California and Washington data, where the approaching speed limits (and traffic speeds) might have been lower before treatment.

Gross, Jaganathan, and Hughes (2009), evaluated the impacts of lane narrowing on major roads at two-lane two-way stop controlled intersections by the introduction of milled rumble strips on the outside shoulders and in a painted yellow median island on the major road approaches. The treatment was implemented in 10 sites in Pennsylvania, Kentucky, Missouri, and Florida. The lane width before the treatment was 12 feet. After the treatment, the lane width varied between 9 and 10.5 feet. Following the implementation of the lane narrowing treatment, speeds decreased by an average of 3.5 mph for all vehicles, and an average of 4.4 mph for trucks. The safety evaluation involved the comparison of rates of crashes (crashes divided by million entering vehicles at the intersection) before and after the implementation of the treatment. The simple before-after comparison found a 31% reduction in the rate of total crashes (not statistically significant at the 0.05 level) and a 20 percent in the rate of reduction injury and fatal crashes (statistically significant at the 0.05 level). The authors indicated that the state of the art empirical Bayes method was not used due to the limited sample size and limited after periods. Hence, it is possible that the results are biased due to various reasons including the regression to the mean and other trends. Hence, the results should be treated with caution, but the lowering of speeds provides support for the crash reduction effects.

Ray et al., (2008) also recently developed guidelines for the selection of speed reduction treatments at high-speed intersections (intersections where the speed limit on at least one of the approaches is 45 mph or higher). The treatments discussed included:

- Dynamic warning signs,
- Transverse pavement markings,
- Transverse rumble strips,
- Longitudinal rumble strips,
- Wider longitudinal pavement markings,
- Roundabouts,
- Approach curvature,
- Splitter islands,
- Speed tables and plateaus,
- Reduced lane width,
- Visible shoulder treatments, and
- Roadside design

Guidelines were developed based on results from published literature and field studies on the first three treatments (dynamic warning signs, transverse pavement markings, and transverse rumble strips).

Srinivasan et al. (2010b) examined the safety impacts of improved curve delineation using data from Connecticut and Washington. Washington implemented chevrons only, but Connecticut implemented a combination of treatments including chevrons, advance warning signs before the curve - in some cases chevrons were added to the ones already existing. Non-intersection lane departure crashes during dark conditions were found to decrease by about 25 percent as a result of improved delineation. Speed related crashes were not specifically investigated but since a significant number of lane departure crashes tend to be speed related, it is possible that speed related crashes decreased due to this treatment, especially during dark.

Additionally, the Safety Edge treatment, in addition to median barriers, center-line and shoulder rumble strips, are among measures considered by FHWA to be a proven safety treatment by helping drivers who have run off the road to recover, with an estimated reduction in crashes of about 6% (FHWA, 2008). This measure is unlikely, however, to reduce driving speeds.

As touched on previously, a strong relationship is needed between design speed, speed limit, and operating speed (Fitzpatrick et al., 2003a). Although drivers take cues from the roadside and geometry as to appropriate driving speeds, occasional, minimally-designed features in otherwise high-design-speed roads, may have negative safety consequences (Donnell, et al., 2009b). Spot treatments, such as enhanced curve delineation, have had good success (Srinivasan et al., 2010b); use of warning signs alone is less certain. Consistency of design is likely to be a more reliable safety measure than use of signs to treat problem spots (AASHTO, 2010).

Research is increasing in the U.S. to identify what factors will induce drivers to drive at lower speeds or how to achieve desired operating speeds from the outset. But it is clear that more guidance in how to change roadways or design new entire roadways to achieve safer operating speeds and smooth flows is needed (Donnell, et al., 2009b, Hauer, 2009). The AASHTO Green Book is the key reference for roadway design engineers tasked with planning and designing new roads or redesigning existing roadways, and it exhorts designers to use greater than minimal values for the designated design speed. What was intended by the designer as an extra margin of safety – the exceeding of minimal design criteria – may be counteracted by drivers' higher speed choice based on their perception of the road as constructed (Donnell et al., 2009b).

Researchers in the Netherlands are also carrying out work aiming towards developing a predictable and recognizable road layout. A core principle of the Dutch road safety vision includes the principle of predictability. Related to this principle, is the principle "functionality of roads," and that road layouts facilitate homogeneous use in "speed, mass, and direction." One of the objectives of the research is to create design consistency within the same functional class of roads or what is more widely known as "self-explaining roads" (Stelling-Konczak, Aarts, Duivenvoorden, and Goldenbeld, 2011). Research aims at providing better cues of features that drivers use to distinguish between different functional road classes and whether the cues that drivers use are also sufficient to recognize transitions from one type to another. Such research in a North American context could help to identify measures to improve driver expectation (and comprehension of expected speeds), in the currently diverse operating environment where road characteristics/design and speed limits often have little obvious relationship. Efforts are currently underway to assess effective high speed to low-speed transition zones for rural highways in the U.S through an NCHRP synthesis project, and through NCHRP 15-40 which aims to offer design guidance. The reviewers are also aware of several current projects underway in urban areas.

<u>ITS and Vehicle Technologies</u>

Other measures may be effective, particularly in the right situations (managers of fleets, employers, large numbers of trucks or others with radar detectors) including:

- Drone radar (NHTSA ,2011).
- Unstaffed speed display devices may work over short distances and times but effects usually quickly disappear once the devices are removed (NHTSA, 2011).

- In-vehicle driver warning systems, as well as in-vehicle monitoring technologies that allow “instant” driver feedback and rewards may work for some drivers (NHTSA, 2011).
- Speed limiters are currently being used by most larger truck fleets, but smaller companies/operators are less likely to have adopted such measures (Hughes, personal communication).
- Effective use of variable message signs to warn of changing conditions may help reduce “too fast for conditions” types of crashes.

Measures by employers, such as the military or even rental car agencies, who have some control over drivers and fleets, may also be able to reduce speeding among particular groups.

Public Information and Education

Persuasive communications are an essential part of successful speed enforcement programs. The objective should be to educate drivers about the program, and most importantly persuade them that detection and sanctions are likely (NHTSA, 2011). Additionally, media may be used to publicize new laws or enforcement strategies.

The Monash University Accident Research Center has conducted a number of evaluations on both the combined and separate effects of enforcement and publicity campaigns and found crash reduction effects associated with the level of publicity, independent of the amount of enforcement (Delaney, Lough, Whelan, and Cameron, 2004). Australia’s initial campaigns were designed to reach a broad audience and were sponsored by the Transport Accident Commission (TAC), the national automotive insurance corporation. Australian researchers conclude that emotive campaigns are more successful than informational-style campaigns (Delaney, Lough, Whelan, and Cameron). But, a key feature of these campaigns has incorporated mention of the enforcement effort at the end of ads (e.g. speed cameras, reduced speed threshold - “shave off five,” etc.). Recent campaigns have aimed at arousing remorse or regret for speeding behavior. Fear-arousing messages alone may backfire, especially with younger drivers (Child Fatality Task Force, 2012) or if they do not show how to alleviate the fear aroused in a way that specifically reinforces the desired behavior (Job, 1988). The complexities of developing a potentially effective fear-based campaign are numerous. For these reasons, fear-based campaigns should be avoided at the present time.

A Norwegian review of 45 anti-speeding campaigns provides descriptions and highlights target audiences, messages, and media used in the campaigns, although safety evaluations are not available (Phillips and Torquato, 2009). Young males were targeted by a large share (24%) of the campaigns; all drivers in 16%; urban drivers in several, and in 36% no target group was apparent according to the summary.

Characteristics of communications measures likely to be effective include those where the safety messages have been carefully pre-tested with the target group, and that reach the target audience with sufficient intensity and duration to be perceived and remembered (Preusser et all, 2008). The “messenger” may also be important. Also communicating “new knowledge” for which there is a specific remedy that drivers may adopt may be effective. Perhaps communicating about how to safely negotiate a roundabout, or the reasons for heeding variable speed limit signs (if used) are examples. NHTSA has recently enhanced information on branding and more effectively marketing traffic safety using principles that work in advertising other “products” (http://www.trafficsafetymarketing.gov/).

There are some cases where communicating effectively about the problem may also assist in shifting public and political willingness to adopt safety measures. Political support is needed to sustain traffic safety programs (whether or not they cost public money), and public opinion may help to shape political support. There are many caveats in how best to do this to attract support and resources. One of the keys of France's success in implementing a widespread and effective automated enforcement program appears to be that the French began to take road safety more seriously. During a period in which statistics on injuries due to motor vehicles was publicized, the public and decision-makers were convinced that traffic injuries were a serious public health problem even though no new measures were implemented during this phase (Hauer, 2010). The political and administrative will to take action seemed to follow and occurred in a top-down fashion as the country's president adopted road safety as a priority. The automated speed enforcement program brings in more money than it costs, and so has not been a public economic burden in France (Hauer 2010).

According to Hauer's (2010) review of French road safety policy, and a review by Chapelon and Lassarre (2010), France has made strides in developing a science-based road safety policy that is founded on 1) reliable and very current information (including crash data, exposure data, measurements of speeds, alcohol, mobile phone use and other risk factors), 2) estimates of risk attributable to such factors, and 3) managing risk by setting benchmarks, policy-making and monitoring. *Policy is currently set with input from science provided by a small panel of experts.*

As far as driver training, however, there has yet to be research demonstrating driver training methods that effectively work to prevent driver risk behaviors such as speeding (Shinar, 2007). As mentioned previously, children are the easiest target audience with respect to teaching voluntary compliance with safe norms of behavior, but since children don't actually drive, it is unknown whether comprehensive traffic safety education programs that start at an early age can make a difference when or if the individuals do actually become drivers. Certainly, learning about traffic and roadway systems is a life-long process from learning how to walk and cycle safely as children to learning to accurately perceive risks and interact safely on the roadway network through all life stages. According to Shinar, there *is* consistent research showing decreasing driver crash risk associated with general levels of education, but these factors tend to be confounded with other demographic factors.

<u>Data</u>

Timely and accurate speed data are used in evaluating treatments and setting and assessing performance targets. Speed data provide earlier feedback on risk trends and program performance than crash data. The Global Road Safety Partnership recommends developing "core speed-monitoring sites" that, in addition to speeds, would ideally measure traffic flows and vehicle types (heavy truck volumes) which would allow assessment of traffic migration to other sites as well as roadway wear (Speed Management, 2008).

Travel speed data have not been routinely and consistently collected (or stored in a useful format) since repeat of the National Maximum Speed limit in 1997 (Harsha and Hedlund, 2009). State and national agencies have a role to play in helping facilitate understanding and treatment of the problem by participating in new studies, collecting and storing speed data, collecting and compiling roadway inventory, crash and other data, in ways that maximize their utility for answering important research questions. Local agencies cannot collect and compile the data needed on their own.

Cost-benefit assessments of the expected benefits resulting from improvements in data and risk assessment are lacking as indicated by a recent review for FHWA. However, cost-benefit analyses while deemed by some to be important in setting road safety priorities, may suffer by discounting future lives that may be saved by current investment in data quality (and other improvements) as well as inadequate consideration of all costs and potential benefits (Hauer, 2011 TRB Annual Meeting presentation).

Expected costs and benefits inherently have different values to different stakeholders, and it is not clear that safety priorities should be established through strict, but flawed “accounting principles” without better-reflecting public input and values. These concerns pertain to all aspects of safety investment, not only to investment in improved data collection and analysis. Due to the perceived trade-offs between mobility (speed) and safety, soliciting public opinion on the issue may be especially important.

Roadway inventory and other data also need to be updated routinely so that problem identification and screening will have maximal utility and accuracy.

Policy

A successful speed and safety program hinges on 1) accurately identifying the problems (a goal of the present research), 2) knowing what types of interventions may effectively address the problems (also an objective), and 3) being able to successfully implement those measures. The third element may be the most limiting. For successful implementation, there must be the know-how, the ability (resources and capacity available), *and* the willingness to implement the appropriate measures (Wegman, 2007).

The science is crucial for the first two elements above. However, many of the aims such as reducing overall road trauma are inherently policy/political decisions to some extent, and these decisions are not made by scientists, although scientists may certainly influence policy (Hauer, 2010). Furthermore, policy goals may change over time. The role of professional practitioners including traffic engineers, transportation planners, urban planners, highway designers, and other professionals is also stressed by Hauer. Professional practice is strongly influenced by training, traditions, and the tools in these professionals’ safety tool boxes. Researchers can better aid practitioners by providing the most up-to-date and crucial information on tools, methods, and knowledge in formats that are most easily utilized.

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Appendix II – Problem Description: Speeding Crash Relationships and NC Speed Management Issues

Crash Analyses

Data from North Carolina's State crash files were compiled and analyzed with respect to factors associated with speeding-related crashes. The crash-based definitions of speeding (speeding-related) used are based on whether one or more drivers were cited for contributing to the crash by exceeding limits (EL) or exceeding safe speed for conditions (ESSC). Driver-level examinations were also conducted using the same indicators for individual drivers' speeding-involvement in the crashes.

A variety of tables were developed and examined to aid understanding of the specific factors that are most highly represented in speeding-related crashes compared to non-speeding-related crashes. However, in determining treatments, it is also important to focus on where, when, and driver characteristics associated with the largest numbers of speeding-related crashes, regardless of whether speeding is over-represented. In addition, uncertainty regarding crash-based definitions of speeding suggests taking a broad view of the problem of speeding. Since we do not have data on actual speeds of vehicles prior to the crashes, nor speed distributions by roadway nor comparisons of crash-involved and not-involved drivers, we have incomplete knowledge of the role that exceeding limits by various amounts may play in increasing crash severity and crash occurrence in different types of locations and under varying conditions.

Data and Methods

The following summary statistics come from analyses of North Carolina (NC) State crash files developed from all crashes reported by State and local agencies across NC. During the six years from January 2004 to December 2009, more than 1.3 million crashes were reported to the NC DMV, involving approximately 2.2 million drivers. This report summarizes basic crash statistics and crash factors associated with speeding-related crashes and drivers/vehicles as contained in the NC crash database.

Definitions. The definitions of speeding used in the descriptions below are from driver contributing circumstances cited by the investigating agencies and contained in the crash data tables. At a crash level, and in most of the descriptions following, a speeding-related (speeding-related) crash is a combined definition resulting when any driver in the crash was cited for one or more speed-related (speeding-related) contributing circumstances – specifically, exceeding limits (EL), exceeding safe speed for conditions (ESSC), or both. In NC, investigating officers use their judgment to determine and indicate up to three contributing circumstances for each driver involved in the crash.

The driver contributing circumstance, "failure to reduce speed" was not included in the definition of speeding used in these comparisons at the study sponsor's request; the belief is that this indication more often reflects inattention or distraction leading to a failure to slow or stop in time as opposed to an obviously inappropriate speed for conditions or exceeding limits prior to the critical crash envelope. It is unknown how accurately the subjective determinations of EL and ESSC reflect the role of speeding in crash occurrence and severity, but at the present time, they are the best crash-based definitions available. There are clearly differences in distributions of the two definitions by severity of crashes and other factors. The contributing circumstance indications may be somewhat more considered definitions for crashes involving fatalities where more in-depth crash investigations occur than for other severity of crashes. When individual types of speeding (ESSC, EL, or both) at a driver level are being discussed, these specific definitions will be indicated. Only the combined definition was used in crash-based tables, since multiple drivers can be cited for multiple types of speeding within a single crash.

Six Year Speeding-related Crash Trends

From 2004-2009, an average of 11.5% of NC's more than 220,000 crashes per year had at least one driver who was indicated to contribute to the crash by improper speed (Table 4). Reported crashes in general decreased in number since 2007, and the number of speeding-related crashes also declined. Despite year-to-year fluctuations, the average proportion of crashes that were speeding-related decreased from an average of 12.2% for the first three years (2004-06) to 10.6% for the latter three (2007-09). However, the 23,896 crashes that were speeding-related in 2009, the latest year currently available, constituted a rise in both number and proportion from 2008 as well as a rise in the speeding-related crash rate per VMT.

The bottom three rows of Table 4 show VMT estimates, and calculated speeding-related and total crash rates per 100 million VMT for the study period. Note that there were 5606 fewer speeding-related crashes in 2005 than in 2004 and 3191 fewer non-speeding-related crashes in 2005 than in 2004. Thus the drop in reported speeding-related crashes accounted for 64% of the total decrease in crashes reported between those two years, even though speeding-related crashes accounted for less than 15% of the total. Again, there was a drop, of 2781 reported speeding-related crashes between 2005 and 2006, while non-speeding-related crashes actually increased slightly. Whether these drops reflect an actual decrease in speeding-related crashes or may reflect changes in reporting and other factors over time is not entirely clear.

Table 4. Six year trend of North Carolina's crash history by speeding-related or not.

	2004	2005	2006	2007	2008	2009	Total
Not Spd-Rel	198,715	195,524	196,167	201,296	192,713	185,799	1,170,214
Not Spd-Rel %	85.9	87.9	89.0	89.7	89.9	88.6	88.5
Spd-Rel	32,527	26,921	24,140	23,011	21,645	23,896	152,140
Spd-Rel %	14.1	12.1	11.0	10.3	10.1	11.4	11.5
Total	231,242	222,445	220,307	224,307	214,358	209,695	1,322,354
100 MVMT	956.27	1008.61	1016.48	1036	1015	1026	
Spd-Rel Rates /100 MVMT	34.0	26.7	22.6	22.2	21.3	23.3	
Total crash rate/100 MVMT	241.8	220.5	216.7	216.5	211.2	204.4	

However, in the most recent years, this trend is shifting. Following significant drops in both speeding-related numbers and speeding-related crash rate per MVMT over the first three years, the speeding-related crash number and the speeding-related crash rate has leveled off at around 21 - 23 per 100 MVMT. The total crash rate, however, continued to decline across the entire six years. Thus, while speeding-related crashes have declined since 2004, continued attention to the problem of speeding is needed to obtain further reductions in speeding-related crashes.

Speeding and the consequent crashes and injuries also continue to burden the State and its citizens with significant economic, social and personal costs. The estimated monetary cost of one year's speeding-related crashes is nearly $880 million using NC crash cost estimates for different severity of injuries within crashes (Table 5). When amounts are included for pain and suffering and other quality of life lost, the comprehensive cost is $2.255 billion. When children and youth are involved, costs are even higher in terms of life-years lost. Nor do the cost estimates include all the future lives that will be lost if we do not learn to better manage speeds and reduce serious crashes and injuries on the State's roadways.

Table 5. Crash Cost Estimates for 2009 speeding-related Crashes (using 2008 crash cost estimates).

Maximum Crash Injury Severity	No. Spd-Rel Crashes	Total Crashes	Estimated Monetary Cost	Comprehensive Crash Cost	Total Monetary Cost of Spd-Rel Crashes	Total Comprehensive Cost Spd-Rel Crashes
Fatal	371	1234	$1,600,000	$4,400,000	$593,600,000	$1,632,400,000
A Injury	495	1995	$79,000	$250,000	$39,105,000	$123,750,000
B Injury	3280	18149	$30,000	$74,000	$98,400,000	$242,720,000
C Injury	5283	49250	$17,000	$36,000	$89,811,000	$190,188,000
PDO	13371	132828	$4,300	$5,000	$57,495,300	$66,855,000
Unknown	1096	6239				
Total	23896	209695			$878,411,300	$2,255,913,000

Most of the downward trend in speeding-related crashes comes from reductions in rural areas which may be reflect changes in less driving in rural versus urban areas in recent years, changes in urban/rural boundaries and potentially other factors related to urban and rural exposure to speeding crashes. Rural speeding-related crashes fell from nearly 24,000 in 2004 to about 15,100 in 2008 before rising again slightly to 16,300 in 2009 (Figure 11). The definition of rural/urban used here depends on municipal boundaries and provides a general idea of development type.

Over the entire time period, Crash data were most likely to indicate that speeding was involved in single-car crashes (27.2% of these were speeding-related) and least likely in collisions involving two units (3.6% speeding-related). Crashes involving multiple (3 or more units) were 5.4% speeding-related (data not shown).

Fatal and disabling-injury crashes (based on maximum injury severity in the crash = Killed or A-type) were most likely to be indicated as speeding-related (32.8% and 26.8%, respectively) while property damage only (PDO) crashes were least likely to be indicated speeding-related (9.3%) (Table 6). In terms of numbers, fatal and disabling injury crashes together accounted for 4.6% of speeding-related crashes, while property damage only (PDO), possible injury (C-type) and evident injury (B-type) crashes accounted for 89% with the remainder being of unknown injury status.

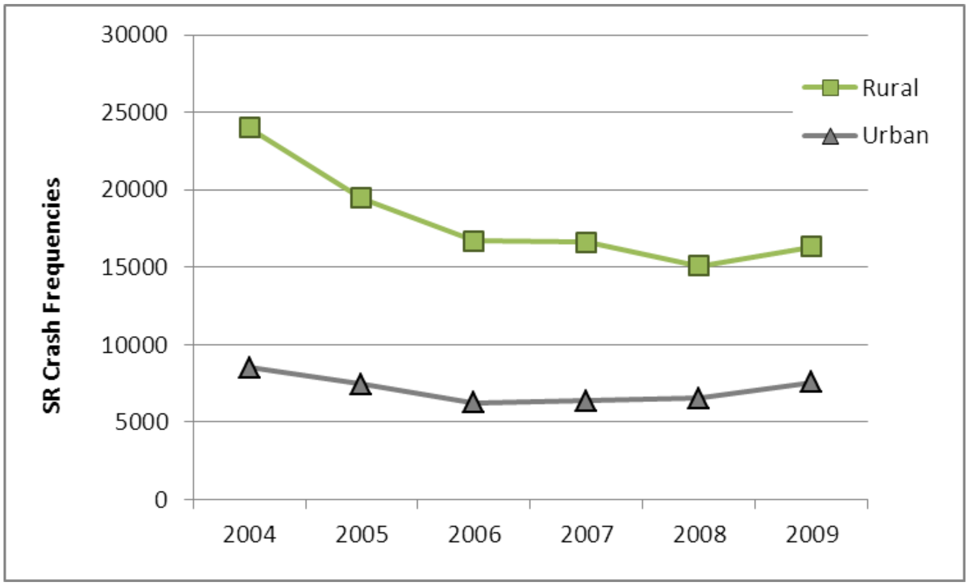

Figure 11. NC Rural and Urban Speeding-related Crash Trends.

Table 6. Speeding involvement (speeding-related) by crash severity, NC crashes, 2004-2009.

Crash Severity	Not Spd-Rel	Spd-Rel	Total
Fatal	5,623	2,746	8,369
	67.2[1]	32.8[1]	
	0.5[2]	1.8[2]	0.6
A Injury	11,577	4,243	15,820
	73.2	26.8	
	1.0	2.8	1.2
B Injury	97,237	23,924	121,161
	80.3	19.8	
	8.3	15.7	9.2
C Injury	282,472	35,511	317,983
	88.8	11.2	
	24.1	23.3	24.0
PDO	739,822	76,248	816,070
	90.7	9.3	
	63.2	50.1	61.7
Unknown	33,482	9,468	42,950
	78.0	22.0	
	2.9	6.2	3.2
Total	1,170,213	152,140	1,322,353
	88.5	11.5	

Frequency Missing = 1

[1]Column percent of row total (in this and future tables)
[2]Row percent of column total (in this and future tables)

Speeding-related fatalities (persons killed in speeding-related crashes), as a proportion of all fatalities, also declined from about 36% to around 30% during the last two years of this six year time period (Figure 12).

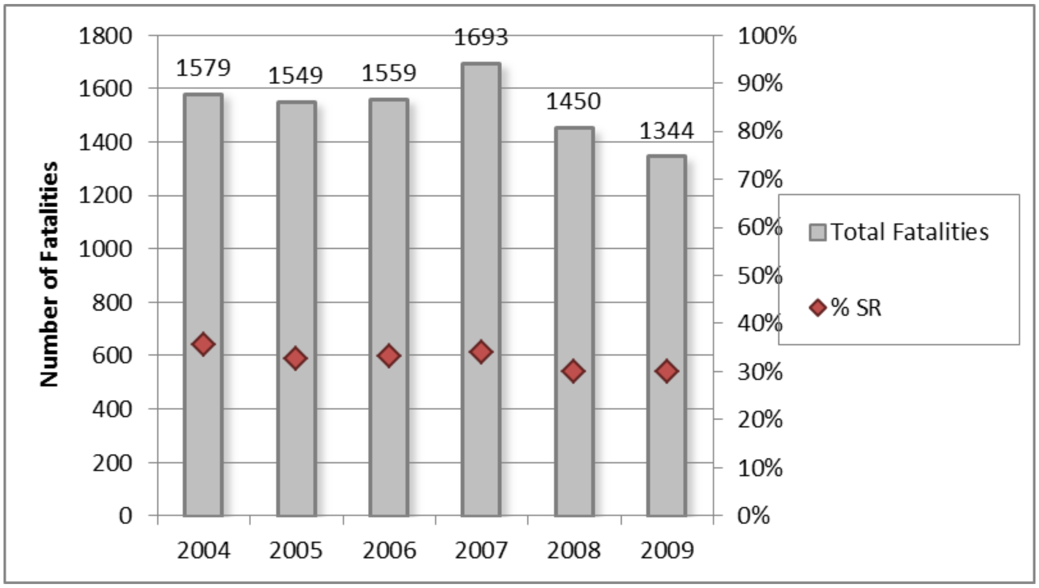

Figure 12. Six-year NC Fatality trends and percentages speeding-related.

Nevertheless, an average of 33%, 500 fatalities per year, were associated with crashes in which one or more drivers were deemed to be traveling in excess of limits or safe speeds for conditions. Given that close to 1000 fatalities per year occurred in crashes that were not clearly indicated as involving inappropriate speed, it may also bear fruit to think more broadly about what constitutes a problem of speed. Obviously not all fatal crashes involve exceeding limits or crashes where the driver clearly exceeded safe speed for conditions. However, given the limits of crash data estimates of speed and exceeding limits, we have incomplete information about the role of traveling above speed limits, including by moderate amounts, in contributing to serious injury crashes in either urban or rural areas of NC. But higher speeds are clearly related to increasing crash severity, as illustrated by the data, and as discussed in the literature review.

Characteristics of Fatal Crashes

Fatal crashes are especially costly to society in terms of actual costs as well as the pain and suffering caused. Since crash data are not entirely clear with regard to the role of speeding in crashes, the following summary characteristics of fatal crashes are provided that may help further consideration about the problem of speed, and potential research topics relating to the role of speed in casualties and other serious injury crashes.

Three-fourths of fatal crashes (73%) over the six years, an average of 1023 per year, occurred in areas designated as rural (outside municipal boundaries); 36% of rural fatal crashes were designated as speeding-related (Table 7). An average of 372 fatal crashes occurred in urban areas of the State over the six years; an average of 25% of these urban fatal crashes were designated as speeding-related.

Table 7. NC Fatal crashes by Rural or Urban Location, 2004-2009.

Urban or Rural	Not Spd-Rel	Spd-Rel	Total
Rural	3951	2187	6138
	64.4	35.6	
	70.3	79.6	73.3
Urban	1672	559	2231
	74.9	25.1	
	29.7	20.4	26.7
Total	5623	2746	8369
	67.2	32.8	100

State Secondary Routes accounted for the largest number (about 511 per year) of fatal crashes and were significantly more likely to be coded as speeding-related (46%) than fatal crashes on Interstate highways, US Highways, NC Highways or Local Streets (all in the range of 21 to 27% speeding-related; Table 8). The State Secondary system also accounts for the most roadway miles in NC, so fatal speeding-related crashes per mile on State Secondary roads are second lowest next to the rate on municipal roads (also shown in Table 8). (Note that crashes in urban areas are sometimes mistakenly attributed to local streets that actually occurred on higher class roadways, US or NC routes). Interstate Roadways account for more than twice as many fatal speeding-related crashes (21.7) on a per 1000 mile basis than the next highest, US Routes (10.5), which was not far above NC Routes (9.3). Of course, these are average crash rates per 1000 miles, and do not consider the application of tools to identify particular crash and fatal hotspots for some types of treatment targeting. In looking at total fatal crashes, the rank orders were the same as for fatal speeding-related crashes, except that local streets had a higher fatal crash rate (10.4) than State Secondaries (7.9). Additionally, the total fatal crash rate per 1000 miles on US Highways (49) was significantly above that for NC routes (34).

Fatal crashes on any type of curve and grade combination were much more likely to be designated as speeding-related than crashes on straight sections of roadway, even those at the bottom of a hill (Table 9). Curves with level grades accounted for the largest number of speeding-related crashes and had the highest percentage (55%) designated speeding-related. All types of curves (with and without vertical grades) accounted for 58% of speeding-related crashes.

The largest number of total fatal crashes, an average of 666 per year, occurred on straight, level sections; about 20% were speeding-related.

Table 8. Distribution of NC Fatal crashes, Not speeding-related (Not Spd-Rel), speeding-related (Spd-Rel), and Total by Road Classification, 2004-2009, with estimates of average yearly crash rate per 1000 roadway miles.

Roadway Class	Not Spd-Rel	Spd-Rel	Total	*2004-09 Avg. Roadway miles (length)*	
				Yrly Fatal Spd-Rel *crashes per 1000 miles*	*Yrly Total Fatal crashes per 1000 miles*
Interstate	476	161	637	1165	
	74.7	25.3		23.0	86.0
	8.5	5.9	7.6		
US Route	1284	351	1635	5565	
	78.5	21.5		10.5	49.0
	22.8	12.8	19.5		
NC Route	1205	451	1656	8115	
	72.8	27.2		9.3	34.0
	21.4	16.4	19.8		
State Secondary Route	1650	1414	3064	64,285	
	53.9	46.2		3.7	7.9
	29.3	51.5	36.6		
Local Street	944	354	1298	20,773	
	72.7	27.3		2.8	10.4
	16.8	12.9	15.5		
PVA	8	2	10		
	80	20			
	0.14	0.07	0.12		
Private Road/Drive	5	0	5		
	100.0	0.0			
	0.1	0.0	0.1		
Other	4	0	4		
	100.0	0.0			
	0.1	0.0	0.1		
Missing	47	13	60		
	78.3	21.7			
	0.8	0.5	0.7		
Total	5623	2746	8369		
	67.2	32.8	100		

Table 9. Distribution of Not speeding-related, speeding-related, and Total fatal NC crashes by roadway alignment, 2004-09.

Road Character (vertical and horizontal alignment)	Not Spd-Rel	Spd-Rel	Total
Straight, level	3211	787	3998
	80.3	19.7	
	57.1	28.7	47.8
Straight, hillcrest	156	42	198
	78.8	21.2	
	2.8	1.5	2.4
Straight, grade	844	281	1125
	75.0	25.0	
	15.0	10.2	13.4
Straight, bottom	68	28	96
	70.8	29.2	
	1.2	1.0	1.2
Curve, level	758	919	1677
	45.2	54.8	
	13.5	33.5	20.0
Curve, hillcrest	54	66	120
	45.0	55.0	
	1.0	2.4	1.4
Curve, grade	452	560	1012
	44.7	55.3	
	8.0	20.4	12.1
Curve, bottom	29	48	77
	37.7	62.3	
	0.5	1.8	0.9
Other	1	0	1
	100.0	0.0	
	0.0	0.0	0.0
Missing	50	15	65
	76.9	23.1	
	0.9	0.6	0.8
Total	5623	2746	8369
	67.2	32.8	100

Fatal crashes and speeding-related fatal crashes were most common under dry roadway conditions with an average of nearly 1200 per year; 31% were indicated to be speeding-related (Table 10). Wet conditions accounted for the next largest number, about 175 fatal crashes per year; 41% were speeding-related. Icy and other frozen surface conditions, and conditions involving standing or moving water were most often indicated to be speeding-related (68 to 76%).

Table 10. Not speeding-related, speeding-related & Total Fatal Crashes by Road Surface Conditions, 2004-2009.

Surface Conditions	Not Spd-Rel	Spd-Rel	Total
Dry	4949	2219	7168
	69.0	31.0	
	88.0	80.8	85.7
Wet	624	436	1060
	58.9	41.1	
	11.1	15.9	12.7
Water standing/moving	14	38	52
	26.9	73.1	
	0.3	1.4	0.6
Ice	8	25	33
	24.2	75.8	
	0.1	0.9	0.4
Snow; Slush	7	15	22
	31.8	68.2	
	0.1	0.5	0.3
Sand, mud, dirt, gravel; Fuel, oil; Other	9	8	17
	52.9	47.1	
	0.2	0.3	0.2
Unknown	12	5	17
	70.6	29.4	
	0.2	0.2	0.2
Total	5623	2746	8369
	67.2	32.8	100

Fatal crashes at night on roads lacking supplemental lighting were 39% speeding-related compared with fatal crashes during daylight hours being 29% speeding-related (Table 11). Fatal crashes at night on lighted roads were not indicated to be speeding-related more often than under daylight conditions. Approximately equal numbers of fatal speeding-related crashes occurred during daylight (all types roads) and at night on unlighted roads.

Table 11. Not speeding-related, speeding-related, and total NC Fatal Crash distributions by Light Conditions, 2004-2009.

Light Conditions	Not Spd-Rel	Spd-Rel	Total
Daylight	2977	1199	4176
	71.3	28.7	
	52.9	43.7	49.9
Dusk	142	56	198
	71.7	28.3	
	2.5	2.0	2.4
Dawn	92	48	140
	65.7	34.3	
	1.6	1.8	1.7
Dark-lighted rd	534	216	750
	71.2	28.8	
	9.5	7.9	9.0
Dark-no light	1859	1210	3069
	60.6	39.4	
	33.1	44.1	36.7
Dark-unknown light	4	4	8
	50.0	50.0	
	0.1	0.2	0.1
Other	2	2	4
	50.0	50.0	
	0.0	0.1	0.1
Unknown	13	11	24
	54.2	45.8	
	0.2	0.4	
Total	5623	2746	8369
	67.2	32.8	100

Within multi-vehicle fatal crashes, 10% of drivers involved were indicated to be speeding. In single-vehicle fatal crashes, 40% of drivers were considered to be speeding-related. Exceeding limits (EL) was the more commonly indicated driver speeding contributing circumstance when crashes were fatal; ESSC was more commonly indicated when crashes were of lower severity (Type A through PDO in both single-vehicle and multi-vehicle crashes). (Both ESSC and EL were indicated for the same driver in fatal single-vehicle crashes about 4% of the time and 0.6% of the time in fatal multi-vehicle crashes. [data not shown])

The remainder of this summary focuses on crashes of all severity. In determining and targeting treatments for greatest effect, it is important to focus on where, when, what, and who, (not to mention why) factors associated with large numbers of speeding-related crashes. Focusing only on factors with high speeding-related percentages may result in targeting insufficient numbers of crashes to yield significant speeding-related crash reductions. In fact, since there is uncertainty about whether crash data definitions of speeding are accurately capturing speeding-related crashes, the information about overall (or non-speeding-related) crash distributions may also be useful in thinking about measures to reduce crashes and crash severity.

Crash Types

The predominant crash types for all crashes in terms of speeding-related-involvement are shown in Figure 13, with the average number of speeding-related crashes per year in the columns, and the percent of the total crashes of that type indicated to be speeding-related highlighted with the diamond point marker. By far, vehicles departing the roadway and striking fixed objects accounted for the greatest number of speeding-related crashes and also a high speeding-related percentage of the total of that crash type (42%). A number of other crash types, several also involving road departures (usually single-vehicle crashes), had high percentages of speeding-related crashes, but accounted for lower numbers. A table (Table 35) showing complete crash distributions by crash type is included in Appendix II – Problem Description: Speeding Crash Relationships and NC Speed Management Issues.

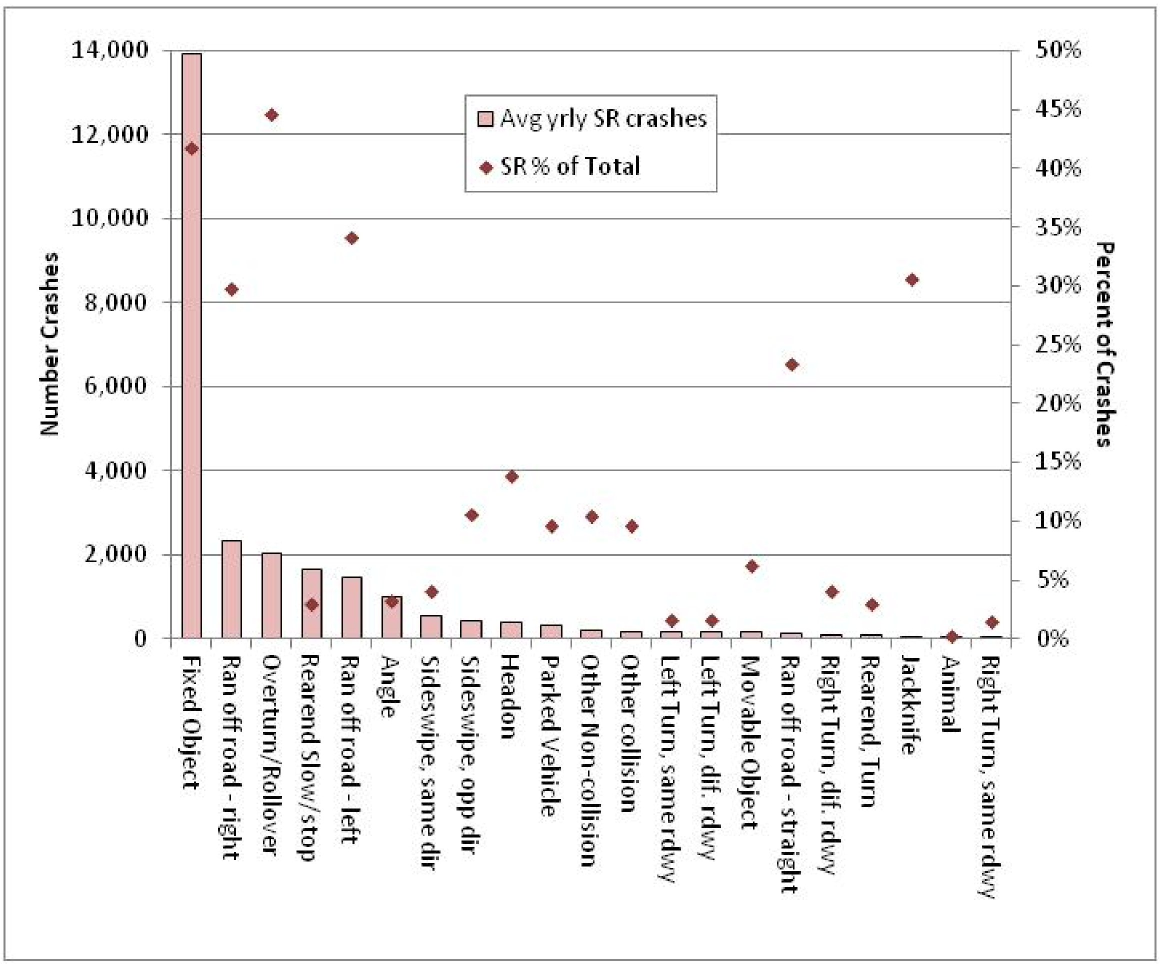

Figure 13. NC's average yearly number of speeding-related crashes by crash type, and percent of crash type that were speeding-related, 2004-2009.

The seven crash types with the lowest speeding-related percentages are not shown in the figures above and included collisions with pedestrians, pedalcyclists, RR train/engine, backing up, and unknown crash types, which, altogether, were indicated to account for an average of 62 speeding-related crashes per year (0.2% of the total speeding-related crashes). During this period, animal crashes alone accounted for nearly 18,000 crashes per year, although only 0.2% were indicated to be speeding-related. Nearly 1500 crashes each year involved pedestrians with 1.7% indicated to be speeding-related. Approximately 670 pedalcyclist crashes occurred each year with about 1.6% indicated to be speeding-related 1.4%.

In contrast, the most common non-speeding-related crash types (by the definitions used here) included Rear-end crashes - following vehicles striking slowing and stopped vehicles, followed by Angle collisions, then Fixed object collisions, and collisions with animals (Figure 14).

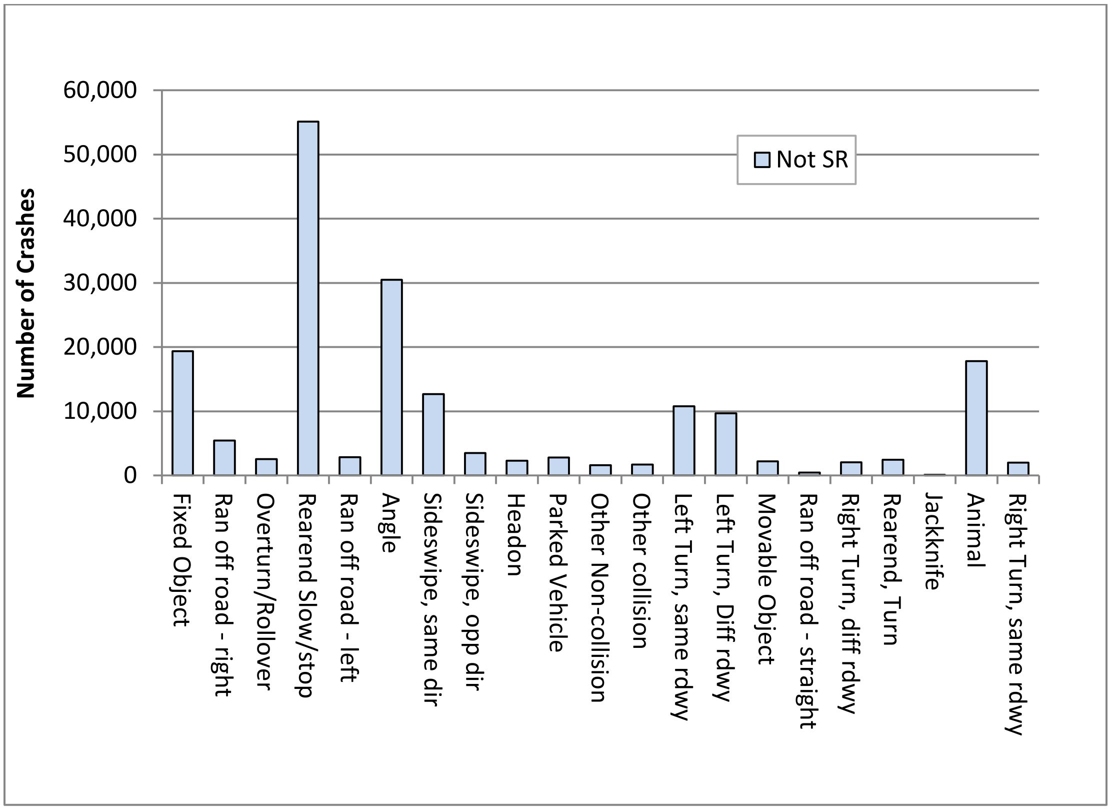

Figure 14. NC's average yearly number of non-speeding-related crashes by crash type (2004-2009).

<u>Crash Locations</u>

Rural/urban location. As mentioned earlier, a greater percentage of rural crashes were speeding-related (18.2%), and rural locations continued to account for the highest numbers – more than 70% – of NC's speeding-related crashes during this six year period (Table 12). However, an average of more than 121,000 crashes occurred in urban areas each year; approximately 6% were indicated to be speeding-related.

Table 12. Speeding involvement in NC crashes by rural and urban crash location, 2004-2009.

Urban/Rural	Not Spd-Rel	Spd-Rel	Total
Rural	485,691	109,097	594,788
	81.7	18.3	
	41.5	71.7	45.0
Urban	684,523	43,043	727,566
	94.1	5.9	
	58.5	28.3	55.0
Total	1,170,214	152,140	1,322,354
	88.5	11.5	

Counties. The top 12 counties (of 100 counties) with the highest percentages of crashes being speeding-related accounted are shown in Table 13. The percentages of crashes that were speeding-related for these counties varied from 24% to 44% compared to the average for the State as a whole of 11.5%. However, this group of 12 counties accounted for only 6.4% of NC's total speeding-related crashes.

Table 13. NC counties with highest proportions of speeding-related crashes relative to all crashes, 2004-2009.

	Speed Related Crash			
County of Crash	Not Spd-Rel	Spd-Rel	% Spd-Rel	Total
Graham	647	510	44.1	1157
Alleghany	792	571	41.9	1363
Polk	1460	729	33.3	2189
Swain	945	429	31.2	1374
McDowell	3680	1602	30.3	5282
Madison	1361	588	30.2	1949
Jackson	3608	1552	30.1	5160
Perquimans	1012	350	25.7	1362
Macon	2930	965	24.8	3895
Haywood	4856	1582	24.6	6438
Warren	1747	548	23.9	2295
Clay	729	225	23.6	954
Total for Top 12	23,767	9651	28.9%	33,418
% of Total NC	2.0%	6.4%		2.53%
Total for NC	1,171,386	150,926		1,322,312
Frequency Missing = 42				

The top 12 counties in terms of numbers of speeding-related crashes accounted for 38% of the total speeding-related crashes, even though the percent speeding-related for many were comparatively low (Table 14). No county was in the top 12 list for both number of speeding-related crashes and high rate of speeding-related crashes. However, there were several counties with high crash numbers that also had higher than average crash rates per VMT (also shown in Table 14). In addition to urban/rural differences and many roadway, environmental and potentially driver factors, there may be variation in practices across the State in terms of how speeding-related driver contributing circumstances are cited that could account for some of the variation in speeding-related crash rates among counties. Local police agencies may also differ from the State Highway Patrol, which investigates most rural crashes, in the tendency to indicate speed as a factor in a crash or there may be less tendency to indicate speed as a factor on lower-speed roads in general.

Table 14. NC counties with highest numbers of speeding-related crashes, 2004-2009.

		Speed Related Crash			
County of Crash	Not Spd-Rel	Spd-Rel	% Spd-Rel	Total	Total Crash rate / 100 million VMT (2009)
Mecklenburg	139096	9736	6.5%	148832	14.9
Wake	125188	8511	6.4%	133699	15.3
Guilford	64857	6117	8.6%	70974	19.8
Forsyth	45429	4551	9.1%	49980	18.4
Cumberland	44504	4089	8.4%	48593	32.0
Buncombe	26285	3914	13.0%	30199	24.8
Randolph	15849	3529	18.2%	19378	41.5
Johnston	18660	3499	15.8%	22159	27.4
Davidson	16703	3286	16.4%	19989	30.0
Robeson	17342	3205	15.6%	20547	35.0
Gaston	25494	3198	11.2%	28692	24.2
Durham	44875	2972	6.2%	47847	15.2
Total top 12	584282	56607	8.8%	640889	
% of NC Total	49.9%	37.5%	11.4%	48.5%	24.5
Total for NC	1171425	150929	11.41%	1322354	

The largest numbers of all speeding-related crashes were observed in the most populous counties as might be expected, but the highest speeding-related crash rates (speeding-related crash proportion of crash total; rate per annual Vehicle Miles Traveled (VMT) by county, or rate per number of county residents) occurred in low-population/rural counties. Similar results were found when speeding-related crashes were normalized by VMTs or by population.

Again, depending on the type of countermeasure, it may be more prudent to target high speeding-related crash number counties to have the greatest impact. For some types of measures, it may be feasible to target counties with a high speeding-related crash rate. See the Appendix for complete tables of crashes by county with speeding-related crash rates by proportion of all crashes, by VMTs, and by resident population. Resident population may not be a good reflection of risk, especially in tourist or other areas with significant driving by non-residents, but lowering risk based on population may still be a worthy goal. For example, some communities may have enhanced transit systems and multi-modal transport that reduces VMT but there is still significant mobility for both residents and non-residents alike.

Roadway Factors

Road classification. All major roadway classes accounted for significant numbers of speeding-related crashes although they varied in the proportion indicated as speeding-related. State Secondary routes accounted for the largest numbers of speeding-related crashes over this time period (43%) and had the highest percentage of all crashes that were speeding-related (24%; Table 15). Local roads accounted for the next largest number of speeding-related crashes (17%), although the speeding-related crash percentage was lower than average.

However, interstates, with less than 1200 miles of roadway in the State, have the highest average frequency of speeding-related crashes per mile among the road classifications at 2779 per 1000 miles of roadway. (If lane miles were examined, a somewhat different picture may emerge.) US Routes are second in terms of speeding-related frequency per mile at 650 per 1000 and by this measure, State Secondary Routes, which account by far for the most centerline miles in the State, rank last. Thus, in terms of measures targeted on a per mile basis (depending on the type), interstates would rank highly in terms of treatment targeting. The challenge in addressing speeding, if widespread, on the State Secondary Routes is apparent. However, other tools are available (and being used by the State) to help further localize high crash zones. The speeding problem may not be spread uniformly across the State, as other associations (with curves, bridges, and so forth) illustrate. However, the fact that many speeding crashes are not associated with particular features or unusual conditions does contribute to challenges in addressing widespread speeding that may lead to crashes across an extensive road network. Actual speed data from a sample of locations may further help to hone in on the problem of speed and where it may be most effectively treated.

Table 15. Non-speeding (Not speeding-related), speeding (speeding-related), and total crashes by NC roadway classification, 2004-2009 with average yearly speeding-related and total crash rates per 1000 roadway miles.

Roadway Class	Not Spd-Rel	Spd-Rel	Total	2004-09 Avg. Miles / Yrly Spd-Rel Crashes per 1000 miles	Yrly Total Crashes per 1000 miles
Interstate	81,206	19,428	100,634	1165	
	80.7[1]	19.3		2779	14,397
	7.4[2]	12.9	8.1		
US Route	169,029	21,707	190,736	5565	
	88.6	11.4		650	5710
	15.4	14.4	15.3		
NC Route	161,596	19,040	180,636	8115	
	89.5	10.5		391	3710
	14.7	12.6	14.5		
State Secondary Route	207,004	64,598	271,602	64,285	
	76.2	23.8		168	704
	18.9	42.8	21.7		
Local Street	461,987	25,343	487,330	20,773	
	94.8	5.2		203	3910
	42.1	16.8	39.0		
PVA	13,287	430	13,717		
	96.9	3.1			
	1.2	0.3	1.3		
Private Road, Driveway	2,653	227	2,880		
	92.1	7.9			
	0.2	0.2			
Other	1,374	133	1,507		
	91.2	8.8			
	0.1	0.1			
Total	1,098,136	150,906	1,249,042		
	87.9	12.1			

Frequency Missing = 73,312

[1]Column percent of row total
[2]Row percent of column total

The tables that follow highlight some of the other roadway factors that associated with speeding crashes in NC.

Traffic flow configuration. Two-way, undivided roadways accounted for the largest number (71%) of speeding-related crashes, but this percentage is only 1.08 times the proportion of all crashes that occurred on such roads (66%). Speeding is most over-represented (17% speeding-related) on two-way, divided roads with a positive median barrier; these roads also accounted for the second largest number of speeding-related crashes (17%) compared with about 13% of all crashes being on this type road (Table 16).

Table 16. Not speeding-related, speeding-related, and total crashes by trafficway flow configuration, 2004-2009.

Traffic Flow Configuration	Not Spd-Rel	Spd-Rel	Total
One-way, undivided	45,849	3,975	49,824
	92.0	8.0	
	4.2	2.6	4.0
Two-way, undivided	713,077	107,456	820,533
	86.9	13.1	
	65.0	71.2	65.7
Two-way, div., no barrier	205,664	13,018	218,745
	94.0	6.0	
	18.74	8.67	17.5
Two-way, div., + barrier	131,360	26,318	157,678
	83.3	16.7	
	12.0	17.4	12.6
Unknown	1,528	61	1,589
	96.2	3.8	
	0.1	0.0	0.1
Total	1,097,478	150,891	1,248,369
	87.9	12.1	
Frequency Missing = 73,985			

Roadway feature. By-far, the most (48%) crash level, first harmful events in multi-vehicle crashes occurred at locations with no special feature (excluding curves and grades); 4.6% of these crashes were speeding-related (Table 17). In general, the remaining speeding-related crashes were spread across diverse features types. Locations where speeding-related crashes were over-represented compared to non-speeding-related crashes included bridges and bridge approaches, underpasses, and private driveways. Apart from the above, intersections accounted for the largest numbers of speeding-related crashes; T-intersections had a slightly higher percentage of speeding-related crashes than other intersection types.

Table 17. Not speeding-related, speeding-related, and total multi-vehicle crashes by road feature, 2004-2009.

Road Feature	Not Spd-Rel	Spd-Rel	Total
No Special Feature	408,461	19,579	428,040
	95.4	4.6	
	47.6	57.9	48.0
Bridge	6962	937	7899
	88.1	11.9	
	0.8	2.8	0.9
Bridge Approach	1831	161	1992
	91.9	8.1	
	0.2	0.5	0.2
Underpass	1353	124	1477
	92	8	
	0	0	0
Driveway, public	32,929	747	33,676
	97.8	2.2	
	3.8	2.2	3.8
Driveway, private	21,665	1042	22,707
	95.4	4.6	
	2.5	3.1	2.6
Alley Intersection	1013	25	1038
	97.6	2.4	
	0.1	0.1	0.1
Four-way Intersection	161,082	3534	164,616
	97.9	2.2	
	18.8	10.5	18.5
T-intersection	103,071	3172	106,243
	97.0	3.0	
	12.0	9.4	11.9
Y-intersection	5174	160	5334
	97	3	
	0.6	0.47	0.6
Traffic Circle/roundabout	907	26	933
	97.2	2.8	
	0.1	0.1	0.1
Five-point or more Inters	1187	25	1212
	97.9	2.1	
	0.1	0.1	0.1
Related to Intersection	20,041	554	20,595
	97.3	2.7	
	2.3	1.6	2.3

Road Feature	Not Spd-Rel	Spd-Rel	Total
Non-intersect median crossing	1875	44	1919
	97.7	2.3	
	0.2	0.1	0.2
End/begin of divided highway	446	18	464
	96.1	3.9	
	0.1	0.1	0.1
Off-ramp entry	3999	161	4160
	96.1	3.9	
	0.5	0.5	0.5
Off-ramp proper	4914	151	5065
	97.0	3.0	
	0.6	0.5	0.6
Off-ramp terminal on cross-rd	4855	73	4928
	98.5	1.5	
	0.6	0.2	0.6
Merge lane btwn on/ off ramp	1155	58	1213
	95.2	4.8	
	0.1	0.2	0.1
On-ramp entry	4197	203	4400
	95.4	4.6	
	0.5	0.6	0.5
On-ramp proper	1361	92	1453
	93.7	6.3	
	0.2	0.3	0.2
On-ramp terminal on cross-rd	1206	77	1283
	94	6	
	0.1	0.2	0.1
RR crossing	772	19	791
	98	2	
	0	0	0
Tunnel	23	3	26
	88.5	11.5	
	0.0	0.0	0.0
Shared-use path/trail crossing	66	1	67
	98.5	1.5	
	0.0	0.0	0.0
Other (in narrative)	2031	67	2098
	96.8	3.2	
	0.2	0.2	0.2
Missing	65,026	2749	67,775
	95.9	4.1	

	7.6	8.1	7.6
Total	857,602	33,802	891,404
	96.2	3.8	100

Not surprisingly, an even larger majority of single-vehicle crashes occurred at segment locations with no special features (70%). Of these, about 32% (nearly 15,000 crashes per year on average) were speeding-related (Table 18). Again, bridges and bridge approaches and private driveways were over-represented with respect to proportion speeding-related, and these locations accounted for about 3% (bridges and bridge approaches) and about 4% (private driveways) of speeding-related crashes respectively. Also over-represented were Y-intersections and all areas associated with on-off ramps, merge areas in between on/off ramps and termini of off-ramps. The latter comprised about 3% of speeding-related crashes while Y-intersections comprised ½ of 1%. Given that both single and multi-vehicle speeding-related crashes tend to be over-represented at on/off ramps and merge areas and these would comprise a small portion of the road network, additional attention to these areas may be beneficial. Without examining crash reports in detail, it is difficult to know whether the single-vehicle collisions that occurred near T intersections and four-way intersections were specifically related to those intersections. T intersections accounted for about 4% of speeding-related crashes and four-way intersections for about 1% but they were not over-represented with respect to speeding compared with not speeding.

Table 18. Not speeding-related, speeding-related, and total single-vehicle crashes by road feature, 2004-2009.

Road Feature	Not Spd-Rel	Spd-Rel	Total
No Special Feature	176,596	84,946	261,542
	67.5	32.5	
	56.5	71.8	60.7
Bridge	4056	3324	7380
	55.0	45.0	
	1.3	2.8	1.7
Bridge Approach	1155	681	1836
	62.9	37.1	
	0.4	0.6	0.4
Underpass	956	257	1213
	78.8	21.2	
	0.3	0.2	0.3
Driveway, public	3236	879	4115
	78.6	21.4	
	1.0	0.7	1.0
Driveway, private	8800	4843	13,643
	65	36	
	3	4	3
Alley Intersection	116	18	134
	86.6	13.4	
	0.0	0.0	0.0

Road Feature	Not Spd-Rel	Spd-Rel	Total
Four-way Intersection	7004	1337	8341
	84.0	16.0	
	2.2	1.1	1.9
T-intersection	15,557	5217	20,774
	74.9	25.1	
	5.0	4.4	4.8
Y-intersection	778	541	1319
	59.0	41.0	
	0.3	0.5	0.3
Traffic Circle/roundabout	196	67	263
	74.5	25.5	
	0.1	0.1	0.1
Five-point or more Inters	72	15	87
	82.8	17.2	
	0.0	0.0	0.0
Related to Intersection	1321	400	1721
	76.8	23.2	
	0.4	0.3	0.4
Non-intersect median crossing	162	42	204
	79.4	20.6	
	0.1	0.0	0.1
End/begin of divided highway	130	58	188
	69.2	30.9	
	0.0	0.1	0.0
Off-ramp entry	1215	771	1986
	61.2	38.8	
	0.4	0.7	0.5
Off-ramp proper	1000	893	1893
	52.8	47.2	
	0.3	0.8	0.4
Off-ramp terminal on cross-rd	186	107	293
	63.5	36.5	
	0.1	0.1	0.1
Merge lane btwn on/off ramp	159	97	256
	62.1	37.9	
	0.1	0.1	0.1
On-ramp entry	975	617	1592
	61.2	38.8	
	0.3	0.5	0.4
On-ramp proper	521	559	1080
	48.2	51.8	
	0.2	0.5	0.3

Road Feature		Not Spd-Rel	Spd-Rel	Total
On-ramp terminal on cross-rd		168	124	292
		57.5	42.5	
		0.1	0.1	0.1
RR crossing		665	166	831
		80.0	20.0	
		0.2	0.1	0.2
Tunnel		18	4	22
		81.8	18.2	
		0.0	0.0	0.0
Shared-use path/trail crossing		48	8	56
		85.7	14.3	
		0.0	0.0	0.0
Other (in narrative)		776	192	968
		80.2	19.8	
		0.3	0.2	0.2
missing		86,745	12,175	98,920
		87.7	12.3	
		27.8	10.3	23.0
Total		312,611	118,338	430,949
		72.5	27.5	100

Roadway profile and alignment (character). The largest number of speeding-related crashes (39%) occurred at straight and level locations, followed by crashes at curves with level grade (25%, Table 19). However, crashes on curves were more often speeding-related (from 31 to 41%) than crashes on straight segments (7 to 14% at the bottom of grades).

Table 19. Not speeding-related, speeding-related, and total crashes by road character (alignment + vertical profile), 2004-2009.

Road Character	Not Spd-Rel	Spd-Rel	Total
Straight, level	783,272	58,152	841,424
	93.1	6.9	
	71.3	38.5	67.4
Straight, hillcrest	36,422	3,203	39,625
	91.9	8.1	
	3.3	2.1s	3.2
Straight, grade	156,664	17,452	174,116
	90.0	10.0	
	14.3	11.6	13.9
Straight, bottom (sag)	9,984	1,626	11,610
	86.0	14.0	

Road Character	Not Spd-Rel	Spd-Rel	Total
	0.9	1.1	0.9
Curve, level	60,778	37,313	98,091
	62.0	38.0	
	5.5	24.7	7.8
Curve, hillcrest	7,435	3,399	10,834
	68.6	31.4	
	0.7	2.3	0.9
Curve, grade	39,992	27,716	67,708
	59.1	40.9	
	3.6	18.4	5
Curve, bottom (sag)	2,832	1,949	4,781
	59.2	40.8	
	0.3	1.3	0.4
Other	748	68	816
	91.7	8.3	
	0.1	0.1	0.1
Total	1,098,127	150,878	1,249,005
	87.9	12.1	
Frequency missing = 73,349			

Work zones. All types of work areas including moving work zones combined accounted for approximately 3400 crashes per year and averaged 8% speeding-related, less than the overall average of 11.5% speeding-related. Work zones and construction areas combined accounted for about 1% of speeding-related crashes. The highest incidence of speeding-related indications for crashes in work areas were for maintenance areas (10%), followed by construction areas (8%).

Table 20. Not speeding-related, speeding-related, and total crashes by work zone indications, 2004-2009.

Work Zone	Not Spd-Rel	Spd-Rel	Total
Construction area	15,410	1,357	16,767
	91.9	8.1	
	1.3	0.9	1.3
Maintenance area	2160	249	2,409
	89.7	10.3	
	0.2	0.2	0.2
Utility area	674	27	701
	96.2	3.9	
	0.1	0.0	0.1
Moving work area	637	31	668
	95.4	4.6	
	0.1	0.0	0.1
None	1,151,333	150,476	1,301,809
	88.4	11.6	
	98.4	98.9	98.4
Total	1,170,214	152,140	1,322,354
	88.5	11.5	

Roadway Functional Class. Council et al. (2010) examined speeding by rural and urban functional classes of roadway in NC (with data available through the HSIS roadway inventory database) and those results are shown in Figure 15. Although not all urban or local streets are included in this database, most principal urban arterials and higher function roadways are included. The table from that report also shows that rural roads had higher percentages of crashes that are speeding-related, and rural roads, especially local and major collectors accounted for the largest numbers of speeding-related crashes. A significant number of speeding-related crashes also occurred on urban local streets, urban minor arterials and urban principal arterials.

Table 23. Frequency and number/percentage of SR crashes regarding functional class in North Carolina.

Functional Class	Over Speed Limit		Too Fast for Conditions		Total SR		Not SR		Total	
	n	Percent	*n*	Percent	*n*	Percent	*n*	Percent	*n*	Percent
Rural principal arterial interstate	500	4.02	4	0.03	4,224	33.96	8,214	66.04	12,438	100.00
Rural principal arterial other	931	4.08	3,661	16.04	4,592	20.12	18,235	79.88	22,827	100.00
Rural minor arterial	703	3.13	2,454	10.93	3,157	14.06	19,296	85.94	22,453	100.00
Rural major collector	1,826	4.14	6,520	14.78	8,346	18.92	35,774	81.08	44,120	100.00
Rural minor collector	1,429	6.01	5,156	21.69	6,585	27.70	17,191	72.30	23,776	100.00
Rural local road or street	2,458	6.63	9,156	24.70	11,614	31.33	25,454	68.67	37,068	100.00
Urban principal arterial interstate	796	2.40	5,770	17.36	6,566	19.76	26,662	80.24	33,228	100.00
Urban principal arterial other freeway or expressway	235	2.05	1,338	11.70	1,573	13.75	9,863	86.25	11,436	100.00
Urban principal arterial other	862	1.02	2,770	3.29	3,632	4.32	80,504	95.68	84,136	100.00
Urban minor arterial	1,200	1.76	3,560	5.21	4,760	6.96	63,591	93.04	68,351	100.00
Urban collector	646	3.68	1,826	10.40	2,472	14.08	15,080	85.92	17,552	100.00
Urban local road or street	1,149	4.39	3,741	14.30	4,890	18.69	21,270	81.31	26,160	100.00
Unknown	67	2.51	268	10.03	335	12.54	2,337	87.46	2,672	100.00
Total	**12,802**	**3.15**	**46,224**	**11.38**	**62,746**	**15.45**	**343,471**	**84.55**	**406,217**	**100.00**

Note: *n* represents frequency of crashes.

Figure 15. Speeding-related crash involvement (and different definitions) by functional classes of roadways in urban and rural areas, 2002-2004 data (Table 23 from Council, et al., 2010, p. 32).

Lane AADTs. Also, from Council et al., the association of speeding-related crashes by traffic volumes per lane are shown in Figure 16. Over Speed Limit (EL in the current tables and analyses) is more common as a proportion when traffic volumes per lane are lower while Too Fast for Conditions (ESSC) is more common as a proportion on both low volume and higher volume roads.

Table 31. Frequency and number/percentage of SR crashes regarding AADT per lane in North Carolina.

AADT Per Lane	Over Speed Limit		Too Fast for Conditions		Total SR		Not SR		Total	
	n	Percent	*n*	Percent	*n*	Percent	*n*	Percent	*n*	Percent
0–2,000	6,693	5.72	4	0.00	30,392	25.99	86,535	74.01	116,927	100.00
2,001–4,000	2,201	2.88	7,674	10.05	9,875	12.93	66,480	87.07	76,355	100.00
4,001–5,500	1,206	2.09	4,197	7.28	5,403	9.37	52,249	90.63	57,652	100.00
5,501–9,000	1,359	1.60	6,097	7.17	7,456	8.77	77,597	91.23	85,053	100.00
9,001–13,000	670	1.86	4,310	11.98	4,980	13.84	30,990	86.16	35,970	100.00
13,001–20,000	458	1.93	2,886	12.15	3,344	14.08	20,411	85.92	23,755	100.00
> 20,000	183	1.83	990	9.89	1,173	11.72	8,834	88.28	10,007	100.00
Unknown	32	6.43	91	18.27	123	24.70	375	75.30	498	100.00
Total	**12,802**	**3.15**	**26,249**	**6.46**	**62,746**	**15.45**	**343,471**	**84.55**	**406,217**	**100.00**

Note: *n* represents frequency of crashes.

Figure 16. Speeding-related crash involvement (and different definitions) by AADT per lane, 2002-2004 data (Table 31 from Council et al., 2010, p. 37).

Time and Environmental Factors

Weekday/weekend. Crashes on weekends were 15% speeding-related and accounted for 31% of the total speeding-related crashes (Table 21).

Table 21. Not speeding-related, speeding-related, and total crashes by weekend or weekday, 2004-2009.

Weekday/ Weekend	Not Spd-Rel	Spd-Rel	Total
Weekend	269,657	46,874	316,531
	85.2	14.8	
	23.0	30.8	23.4
Weekday	900,557	105,266	1,005,823
	89.5	10.5	
	77.0	69.2	76.6
Total	1,170,214	152,140	1,322,354

Time of Day. Speeding is a relatively larger problem during late evening and nighttime hours compared to non-speeding-involved crashes (Figure 17), but the largest numbers of speeding crashes occur during afternoon and morning peak travel periods (Table 22, Figure 17). The largest number of speeding-related crashes occurred during the three hour period from 3 to 6 pm (nearly one-fifth). However, fatal speeding-related crashes are greater during nighttime and early morning hours.

Table 22. Not speeding-related, speeding-related, and total crashes by time period, 2004-2009.

Hour of Day	Not Spd-Rel	Spd-Rel	Total
midnight to 5:59 am (6 hour span)	92,364	23,769	116,133
	79.5	20.5	
	7.9	15.6	8.8
six to 8:59 am	155,440	22,038	177,478
	87.6	12.4	
	13.3	14.5	13.4
nine am to 11:59 am	149,013	18,107	167,120
	89.2	10.8	
	12.7	11.9	12.6
noon to 2:59 pm	216,714	20,975	237,689
	91.2	8.8	
	18.5	13.8	18.0
three to 5:59 pm	286,902	27,469	314,371
	91.3	8.7	
	24.5	18.1	23.8
six to 8:59 pm	173,950	21,525	195,475
	89.0	11.0	
	14.9	14.2	14.8
nine pm to midnight	95,831	18,257	114,088
	84.0	16.0	
	8.2	12.0	8.6
Total	1,170,214	152,140	1,322,354
	88.6	11.4	

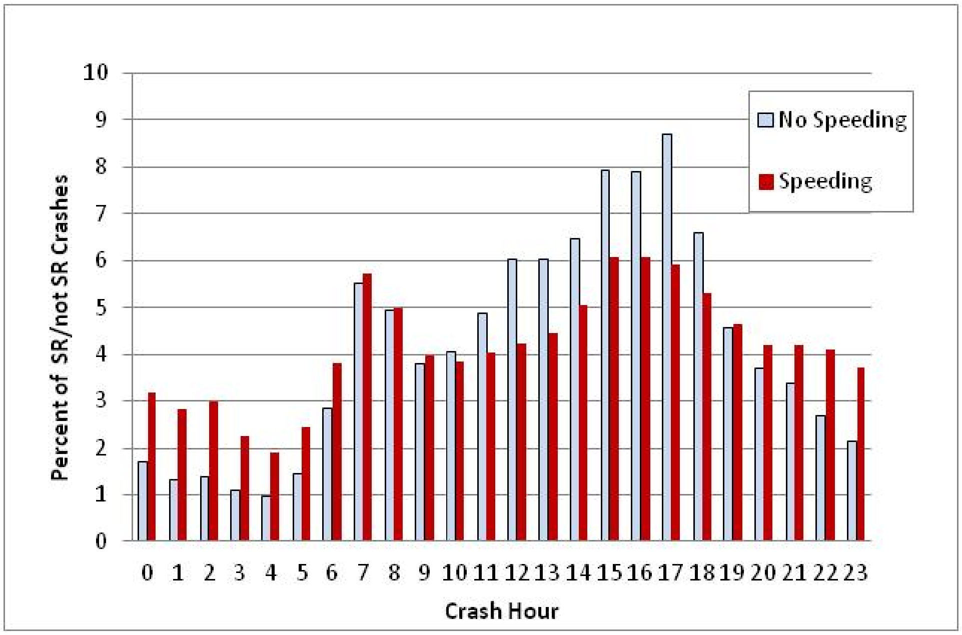

Figure 17. Proportions of speeding-related and non-speeding-related crashes by hour of day, 2004-2009.

Light Conditions. Speeding is also over-represented in crashes at night, but only on roadways with no supplemental lighting (19% speeding-related; Table 23). Nearly 30% of all speeding-related crashes also occurred under such conditions. However, the largest number of speeding-related crashes (58%) occurred during daylight conditions.

Table 23. Not speeding-related, speeding-related, and total crashes by light conditions, 2004-2009.

Light Conditions	Not Spd-Rel	Spd-Rel	Total
Daylight	805,605	88,065	893,670
	90.2	9.9	
	68.8	57.9	67.6
Dusk	27,322	3,263	30,585
	89.3	10.7	
	2.3	2.1	2.3
Dawn	18,689	3,333	22,022
	84.9	15.1	
	1.6	2.2	1.7
Dark-lighted road	120,122	11,509	131,631
	91.3	8.7	
	10.3	7.6	10.0
Dark-no supplemental lighting	192,231	45,291	237,522
	80.9	19.1	
	16.4	29.8	18.0
Dark-unknown lighting	2,379	290	2669
	89.1	10.9	
	0.2	0.2	0.2
Other	472	62	534
	88.4	11.6	
	0.0	0.0	0.0
Unknown	3,394	327	3,721
	91.2	8.8	
	0.3	0.2	0.3
Total	1,170,214	152,140	1,322,354
	88.5	11.5	

Weather and Surface Conditions. Speeding is more highly represented under adverse weather conditions than clear conditions, but due to the overwhelming majority of crashes occurring under clear or cloudy skies, a majority of speeding-related crashes (68%) occurred under one of these conditions (Table 24). Approximately 24% of speeding-related crashes occurred during rain.

Table 24. Not speeding-related, speeding-related, and total crashes by weather conditions, 2004-2009.

Weather conditions	Not Spd-Rel	Spd-Rel	Total
Clear	864,099	66,384	930,483
	92.9	7.1	
	73.8	43.6	70.4
Cloudy	203,923	36,715	240,638
	84.7	15.3	
	17.4	24.1	18.2
Rain	87,654	35,977	123,631
	70.9	29.1	
	7.5	23.7	9.3
Snow	4,032	7,533	11,565
	34.9	65.1	
	0.3	5.0	0.9
Fog, smog, smoke	6,852	1,941	8,793
	77.9	22.1	
	0.6	1.3	0.7
Sleet, hail, freezing rain	1,902	3,366	5,268
	36.1	63.90	
	0.2	2.2	0.4
Severe Crosswinds	366	47	413
	88.62	11.38	
	0.0	0.0	
Other	1,316	135	1,451
	90.7	9.3	
	0.1	0.1	0.1
Total	1,170,144	152,098	1,322,242
	88.5	11.5	
Frequency Missing = 112			

Keeping with the association of speeding with adverse weather conditions, speeding-related indications are far more prevalent under adverse surface conditions. Crashes associated with wet, snowy or icy surface conditions were increasingly speeding-related up to 70% when icy or snowy surface conditions were present. Wet conditions accounted for about 36% of speeding-related crashes and snowy/icy/slushy conditions for about 13%. Nearly half (48%) of speeding-related crashes occurred when surfaces were dry, however.

Table 25. Not speeding-related, speeding-related, and total crashes by road surface conditions, 2004-2009.

Surface Conditions	Not Spd-Rel	Spd-Rel	Total
Dry	983,526	72,216	1,055,742
	93.2	6.8	
	84.1	47.5	79.8
Wet	168,411	54,320	222,731
	75.6	24.4	
	14.4	35.7	16.8
Water standing/moving	4,986	5,235	10,221
	48.8	51.2	
	0.4	3.4	0.8
Ice	4,851	10,354	15,205
	31.9	68.1	
	0.4	6.8	1.1
Snow	3,026	7,172	10,198
	29.7	70.3	
	0.3	4.7	0.8
Slush	780	1,907	2,687
	29.0	71.0	
	0.1	1.3	0.2
Other*	1363	670	2033
	67.0	33.0	
	0.1	0.4	0.2
Unknown	3,271	266	3,537
	92.5	7.5	
	0.3	0.2	0.3
Total	1,170,214	152,140	1,322,354
	88.5	11.5	

*Sand mud, dirt, gravel, soil, or other

Driver and Vehicle Factors

Among drivers of all ages, 6.5% of drivers (n = 2,191,817 all six years) involved in these crashes were cited for EL, ESSC, or both. The total number of drivers cited for contributing to their crashes by speeding averaged 23,591 per year in NC.

- In total, nearly 27% of single-vehicle crash-involved drivers were cited for speeding, but less than 2% of multi-vehicle-crash-involved (Table 26, Table 27). Numerically, more than 3 times as many drivers in single-vehicle crashes were indicated to have contributed to the crash by speeding as drivers involved in multi-vehicle crashes.
- As mentioned before, the highest percentages of speeding (Any speeding-related) are associated with drivers in fatal crashes - for both multi-vehicle and single-vehicle crashes. The proportion cited for exceeding limits (EL) is much higher – 22% for single-vehicle and 6% for multi-vehicle crash-involved drivers in fatal crashes – than for lower crash severities. In contrast

exceeding safe speed for conditions (ESSC) was cited most frequently for drivers in single-vehicle, non-fatal injury crashes (25%). In multi-vehicle crashes, ESSC was also cited at a higher rate in fatal crashes (although less often than EL) than for other severity of crashes at 3%.

- A majority (62%) of all speeding drivers in crashes as indicated by the driver contributing circumstances, were drivers in single-vehicle crashes indicated as ESSC (87,060 of 141,543 – Any speeding-related for single and multi-vehicle crash-involved drivers).
- Also, 30% of all speeding drivers in the crashes over this time period were identified as ESSC on State Secondary Roads (data not shown).

Table 26. speeding-related contributing circumstances for NC drivers in single-vehicle crashes, 2004-2009.

	Driver Speeding at the Time of the Crash					
Crash Severity	Not speeding-related	Both EL & ESSC	EL	ESSC	Any Spd-Rel	Total
Fatal	2932	199	1072	706	1977	4909
	59.7	4.1	21.8	14.4	40.3	
	1.0	4.9	6.1	0.8	1.8	1.2
Injury	94,928	2316	9959	34,933	47208	142,136
	66.8	1.6	7.0	24.6	33.2	
	31.6	57.3	56.3	40.1	43.4	34.7
PDO	202,479	1530	6672	51421	59,623	262,102
	77.3	0.6	2.6	19.6	22.8	
	67.4	37.8	37.7	59.1	54.8	64.1
Total	300,339	4045	17703	87,060	108,808	409,147
	73.4	1.0	4.3	21.3	26.6	

Table 27. Spd-Rel contributing circumstances for NC drivers involved in multi-vehicle collisions, 2004-2009.

	Driver Speeding at the Time of the Crash					
Crash Severity	Not Spd-Rel	Both EL & ESSC	EL	ESSC	Any Spd-Rel	Total
Fatal	6664	41	461	229	731	7395
	90.1	0.6	6.2	3.1	9.9	
	0.4	6.4	5.1	1.0	2.2	0.4
Injury	644,931	369	5265	9674	15,308	660,239
	97.7	0.1	0.8	1.5	2.3	
	36.9	57.9	58.5	41.9	46.8	37.0
PDO	1,098,340	227	3276	13,193	16,696	1,115,036
	98.5	0.0	0.3	1.2	1.5	
	62.8	35.6	36.4	57.1	51.0	62.5
Total	1,749,935	637	9002	23,096	32,735	1,782,670
	98.2	0.0	0.5	1.3	1.8	

Driver age group. Proportion speeding-related by age group declines by increasing driver age, from a high of 12% for drivers ages < 20, to 1% for drivers ages 71 and up (Table 28). Adults between the ages of 31 to 50 accounted for the largest overall numbers of crashes - an average of 37% of all crashes over this period, but 48% of all drivers indicated as speeding in their crashes were from 16 to 25 years of age and 59% were between the ages of 16 to 30.

Table 28. speeding-related Contributing Circumstances by Driver Age Group (all collisions), 2004-2009.

Driver Age group	Driver Speeding at the Time of the Crash					
	No Spd-Rel	Both EL & ESSC	EL	ESSC	Total Spd-Rel	Total
14 to 15	4007	58	219	357	634	4641
	86.3	1.3	4.7	7.7	13.7	
	0.2	1.2	0.8	0.3	0.4	0.2
16 to 20	294,691	1818	8367	29974	40159	334,850
	88.0	0.5	2.5	9.0	12.0	
	14.4	38.8	31.3	27.2	28.4	15.3
21 to 25	279,542	969	6120	21032	28121	307,663
	90.9	0.3	2.0	6.8	9.1	
	13.6	20.7	22.9	19.1	19.9	14.0
26 to 30	224,383	548	3502	13188	17238	241,621
	92.9	0.2	1.5	5.5	7.1	
	10.9	11.7	13.1	12.0	12.2	11.0
31 to 40	405,922	634	4367	19390	24391	430,313
	94.3	0.2	1.0	4.5	5.7	
	19.8	13.5	16.4	17.6	17.2	19.6
41 to 50	352,480	396	2509	13785	16690	369,170
	95	0	1	4	5	
	17	8	9	13	12	17
51 to 60	252,959	177	1008	7921	9106	262,065
	96.5	0.1	0.4	3.0	3.5	
	12.3	3.8	3.8	7.2	6.4	12.0
61 to 70	135,661	52	346	2959	3357	139,018
	97.6	0.0	0.3	2.1	2.4	
	6.6	1.1	1.3	2.7	2.4	6.3
71+	98,322	20	179	1349	1548	99,870
	98.5	0.0	0.2	1.4	1.6	
	4.8	0.4	0.7	1.2	1.1	4.6
age missing	2308	10	88	201	299	2607
	88.5	0.4	3.4	7.7	11.5	
	0.1	0.2	0.3	0.2	0.2	0.1
Total	2,050,275	4682	26,705	110,156	141,543	2,191,818
	93.5	0.2	1.2	5.0		100

Counts of speeding-crash involvement by driver age group over this time period are shown in Figure 18. In general, both the numbers (shown in the figure) and the proportion of all crashes that were speeding-related by age group (proportional data not shown) declined over most of the time period, except increases were noted for all ages in speeding-related crash involvements from 2008 to 2009.

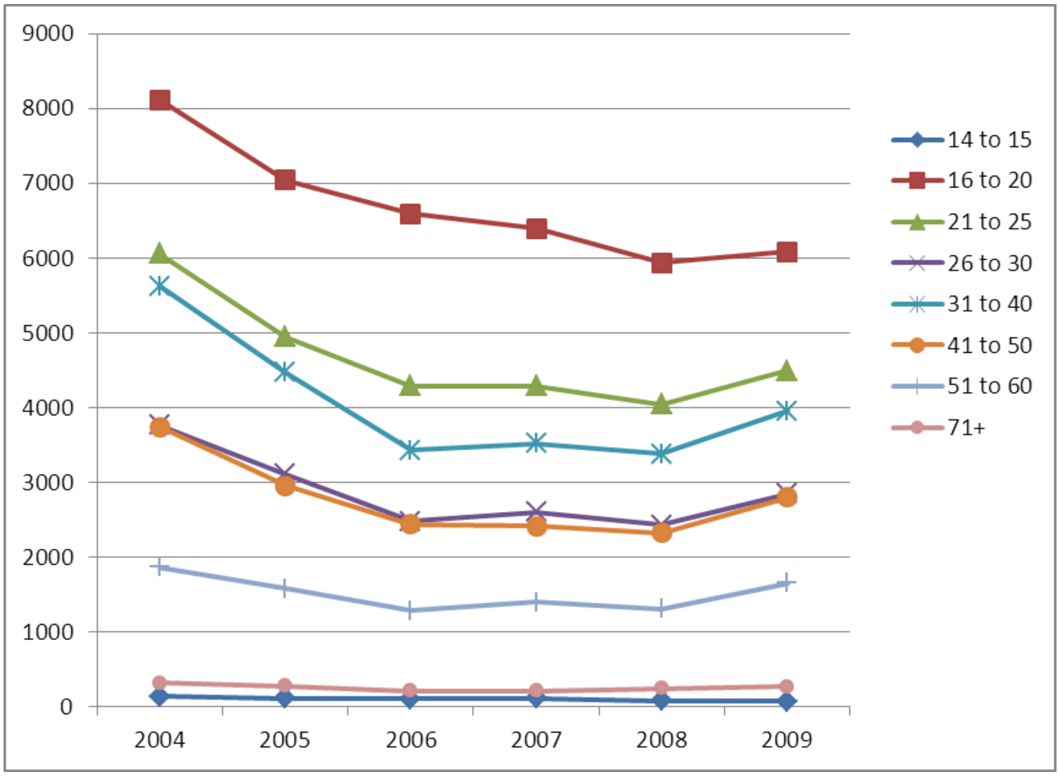

Figure 18. Six year trend of speeding-related crash involvement frequencies by driver age group.

Driver sex. Females were more likely to be involved in multi-vehicle collisions as a proportion of drivers (45% of involved drivers) than they were in single-vehicle crashes (38% of the total). Therefore, we examined the roles of speeding for male and female drivers in single- and multi-vehicle collisions separately. Males (28% speeding-related) were somewhat more likely to be cited for speeding than females (24% speeding-related) in single-vehicle crashes, thereby increasing their speeding-crash involvement to 66%, somewhat higher than their overall crash involvement of 62% in these types of crashes (Table 29).

Table 29. Drivers speeding by sex in single-vehicle crashes, 2004-2009.

Driver Sex	Driver Speeding at the Time of the Crash					Total
	No Spd-Rel	Both EL & ESSC	EL	ESSC	Any Spd-Rel	
Male	181,905	2899	13,671	54,860	7,430	253,335
	71.8	1.14	5.4	21.66	28.2	
	60.63	71.74	77.36	63.07	65.7	62.0
Female	118,112	1142	4000	32,123	37,265	155,377
	76.0	0.7	2.6	20.7	24.0	
	39.4	28.3	22.6	36.9	34.3	38.0
Total	300,017	4041	17,671	86,983	108,695	408,712
	73.4	1.0	4.3	21.3		
Frequency Missing = 435						

Males in multi-vehicle crashes were also more likely to be cited for speeding than females (although the percentages were still very low at 2.3%, Table 30). Males accounted for more than two-thirds (68%) of speeding drivers involved in multi-vehicle crashes compared with 55% for all crashes.

Table 30. Drivers speeding by sex in multi-vehicle crashes, 2004-2009.

Driver Sex	Driver Speeding at the Time of the Crash					Total
	No Spd-Rel	Both EL & ESSC	EL	ESSC	Any Spd-Rel	
Male	950,965	488	6744	14891	22,123	973,088
	97.7	0.1	0.7	1.5	2.3%	
	54.4	76.61	74.98	64.55	67.7	54.6
Female	797,094	149	2250	8178	10,577	807,671
	98.69	0.02	0.28	1.01	1.3%	
	45.6	23.39	25.02	35.45	32.3	45.4
Total	1,748,059	637	8994	23,069	32,700	1,780,759
	98.2	0.0	0.5	1.3	1.8	
Frequency Missing = 1911						

Alcohol/drug use. Alcohol was more prevalent as a factor among drivers in single-vehicle collisions than in multi-vehicle. When alcohol or drug use was suspected or detected, 30% of drivers in single-vehicle crashes were speeding compared with 26% speeding when alcohol was not suspected (Table 31).

Table 31. Not speeding-related, speeding-related and total involvement by drivers in single-vehicle crashes, 2004-2009.

Alcohol Involved	Not Spd-Rel	Spd-Rel	Total
No	270,701	95,843	366,544
	73.8	26.2	
	90.1	88.1	89.6
Yes	29,638	12,965	42,603
	69.57	30.43	
	9.87	11.92	10.4
Total	300,339	108,808	409,147
	73.4	26.6	

In multi-vehicle crashes, 4.4% of drivers who were suspected of drug or alcohol use were speeding compared with 1.8% of drivers when no drug or alcohol use was suspected (Table 32).

Table 32. Not Spd-Rel, Spd-Rel and total involvement of alcohol by drivers in multi-vehicle crashes, 2004-2009.

Alcohol Involved	Not Spd-Rel	Spd-Rel	Total
No	1,700,690	30,469	1,731,159
	98.2	1.8	
	97.2	93.1	97.1
Yes	49,245	2266	51511
	95.6	4.4	
	2.8	6.9	2.9
Total	1,749935	32,735	1,782,670
	98.2	1.8	

State of licensure. Finally, of drivers whose license status was known (from crash data), about 7% of drivers cited for speeding in crashes on NC roadways (n = 140,736) were licensed in another state. The largest number of such out-of-state speeding drivers were involved in collisions on Interstate roadways (36%). Drivers licensed out of State and Speeding by Road Class (2004-2009):

- Interstates 3381 (35.6% of total out-of-state speeding drivers)
- US Routes 1758 (18.6%)
- NC Routes 1226 (12.9%)
- State Secondary 2009 (21.2%)
- Local 997 (10.5%)

Similarly, a preliminary examination by county shows that some counties along interstate corridors, tourist areas, and those neighboring adjacent states have higher proportions of speeding drivers from out of state. For example, 39% of Graham County's (a western county adjacent to Tennessee) speeding drivers were indicated to be licensed in another state.

Vehicle type. Among vehicle types involved in crashes, motorcycles were most often indicated to have contributed by speeding at 20% of their total presence in crashes. In single-vehicle crashes, the percentage was 32% and in multi-vehicle crashes, 7% of motorcyclists were indicated to be speeding prior to the crash. Overall, however, motorcycles accounted for 3% of single-vehicle speeding drivers and 2.2% of speeding drivers in multi-vehicle crashes. Passenger vehicles accounted for about 94% of speeding in both single-vehicle and multi-vehicle crashes (data not shown).

Repeat speed-crash involvement by same drivers. We also examined the frequencies and occurrence of repeat crash involvement by speeding and non-speeding drivers. We counted drivers with one, and two or more speeding crash involvements and the remaining crash-involved drivers (but whose involvement was not speed-related) in 2009 (Table 33). We then searched for prior speed-related and not speed-related crash involvements by the same set of drivers over the previous five year period (2004-2008).

- Of all drivers involved in crashes in 2009, 19,838 or 6.7% of the total drivers in 2009 crashes, had one speeding-related crash, and 0.04% or 126 drivers had two or more speeding-related crash involvements during 2009. (Two or more speeding-related crash-involvements mean that the same driver was cited as contributing by EL or ESSC to multiple crashes within 2009).

- 97.7% of drivers with any crashes during 2009 did not have any speeding-related crashes in the five previous years (row 0 total %). Only 2.3% (7008) of all drivers involved in crashes in 2009 had one to four prior speeding-related crashes in the previous five years. Of these, the vast majority (6032/6750 or 89%) were not indicated to have contributed by speeding in their 2009 crash (None column).
- Drivers who did have a speeding-related crash involvement in 2009 were, however, somewhat more likely to have one or more prior speeding-related crash involvements compared to drivers who were not speeding in their 2009 crash (Table 33). In total, 3.6% of drivers with one speeding-related crash involvement and 6% of drivers with two or more 2009 speeding-related crash involvements had one or more prior speeding-related crash involvements compared to 2% for drivers who were not speeding in their 2009 crash(es).

Table 33. Prior speeding-related crash involvement (2004-2008) for drivers involved in crashes in 2009.

	Counts of Drivers by Not Spd-Rel and Spd-Rel Number of Crashes in 2009							
Prior Speeding Crash Count 2004-2008	None	None %	One Spd-Rel	One Spd-Rel %	2+ Spd-Rel	2+ Spd-Rel %	Total	Total %
0	277,351	97.80[1]	19,838	96.37	126	94.03	297,315	97.70
1	6032	2.13	711	3.45	7	5.22	6750	2.22
2	208	0.07	33	0.16	1	0.75	242	0.08
3	12	0.00	3	0.01	0	0.00	15	0.00
4	1	0.00	0	0.00	0	0.00	1	0.00
∑ any prior (1 – 4)	6253	2.20	747	3.62	8	5.97	7008	2.30
Total	283,604	93.19[2]	20,585	6.76	134	0.04	304,323	

[1] Row percent of column total
[2] Column percent of total

- In general, there was a much greater likelihood of any type of prior crash involvement for drivers involved in crashes in 2009 whether speeding-related or not speeding-related (Table 34). Nearly 27% of drivers involved in one or more crashes in 2009 also had one or more prior crashes in the preceding five years (80,835, sum of rows 1 to 4).
- Drivers who had only one speeding-related crash involvement in 2009 were only slightly more likely (27.9% with one or more prior) to have any prior crashes than drivers who had non-speeding-related crash involvements in 2009 (26.5% with one or more prior; Table 34). However, 38% of drivers who had two or more speeding-related crash involvements in 2009 had one or more prior crashes in the preceding five years (1.4 times as likely). The number of drivers involved in multiple 2009 speeding-related crashes was only 134 altogether.

Table 34. Prior total crash involvement for drivers involved in crashes in 2009.

	Counts of Drivers by Number of Not Spd-Rel and Spd-Rel Crashes in 2009							
Prior Total Crash Count 2004-2008	Not Spd-Rel 2009	Not Spd-Rel %	One Spd-Rel	One Spd-Rel %	2+ Spd-Rel	2+ Spd-Rel%	Total 2009	Total %
0	208558	73.54[1]	14847	72.13	83	61.94	223488	73.44
1	56732	20.00	4251	20.65	36	26.87	61019	20.05
2	13810	4.87	1117	5.43	11	8.21	14938	4.91
3	3227	1.14	265	1.29	2	1.49	3494	1.15
4	873	0.31	75	0.36	1	0.75	949	0.31
5+	404	0.14	30	0.15	1	0.75	435	0.14
∑ any prior (1 – 5+)	75046	26.46	5738	27.88	51	38.07	80,835	26.56
Total	283604	93.19[2]	20585	6.76	134	0.04	304323	

[1] Row percent of column total
[2] Column percent of total

If there are effective and easily implementable measures, it may make sense to investigate further the role of repeat crash involvement, but generally speaking targeting countermeasures toward drivers indicated to have repeat speeding-crash involvements (as currently defined by crash data) would not be an effective strategy to significantly reduce speeding-related or total crashes.

Table 35 shows crash types and speeding involvement. By far, fixed object and other road departure crash types types account for the highest percentages and largest numbers of speeding-related crashes.

Table 35. NC Crash Types and Speeding Involvement in the Crash, 2004 – 2009.

First Harmful Event in the Crash	Not Spd-Rel	Spd-Rel	Total
Ran off road - right	32,752	13,914	46,666
	70.2[1]	29.8[1]	
	2.8[2]	9.2[2]	3.5[2]
Ran off road - left	17,022	8829	25,851
	65.9	34.2	
	1.5	5.8	2.0
Ran off road - straight	2814	860	3674
	76.6	23.4	
	0.2	0.6	0.3
Jackknife	695	307	1002
	69.4	30.6	
	0.1	0.2	0.1
Overturn/Rollover	15,228	12,269	27,497
	55.4	44.6	
	1.3	8.1	2.1
Other Non-collision	9647	1134	10,781
	89.5	10.5	
	0.8	0.8	0.8

First Harmful Event in the Crash	Not Spd-Rel	Spd-Rel	Total
Pedestrian	8734	155	8889
	98.3	1.7	
	0.8	0.1	0.7
Pedalcyclist	3944	62	4006
	98.5	1.6	
	0.3	0.0	0.3
RR train/engine	175	3	178
	98.3	1.7	
	0.0	0.0	0.0
Animal	106,877	223	107,100
	99.8	0.2	
	9.1	0.2	8.1
Movable Object	13,210	885	14,095
	93.7	6.3	
	1.1	0.6	1.1
Fixed Object	116,344	83,438	199,782
	58.2	41.8	
	9.9	54.8	15.1
Parked Vehicle	16,874	1794	18,668
	90.4	9.6	
	1.4	1.2	1.4
Rearend Slow/stop	330,931	9900	340,831
	97.1	2.9	
	28.28	6.51	25.77
Rearend, Turn	14,693	434	15,127
	97.1	2.9	
	1.3	0.3	1.1
Left Turn, same rdwy	64,850	1065	65,915
	98.4	1.6	
	5.5	0.7	5.0
Left Turn, Diff rdwy	58,171	930	59,101
	98.4	1.6	
	5.0	0.6	4.5
Right Turn, same rdwy	11,940	182	12,122
	98.5	1.5	
	1.0	0.1	0.9
Right Turn, diff rdwy	12,290	528	12,818
	95.9	4.1	
	1.1	0.4	1.0
Head-on	13,864	2245	16,109
	86.1	13.9	
	1.2	1.5	1.2
Sideswipe, same dir	76216	3172	79388
	96.0	4.0	
	6.5	2.1	6.0

First Harmful Event in the Crash	Not Spd-Rel	Spd-Rel	Total
Sideswipe, opp dir	20,984	2475	23,459
	89.5	10.6	
	1.8	1.6	1.8
Angle	183,031	6110	189,141
	96.8	3.2	
	15.6	4.0	14.3
Backing Up	26,713	95	26,808
	99.7	0.4	
	2.3	0.1	2.0
Other collision	10,119	1076	11,195
	90.4	9.6	
	0.9	0.7	0.9
Unknown	2096	55	2151
	97.4	2.6	
	0.2	0.0	0.2
Total	1,170,214	152,140	1,322,354
	88.5	11.5	100

[1] Column percent of row total
[2] Row percent of column total

Counties

The following figures and tables provide speeding-related crash results by County, including VMT and population-based rates.

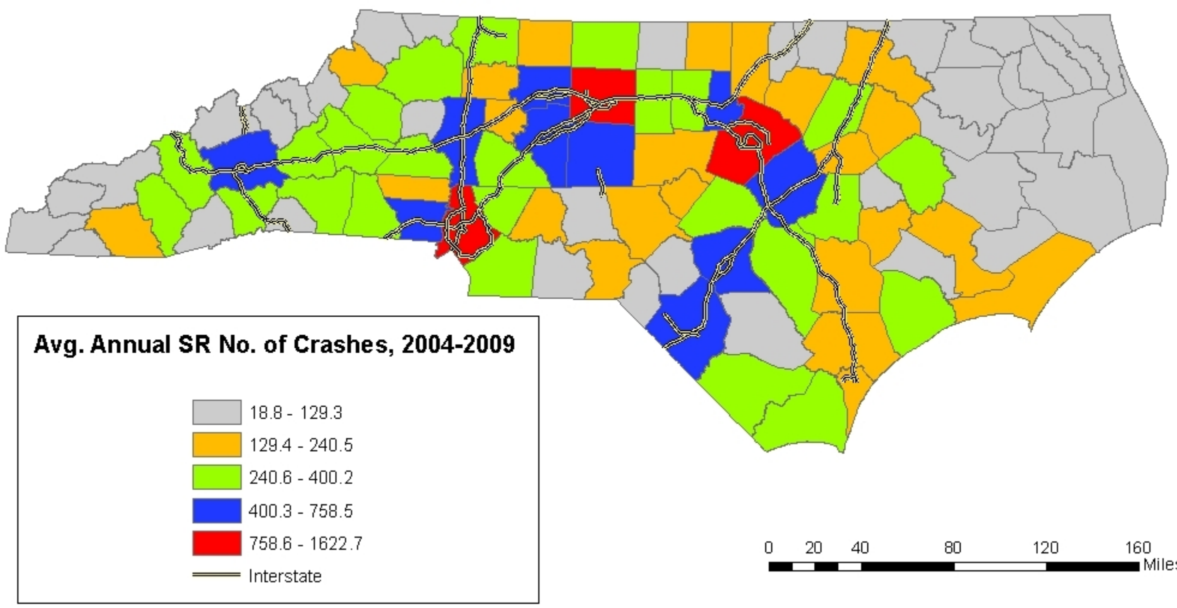

Figure 19. Average annual number of Spd-Rel crashes (using natural breaks in ranges) by NC County, 2004-2009.

Table 36 shows speeding-related crash rates per county population for each of the 100 counties, ranked form highest speeding-related rates to lowest.

Table 36. Crash rates (2004-2009 average yearly) per population (using July 2008 county population estimates), ranked in descending order of crash rate / population.

County of Crash	Not Spd-Rel	Spd-Rel	Total	July 2008 Population Estimate	Avg. 1 year Spd-Rel crash rate/10,000 pop.
Graham	647	510	1,157	8,087	105.1
Alleghany	792	571	1,363	11,125	85.5
Jackson	3,608	1,552	5,160	36,990	69.9
Polk	1,460	729	2,189	18,992	64.0
McDowell	3,680	1,602	5,282	44,562	59.9
Jones	1,536	328	1,864	10,292	53.1
Swain	945	429	1,374	13,982	51.1
Columbus	7,858	1,670	9,528	54,758	50.8
Bertie	2,445	608	3,053	20,074	50.5
Madison	1,361	588	1,949	20,810	47.1
Martin	2,809	673	3,482	23,870	47.0
Macon	2,930	965	3,895	34,227	47.0
Surry	7,996	2,042	10,038	73,388	46.4
Tyrrell	644	119	763	4,280	46.3
Haywood	4,856	1,582	6,438	57,108	46.2

County of Crash	Not Spd-Rel	Spd-Rel	Total	July 2008 Population Estimate	Avg. 1 year Spd-Rel crash rate/10,000 pop.
Warren	1,747	548	2,295	19,918	45.9
Greene	2,130	579	2,709	21,205	45.5
Perquimans	1,012	350	1,362	12,962	45.0
Person	4,437	1,000	5,437	37,510	44.4
Montgomery	2,496	735	3,231	27,651	44.3
Stokes	4,346	1,231	5,577	46,638	44.0
Ashe	2,835	693	3,528	26,319	43.9
Northampton	2,232	554	2,786	21,168	43.6
Davie	4,006	1,065	5,071	40,970	43.3
Gates	1,289	301	1,590	11,836	42.4
Randolph	15,849	3,529	19,378	140,980	41.7
Rutherford	6,093	1,574	7,667	63,555	41.3
Edgecombe	6,499	1,281	7,780	51,800	41.2
Robeson	17,339	3,205	20,544	130,316	41.0
Bladen	4,106	776	4,882	32,153	40.2
Transylvania	2,501	745	3,246	30,991	40.1
Duplin	8,127	1,282	9,409	53,431	40.0
Watauga	6,710	1,086	7,796	45,319	39.9
Sampson	7,728	1,559	9,287	65,396	39.7
Avery	1,568	434	2,002	18,428	39.3
Wilkes	7,456	1,584	9,040	67,297	39.2
Anson	3,357	595	3,952	25,368	39.1
Burke	9,841	2,086	11,927	89,259	39.0
Nash	13,550	2,187	15,737	93,981	38.8
Yadkin	3,824	888	4,712	38,162	38.8
Caswell	1,940	543	2,483	23,422	38.6
Clay	729	225	954	10,458	35.9
Johnston	18,658	3,499	22,157	162,746	35.8
Pamlico	1,073	268	1,341	12,892	34.6
Davidson	16,701	3,286	19,987	158,866	34.5
Washington	1,451	270	1,721	13,172	34.2
Hyde	609	113	722	5,516	34.1
Rockingham	10,614	1,867	12,481	91,691	33.9
Mitchell	1,414	325	1,739	16,034	33.8
Alexander	2,538	745	3,283	36,953	33.6
Henderson	11,681	2,085	13,766	103,836	33.5
Cleveland	11,238	1,954	13,192	97,936	33.3
Richmond	4,576	920	5,496	46,842	32.7
Cherokee	2,003	524	2,527	27,128	32.2
Caldwell	8,545	1,525	10,070	80,020	31.8
Franklin	5,832	1,101	6,933	57,923	31.7
Halifax	6,869	1,013	7,882	55,217	30.6

County of Crash	Not Spd-Rel	Spd-Rel	Total	July 2008 Population Estimate	Avg. 1 year Spd-Rel crash rate/10,000 pop.
Wilson	10,536	1,443	11,979	78,917	30.5
Harnett	10,363	1,965	12,328	109,637	29.9
Chatham	7,161	1,089	8,250	60,881	29.8
Iredell	19,784	2,754	22,538	154,135	29.8
Lincoln	7,635	1,325	8,960	74,538	29.6
Lee	8,425	1,007	9,432	57,500	29.2
Scotland	2,987	647	3,634	37,064	29.1
Orange	14098	2,251	16,349	129,296	29.0
Vance	5,818	757	6,575	43,502	29.0
Buncombe	26,284	3,913	30,197	227,875	28.6
Pender	6,716	890	7,606	51,853	28.6
Brunswick	10,710	1,741	12,451	102,857	28.2
Stanly	6,459	1,007	7,466	59,714	28.1
Hertford	2,635	399	3,034	23,764	28.0
Yancey	1,311	311	1,622	18,592	27.9
Chowan	1,245	240	1,485	14,687	27.2
Camden	734	157	891	9,730	26.9
Alamance	18,682	2,298	20,980	145,995	26.2
Gaston	25,492	3,198	28,690	204,971	26.0
Lenoir	7,319	893	8,212	57,521	25.9
Catawba	23,665	2,321	25,986	154,941	25.0
Wayne	13,923	1,730	15,653	115,696	24.9
Granville	5,718	815	6,533	56,250	24.1
Currituck	1,957	340	2,297	23,773	23.8
Rowan	16,716	1,970	18,686	138,512	23.7
Craven	10,244	1,380	11,624	97,757	23.5
Beaufort	5,936	645	6,581	46,590	23.1
Onslow	19,986	2,401	22,387	176,004	22.7
Hoke	3,521	599	4,120	44,432	22.5
Forsyth	45,426	4,551	49,977	343,704	22.1
Moore	9,631	1,124	10,755	85,280	22.0
Carteret	6,594	833	7,427	63,520	21.9
Guilford	64,856	6,117	70,973	468,344	21.8
Cumberland	44,504	4,089	48,593	316,914	21.5
Pasquotank	4,399	520	4,919	41,330	21.0
Pitt	23,243	1,944	25,187	155,570	20.8
Union	20,365	2,362	22,727	191,108	20.6
Durham	44,875	2,972	47,847	260,420	19.0
Dare	4,225	381	4,606	33,955	18.7
Mecklenburg	139,083	9,734	148,817	877,007	18.5
Cabarrus	22,385	1,791	24,176	170,406	17.5
Wake	125,185	8,511	133,696	864,429	16.4

County of Crash	Not Spd-Rel	Spd-Rel	Total	July 2008 Population Estimate	Avg. 1 year Spd-Rel crash rate/10,000 pop.
New Hanover	29,439	1,413	30,852	192,235	12.3
Total	1,171,386	150,926	1,322,312	9,227,016	27.3

Table 37 shows crash rates per vmt, ranked from high to low.VMTs changed significantly for many counties, particularly rural ones, from 2007 to 2009. Since we were examining average crash rates for a six year period, we used both 2007 and 2009 as rate denominators to determine the impact.

Table 37. Average annual county Spd-Rel crash rates (2004-2009 crashes) based on 2007 and 2009 100 Million VMT estimates, sorted in descending order by crash rate / 2007 VMT.

County of Crash	Not Spd-Rel	Spd-Rel	Total	Avg. annual Spd-Rel rate/2009 100 MVMT	Avg. annual Spd-Rel rate/2007 100 MVMT
Graham	647	510	1,157	110.5	106.0
Alleghany	792	571	1,363	111.6	87.9
Stokes	4,346	1,231	5,577	53.2	55.6
Alexander	2,538	745	3,283	49.0	47.3
Person	4,437	1,000	5,437	50.8	46.8
Jackson	3,608	1,552	5,160	48.8	45.9
Macon	2,930	965	3,895	44.2	42.4
Ashe	2,835	693	3,528	43.6	42.0
Greene	2,130	579	2,709	47.6	39.7
Rutherford	6,093	1,574	7,667	43.7	39.2
Madison	1,361	588	1,949	43.5	38.5
Watauga	6,710	1,086	7,796	39.9	38.5
Top 12 Total	38,427	11,094	49,521		
% of NC Total	3.28%	7.35%	3.74%		
Randolph	15,849	3,529	19,378	41.5	37.9
Gates	1,289	301	1,590	42.4	37.9
McDowell	3,680	1,602	5,282	40.3	36.8
Transylvania	2,501	745	3,246	52.1	36.5
Caldwell	8,545	1,525	10,070	33.8	36.0
Clay	729	225	954	38.8	35.4
Caswell	1,940	543	2,483	42.7	35.4
Columbus	7,858	1,670	9,528	37.5	35.0
Warren	1,747	548	2,295	38.2	35.0
Mitchell	1,414	325	1,739	39.3	34.4
Surry	7,996	2,042	10,038	32.9	34.2
Franklin	5,832	1,101	6,933	35.8	33.8
Perquimans	1,012	350	1,362	37.1	33.7
Wilkes	7,456	1,584	9,040	38.4	33.0
Henderson	11,681	2,085	13,766	32.8	32.9

County of Crash	Not Spd-Rel	Spd-Rel	Total	Avg. annual Spd-Rel rate/2009 100 MVMT	Avg. annual Spd-Rel rate/2007 100 MVMT
Polk	1,460	729	2,189	38.7	32.4
Bertie	2,445	608	3,053	34.0	32.1
Rockingham	10,614	1,867	12,481	33.6	32.1
Sampson	7,728	1,559	9,287	33.8	31.7
Edgecombe	6,499	1,281	7,780	39.2	31.6
Avery	1,568	434	2,002	41.0	31.2
Burke	9,841	2,086	11,927	34.5	31.2
Davidson	16,701	3,286	19,987	30.0	31.1
Harnett	10,363	1,965	12,328	31.5	31.1
Davie	4,006	1,065	5,071	32.7	30.6
Hertford	2,635	399	3,034	29.0	30.0
Swain	945	429	1,374	33.7	30.0
Martin	2,809	673	3,482	36.7	29.8
Hoke	3,521	599	4,120	30.1	29.8
Robeson	17,339	3,205	20,544	34.9	29.5
Lincoln	7,635	1,325	8,960	30.9	29.2
Tyrrell	644	119	763	29.2	28.9
Anson	3,357	595	3,952	31.5	28.8
Cleveland	11,238	1,954	13,192	32.9	28.8
Montgomery	2,496	735	3,231	38.4	28.7
Stanly	6,459	1,007	7,466	31.6	28.5
Washington	1,451	270	1,721	29.5	28.5
Bladen	4,106	776	4,882	30.6	27.6
Yancey	1,311	311	1,622	31.1	27.5
Hyde	609	113	722	37.0	27.1
Richmond	4,576	920	5,496	33.4	27.0
Johnston	18,658	3,499	22,157	27.4	26.9
Chowan	1,245	240	1,485	31.7	26.6
Pasquotank	4,399	520	4,919	26.7	26.5
Cherokee	2,003	524	2,527	29.8	26.4
Union	20,365	2,362	22,727	26.5	26.3
Yadkin	3,824	888	4,712	27.8	25.8
Onslow	19,986	2,401	22,387	28.0	25.8
Wayne	13,923	1,730	15,653	27.9	25.7
Haywood	4,856	1,582	6,438	30.0	25.6
Northampton	2,232	554	2,786	29.1	25.6
Duplin	8,127	1,282	9,409	29.4	25.3
Jones	1,536	328	1,864	29.7	24.9
Pamlico	1,073	268	1,341	33.3	24.8
Scotland	2,987	647	3,634	27.3	24.2
Alamance	18,682	2,298	20,980	25.6	24.2
Lee	8,425	1,007	9,432	28.6	23.6
Buncombe	26,284	3,913	30,197	24.8	23.5
Pitt	23,243	1,944	25,187	24.5	23.1
Orange	14,098	2,251	16,349	22.5	23.1
Chatham	7,161	1,089	8,250	27.0	22.9
Gaston	25,492	3,198	28,690	24.2	22.9
Nash	13,550	2,187	15,737	24.2	22.6

County of Crash	Not Spd-Rel	Spd-Rel	Total	Avg. annual Spd-Rel rate/2009 100 MVMT	Avg. annual Spd-Rel rate/2007 100 MVMT
Vance	5,818	757	6,575	24.9	22.1
Lenoir	7,319	893	8,212	23.4	22.0
Beaufort	5,936	645	6,581	21.3	21.9
Halifax	6,869	1,013	7,882	23.3	21.8
Wilson	10,536	1,443	11,979	24.0	21.7
Rowan	16,716	1,970	18,686	20.7	21.3
Iredell	19,784	2,754	22,538	20.9	21.2
Cumberland	44,504	4,089	48,593	32.0	21.1
Guilford	64,856	6,117	70,973	19.8	20.8
Moore	9,631	1,124	10,755	21.4	20.7
Forsyth	45,426	4,551	49,977	18.3	20.5
Carteret	6,594	833	7,427	19.9	19.5
Brunswick	10,710	1,741	12,451	20.9	19.2
Pender	6,716	890	7,606	21.1	19.0
Catawba	23,665	2,321	25,986	21.7	19.0
Craven	10,244	1,380	11,624	12.8	18.9
Camden	734	157	891	21.2	18.6
Granville	5,718	815	6,533	19.3	18.4
Mecklenburg	139,083	9,734	148,817	14.9	18.0
Wake	125,185	8,511	133,696	15.3	17.3
Durham	44,875	2,972	47,847	15.2	17.2
Cabarrus	22,385	1,791	24,176	15.1	16.4
New Hanover	29,439	1,413	30,852	15.3	15.0
Currituck	1,957	340	2,297	18.1	14.1
Dare	4,225	381	4,606	12.2	10.6
Total	1,171,386	150,926	1,322,312	24.5	24.3

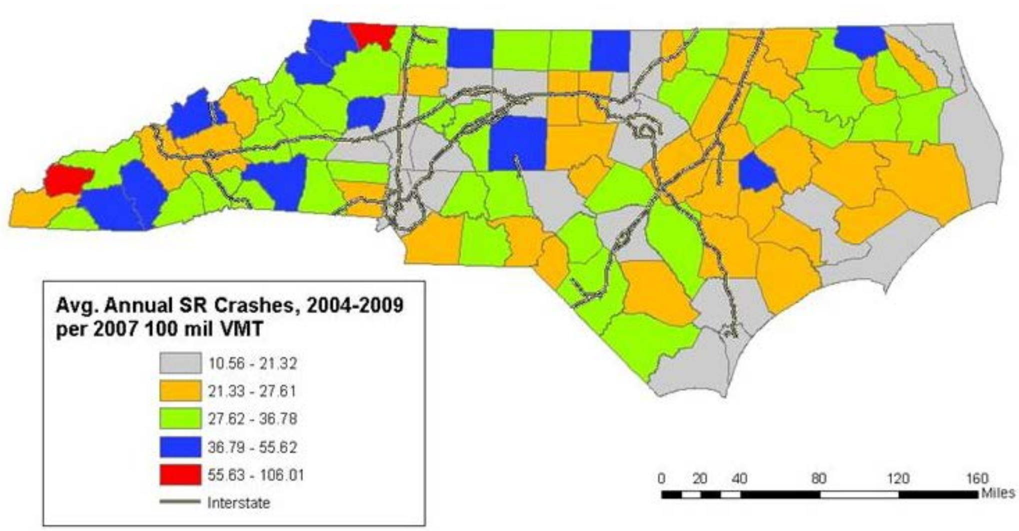

Figure 20. Average annual number of Spd-Rel crashes per 100 million vehicle miles traveled (MVMT) by NC county, 2004-2007.

Current Laws, Policies, Practices and Challenges

Based on the 2010 census, NC's population was more than 9.5 million, reflecting an 18% increase since 2000. This increase continues a longer-term State population growth trend of 48% between 1980 and 2005. Over this period, the number of drivers increased by 65% and the annual number of miles driven increased by 145% (from 41 to 101 billion miles) (Garrison, 2010). Since 2005, vehicle miles traveled has remained high, above 101 billion vehicle miles each year through 2009 (data from NCDOT).

This rapid growth in population and driving adds to the challenges of keeping roadways safe. From 1998 to 2008, vehicle miles traveled increased 2.5 times as much as travel lane miles (Garrison, 2010). Thus roadways are becoming increasingly crowded, especially in the higher population centers. (Based on the recent crash and speeding crash trends, it is conceivable that increasing congestion could be contributing to a reduction in potential for speeding, and consequently a reduction in the severest crashes and fatalities.)

The population is dispersed over 100 counties, covering an area of around 54,000 sq. mi., which ranks it at 28th in area of the 50 U.S. states. Although the State is undergoing increasing urbanization, many of the counties are still largely rural in nature. Forty-five counties have fewer than 50,000 residents.

There are three distinct physiographic provinces and 100 counties within the State. However, in NC, the State manages all of the rural road network and significant roadways within urban areas as well. The western counties (approximately NCDOT divisions 11, 13, and 14 in Figure 22) are mountainous and mostly rural, although there are many small, and a few medium sized cities. The middle counties form the Piedmont region of rolling terrain and contain the largest population centers, which tend to sprawl along a corridor from Mecklenburg to Wake County. Each of these two counties has over 800,000 residents with other smaller cities in between. The eastern counties, (approximately districts 1,2,3,4, and 6) make up the coastal plain with a mix of farmland, towns, beach resorts, and a few medium-sized cities.

Legal Framework - Speeding Statutes

Speeding is legally defined in NC as exceeding the posted speed limit or driving too fast for existing conditions and similar definitions tend to be found in most U.S. states. NC's basic speed rule statute (GS 20-141(A) states:

> "No person shall drive a vehicle on a highway or in a public vehicular area at a speed greater than is reasonable and prudent under the conditions then existing."

Driving too fast for conditions is open to officers' interpretations, but may often be related to weather, congestion, or other roadway conditions prevailing either at the time or place (NHTSA, 2011). Although actual travel speed data are not available in crash databases, "exceeding limits" or "exceeding safe speed for conditions" are frequently cited as driver contributing factors. Estimates (usually from the drivers) of pre-crash traveling speed are sometimes (about half the time) noted in a data field available for the purpose. As described in *Council et al.* (2010), 3% of NC collisions had "over the limit" indicated as a driver contributing factor, while 14.9% had "exceeding safe speed for conditions (ESSC)" or "over the limit (EL)" combined. Thus, ESSC was the predominant speeding-related driver contributing factor in NC crashes. ESSC was also more highly associated with adverse weather and surface conditions, as suggested above, compared with EL. Early examinations of citation data indicate however, that ESSC violations based on the basic speed rule are seldom issued, with speeding-related infractions being issued predominantly on the basis of EL statutes.

In North Carolina, the key speed restricting laws focused on speed limits, are, as in many states, set both statutorily, and through engineering review, and outlined as follows:

- Statutory limits are defined by GS20-141(B) as 35 mph inside municipal corporate limits for all vehicles, and 55 mph outside municipal corporate limits for all vehicles except for school buses and school activity buses.
- GS 20-141 Subsections d, e, and f allow the State DOT and local authorities to set higher and lower than statutory limits upon engineering and traffic review to determine whether a lower limit is needed to be reasonable and safe, or a higher limit than statutorily set is reasonable and safe; local authorities are, however restricted to setting limits no higher than 55 mph while the State maximum is 70 mph. The State may set limits up to 70 mph on “any part of a highway designated as part of the Interstate Highway System or any part of a controlled access highway (either inside or outside the corporate limits of a municipality).” Signs are required to notify of these limits.
- Speeds less than posted maximums are restricted to no lower than 40 mph in speed zones of 55 mph and 45 mph in speed zones of 60 miles per hour and greater, including on interstate highways, and again, appropriate signs are required to be posted.
- Statutes also authorize setting of special speed zones of no less than 20 mph for school zones and special speed zones in work zones with a penalty of $250 for violations.
- Finally, a statute defines a misdemeanor speeding offense as “A person who drives a vehicle on a highway at a speed that is either more than 15 miles per hour more than the speed limit established by law for the highway where the offense occurred or over 80 miles per hour is guilty of a Class 2 misdemeanor.”

Law Enforcement

The NC State Highway Patrol (SHP) has eight troop divisions across the state (Figure 21) and is the primary agency tasked with enforcing speeds throughout the State on Interstates highways and rural roads although in some counties Sheriffs’ departments may also conduct enforcement. Municipal police agencies are primarily responsible for enforcing traffic laws in urban areas.

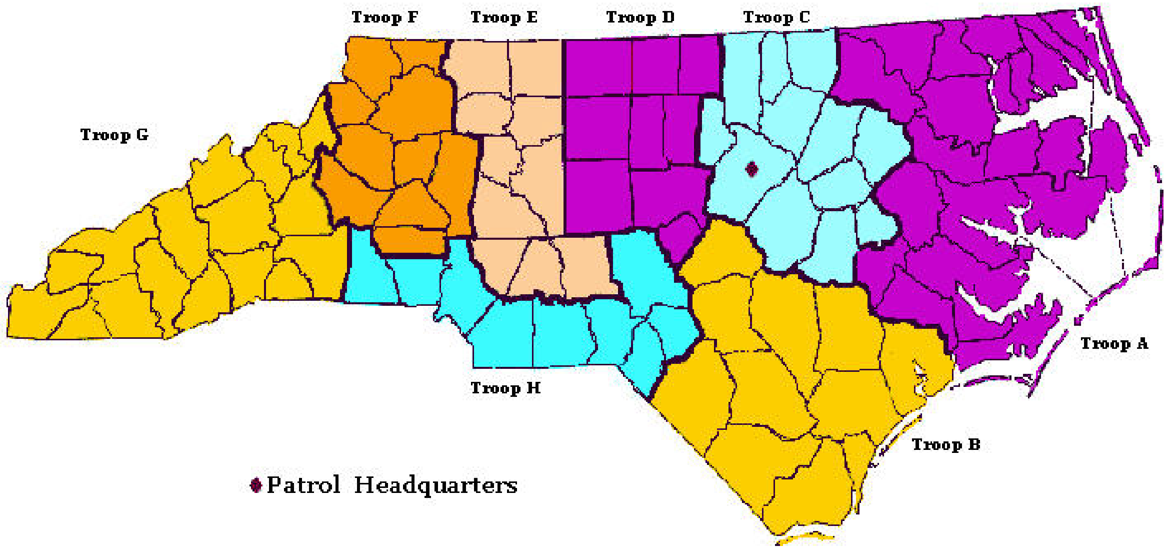

Figure 21. NC State Highway Patrol troop divisions.

NC State Highway Patrol

Interviews with several NC State Highway Patrol **(**SHP) persons revealed the following as indicated in the sections below:

General facts - at any point in time about 25% of troopers are doing speed enforcement

- For more than a decade the planning or targeting of speed enforcement has been data driven
- Tend to pick Top 5 crash locations (presumably all crashes) by county and enforce
- Also for education programs (e.g., Operation Slow Down) (we lack additional information about this program)
- Requires shifts as things change – review data every 3 months and adjust
- Also focus on holidays and other activities with the Governor's Highway Safety Program (GHSP)
- Look at major corridors and the big picture – may have multiple districts looking at the I-85 corridor, for example

Special program enforcement versus regular enforcement responsibilities

- Unless there are special grants like "No Need 2 Speed" from GHSP, speed enforcement has to be done along with all other duties, so a trooper may get called away for a collision or something else
- The SHP receives complaints from the public or others and will respond to a valid complaint

Challenges or problems that concern the SHP regarding speed enforcement

- Do not do as much stationary radar as in past – on Interstate and working from a ramp, harder to get a clean clocking of speed – and harder to cross the roadway to chase with median barriers and cable – using some equipment like VASCAR now

- Traffic volume and congestion a problem, as in Charlotte, and hard to pick out the offender – LIDAR helps – also want the pursuit to be done safely – secondary roads have their own problems – less traffic, but may require a turnaround on road with poor or no shoulders
- Need more manpower
- Adjudication a problem – 1st speeding ticket may be reduced to less than 9 over – 2nd may get a Prayer for Judgment Continued (PJC) – 3rd maybe improper equipment – perhaps the 4th ticket has impact on license or insurance - someone needs to do a better job of educating the court that people are dying every day in speed related crashes – mandating punishments would be a help to eliminate some of the plea bargaining
- Interstate speeds have crept higher – some very high speeds – perhaps we should deal with separately as a problem area with bigger fine – however, troopers are human and would be reluctant to issue many tickets w $1000 fine
- Median barriers a problem – cannot turn around and pursue

Different approaches to enhance speed enforcement and/or reduce speeding in NC

- Differing viewpoints on use of speed cameras - public most concerned that contractors are receiving revenue – perhaps the NCDOT or SHP should manage the program and cameras.
- Work zone project called HAWKS (Helping All Work Zones be kept Safe) that is connected with NCDOT
- Need to make more use of technology, such as air cards – costly but would give them GPS and vehicle locator – SHP Motor Carrier group has something like a Garmin system now where they can locate all vehicles on patrol
- Need for GIS mapping to really know where speed crashes taking place – too broad now
- LIDAR has been successful – sometimes used in an individual car or in conjunction with other units – can single out an individual speeder - LIDAR operator identifies and notifies other troopers (Note: Not all troopers are certified to use LIDAR)
- Consider fine restructuring – and perhaps some different fines for work zones and school zones – perhaps change 1 speeding ticket in 3 years at less than 10 mph over limit to have some insurance impact – or change defective speedometer allowance to 1 every 3 years – if exceed, could have an impact with DMV, an example being making license renewal good for only 1 year
- Perhaps focus interstate ticketing to 5 mph over posted limit, but SHP sees speeds from 90-120 mph on interstates
- Consider variable speed limits
- Need traffic management centers, and need evaluation of how these work
- May need a broader look at law enforcement – perhaps more dividends if traffic and criminal enforcement combined

Local Law Enforcement overview

Interviews with several local enforcement persons revealed the following as highlighted in the sections below:

General facts

- At any point in time about 20-25% of officers are doing speed enforcement [Note – this level of enforcement likely varies widely among different local agencies.]
- Some localities choose enforcement targets based on intersections with the most speeding related crashes – they are also receptive to complaints of speeding – present in school and work zones, areas where speeds are known to be high, and also high crash areas
- Some combined enforcement with other communities or agencies is done - some are doing more and some less than in the past

Challenges or problems regarding speed enforcement

- Need more people to cover the demands – have to cover crashes, domestic disturbances, variety of other things
- Takes time for training to be radar certified
- Need more equipment – much old and expensive to replace
- The public not educated enough about what local enforcement does and why, or the number of crashes that are occurring in their own midst - one example county had 1 homicide last year and 15 traffic fatalities
- Funding needed – enforcement activity not cheap
- Need for GIS mapping to really know where speed crashes taking place – too broad now

Different approaches to enhance speed enforcement and/or reduce speeding in NC

- Supportive of speed cameras – local police think the public is not positive toward speed cameras because of no contact with officer – officers support the concept of using speed cameras in school zones and work zones - think the systems are very inefficient if the officers have to sit in a van with the equipment (evidently what was done in Charlotte previously)
- More interagency cooperation needed – the SHP has very little coverage considering the miles of roadway under their charge
- Provide more education to various groups about the seriousness of the problem - young drivers would be an emphasis group

<u>GHSP-funded programs</u>

The NC Governor's Highway Safety Program (GHSP) has seat belt ("Click It or Ticket") and alcohol campaigns ("Booze It and Lose It") that have been very active in generating widespread enforcement cooperation. The "No Need 2 Speed" program remains active but has not been as widespread as the seat belt and alcohol campaigns. GHSP indicates that funding is a problem. On the positive side, State and local law enforcement officers cited 12,476 motorists for speeding during the "No Need 2 Speed" campaign which ran March 28-April 3, 2011. A total of 38,104 traffic and criminal citations were issued statewide.

<u>Automated enforcement in the State</u>

(Some information about ASE is summarized from news accounts below under Publicity section.)

The City of Charlotte used speed cameras in high crash corridors in 2005 and part of 2006, and special enabling legislation was required. The dismantling of this effective Charlotte program (safety evaluation was performed) occurred after the courts ruled that proceeds from the use of red light cameras in the City of High Point, NC had to revert to the school system by State law. Thus, localities and vendors could not recover their operating costs.

Courts Operations and Administration

(There is more information in the Publicity section below as summarized from news accounts)

The Administrative Office of the Courts (AOC) processes all records from the court proceedings around the State of NC. Some 83% of citations are received from the enforcement officer and processed electronically through a program known as e-citation. The clerk enters the disposition of the citation in court and immediately sends to AOC. The e-citation program is statewide, but not every agency participates. Currently 282 law enforcement agencies out of 560 total (total includes campus police) are using e-citation. All SHP troopers use the program, and a total of 13,444 law enforcement officers have access.

If a person cited for speeding comes to court (or more likely a fast-track administrative court), the DA can review the citation with the person beforehand and possibly amend the citation or agree to a PJC. The DA has access to information on prior driver histories to use before determining plea arrangements. The final disposition is entered by Clerk of Court and then sent to DMV.

As of 2010 the AOC has been using an online system called "Pay NC ticket," where one can pay online and have disposition this way. In the past year or so, fines totaling $22M have been collected – about 400 tickets per day. The majority using this method may be people from out of state who want no part of having to go to court. If you pay this way, you are not able to plea to a lesser charge and are subject to insurance points and penalties.

Recent budget cuts in NC have resulted in loss of staff. Some 30% of AOC IT unit positions have been cut, along with 100 DA's positions. It is assumed that the loss of staff results in a slower court process with fewer DA's working the lines appearing in court.

Licensing, Driver Education, and Sanctions

(See more information in the Publicity section below.)

Driver records only reflect convictions and points are assigned only to traffic offenses. For example, evidence from courts (AOC) data suggests that about 31% of cases across the entire State with "original" speeding charges over a recent three-year period were reduced to "improper equipment – speedometer" in convictions. These convictions would not appear on the drivers' records or affect points toward license sanctions, nor affect insurance premiums. We have little other information at present, however, nor understanding of whether such reductions have an impact on future safety of either the involved drivers or on the overall deterrence effect of enforcement.

Along with a high-quality graduated driver licensing system, NC still offers school-based driver education, although there has been no evaluation of this measure in NC. Evaluations from the U.S. and a critical review first published by the Cochrane Collaboration in 2001 have found no evidence that school-based driver education in its present forms works to prevent road traffic crashes.

Roadway Planning, Design, and Maintenance

The information below results from the project kickoff meeting, an additional meeting with NCDOT State engineers, and conversations with NCDOT staff and oversight panel members from across the State.

NCDOT Speed limit setting and design

In NC, all rural roads, and the vast majority of major urban arterial and some collector streets are owned and operated by the State. There are 100 counties across the State, but counties have not played a significant role in managing the transportation network. In NC, there are eight regional traffic offices and 14 NCDOT Divisions as shown in Figure 22. The divisions have primary front-line interaction with the public on projects, and setting speed limits according to an NCDOT official (although regional offices may also be involved).

Figure 22. Map of North Carolina Department of Transportation divisions and counties.

As in most states since the repeat of national maximum speed limits, NC does not collect or monitor speeds on roadways in any consistent basis. Speed studies are conducted in a limited way for particular projects or for areas identified through complaints or crashes as having a potential speed problem.

Regarding speed limit setting, speed limits for new roadways or proposed changes are reviewed at the State level, but engineering judgment plays a role in setting appropriate speed limits across the different DOT divisions of the State. A variety of factors - the engineering judgment latitude; variation in population, terrain, and road network across the state; the age structure of the roadways; a variety of political and other methods of setting speed limits in municipalities, and changing design standards over time - have resulted in a diversity of speed limits for comparable types of roadways. Similarly, roadways that look and operate very differently can have the same limits. NC DOT does not currently use the US Limits tool, an FHWA product, as a resource in setting speed limits.

NCDOT officials believe that the driving public likes the highest speed at which they can safely travel, especially on rural roads or high design roadways. However, this belief may stem from the anecdotal experience of requests and complaints by the public. As far as we are aware, there has been no statistically reliable survey of public attitudes. DOT officials also indicate that the most common request is to *lower* speed limits, particularly in urban areas.

- NCDOT may use speed studies and other on-site investigations to note development, alignment, shoulder, clear zone, etc. – statutes set speed limits as 55 on rural roads and 35 in municipal limits if not signed – get a few requests to change these - use prevailing speeds on high % of roads

- A traffic ordinance is needed to support change from 55 to 35 mph – NCDOT has authority to write the ordinance – if roadway is access controlled, municipal concurrence is not needed
- Type of speed study depends somewhat on the NCDOT Division, but they have guidance on what should be considered, such as 85% speed, development type and amount, sight distance, clear zone, etc. – they try to report the pace speed (10 mph range with the highest proportion of speeds) in their speed studies – the difference between 85^{th} and 50^{th} % speeds is usually 5-7 mph
- Most speed studies triggered by citizen requests – or pattern of crashes, many of which are speed related – they typically do not use crash data definitions of speed-related to define a hot spot for targeting enforcement, since there is a belief that definitions of speeding from crash data are inadequate.
- Urban speed studies are similar but a different set of players is involved – 35 mph speed limit is the rule unless otherwise posted - would need a local ordinance to change, but this has to be agreed to by NCDOT if the road is a State-owned road – municipalities may not follow regular procedures, and may ask for speed limit changes based on public desire or political reasons.
- Voluntary compliance is what NCDOT is after – they tend to set speed limits on what is practical for the conditions – however, they know speed "creeps" because the public knows there is not enough law enforcement, court time, etc. to really handle all offenders.
- There may be some unreasonably low speed limits in place – the feeling is that more would be in urban areas, and particularly urban multilane sections.

Enforcement of speeds is not considered in setting speed limits - NCDOT does not take into account how enforcement works in that it differs by community – not repeatable and can change over time – also there is enforcement discretion on who to ticket to relieve the court docket, so may not ticket unless 10 mph over - NCDOT gets requests to set limit at 25 mph so that drivers tend to drive at 35 mph

- NCDOT tries to attack the buffer of drivers going 10 mph over, but NCDOT must have a speed limit that is defendable, practical, and repeatable in that they are sued frequently - 85% of drivers usually just under 10 mph over – so not everybody is 10 over – this is a misconception
- Trying to free up court time w some administrative actions (e.g., automatic penalties) so that there is more court time to deal w speeding cases
- The enforcement community is not held accountable for not enforcing, and the courts are not held accountable for not handling tickets, so that the engineering community is held accountable for the speed limit, and they get many lawsuits – they take the job of speed limit setting seriously, because in reality they could lose their job if done in a flippant manner – they are trying to set driver expectation for the look and feel of a roadway and get them to adhere to this expectation (speed limit) when they drive

Design speed issues include the following:

- Urban design speed of 50 mph is quite typical – if community wants a speed limit of 45, the design speed would be 5 mph above the speed limit – a design speed may allow actual higher speeds because the road is flat, not curvy, good sight distance, few roadside obstacles, etc. – so NCDOT needs to work with what the community desires and what the terrain allows – also try to make decisions that reflect a network effect across the state.

- In reference to using objects near the roadway to lead to a perceptual change that the roadway is narrowing, they counter that the physics of the crash do not change – again, trying for expectancies to be the same along a roadway.
- Transitions along a roadway can result in speeding.
- Roads with different design speeds and safety features may end up w same speed limit – they want roads outside of municipalities to look and be consistent
- Consider example of a 2L road at 55 mph and improving the road to a 4L with curb and gutter, better sight distance, etc. and then actually lowering the speed limit to 45 mph – might do so because of impending development.

<u>Publicity</u> – All of the information that follows is from News reports and not independently verified by HSRC. We have made some preliminary examinations of traffic and speeding convictions by citations, but were unable to analyze the data in time for this summary.

A 2007 report series in the News and Observer (N&O) (Raleigh newspaper) resulting from investigations using AOC data contained a wide variety of information in regard to speeding as highlighted in the sections below:

General facts reported by N&O- approximately 10 persons killed per week in speed-related (speeding-related) crashes (510 killed in 2008) – approximately 1,600 people per year die on NC highways in all crashes

- Crowded courtrooms - 80%, or more than ½ million speeders, were able to get reduced charges in court - usually broken speedometers, which sidesteps driver license points and insurance increases – Prayer for Judgment Continued (PJC) used a lot.
- This practice drives up insurance for everyone by passing on lost revenue from speeders into the overall base rate – forced drivers to pay additional $58 million in 2006, or about $9 per vehicle per year.
- 2.4% of those accused of driving above 55 mph and more than 15 mph over speed limit were convicted as charged.

In 2006-2007, as compared to 2000:

- State Highway Patrol wrote 434,000 tickets, amounting to 100,000 more than 6 years ago
- 40% more drivers going faster than 55 mph and more than 15 mph over speed limit
- N&O analysis of patrol citations shows 99% written were for 10 mph or more over limit.
- Number of drivers speeding 100 mph or more increased by 79%.
- Almost half the drivers charged with speeding were younger than 30 years.
- 19% of drivers ticketed at 100 mph or more were convicted as charged.

Speed limits – the State Traffic Engineer says there is tremendous pressure to reduce speeds in neighborhoods and some pressure to increase speeds on major highways – there is no consensus on how to set speed limits - typically the 85^{th} percentile speed and the 10 mph range within which largest number of vehicles are traveling are used - the State Traffic Engineer says the goal is to set a limit that is seen as reasonable

Court practices - these vary widely – the article cites Cumberland, Guilford, New Hanover, and Pender counties, as well as the group of Davie, Alexander and Iredell – the Wake County District Attorney will not allow pleas for improper equipment but routinely allows speeders to plead guilty to 10 mph or less over the limit

- For the Wilson, Nash and Edgecombe court district 19% driving at least 100 mph were allowed to plead 10 mph over speed limit
- Speeders are often allowed to plead to a lesser charge of improper equipment, but these charges do not get placed on the driver record and officers do not know how many a driver has been given when the record is examined in a traffic stop
- For a DA who tries to get tough on speeders the lawyers ask for trials, and the court system would be overwhelmed – thus, the courts have to find ways to dispose of less serious offenses to have time for the more serious crimes - in Wake Co. 1000 cases can be scheduled for disposition court on a single day
- Court costs are generally $110 and fines $15-30, whereas the average cost of a jury trial is $2162
- The courts turned over $127 million in 2006, but the state's total court budget was $468 million in 2007
- Example offender - a 23 year old from Rockingham, NC was charged 29 times over 5 years ending June 30, 2006 – pleaded guilty to improper equipment 21 times, received 4 other reductions and a PJC – convicted as charged once, one charge dismissed , one charge pending
- 4 of 5 had speeding charges reduced or dismissed or were given a PJC (June 30, 2006) – can get one PJC every 3 years

S**peed cameras** – Evidence and NC history includes the following:

- Speed cameras have been in use in Europe, Australia and New Zealand for 25 years or so
- In Victoria, Australia, the number of people killed in traffic crashes was cut in half in 5 years.
- Charlotte used speed cameras in high crash corridors – reduced speeders going more than 10 mph over limit by 55% and reduced crashes by 12% (from a Charlotte police captain) – in 2005 cameras accounted for 43,000 tickets and one half of one percent appealed the $50 fine
- Charlotte cameras were turned off after the High Point, NC court decision on red light cameras, where the ruling was that fines had to go to the state instead of being used to help offset the cost of the program
- There were at least 2 attempts in the NC legislature, in 2005 and 2006, to work around the constitutional requirement that the "clear proceeds" of all penalties, forfeitures and fines must go to the schools, but both failed – tried to define clear proceeds as money left over after paying for the cameras and cost of operating – the counsel to the Judiciary committee said this was unconstitutional

L**oopholes** – in 2006-2007 in more than 11,000 cases of drivers charged with going 90 mph or above were allowed to plead guilty to improper equip, or to a lesser speed, or got a PJC. The following points were noted:

- The NC legislature has been passing loophole laws for 24 years – seems to have started in 1983 where drivers got one free pass every 3 years for speeding 10 mph or less over the limit – the feeling was if you are speeding less than 11 mph over the limit your insurance costs should not go up – in 2006-2007 some 19% of speeding charges were bargained down to 10 mph or less

- For a single speeding citation of 81 mph in a 65 mph zone a driver would lose his license for 30 days and would have to pay 80 % more for insurance for 3 years – the legislature provides legal ways to beat the system
- PJC came about in 1987 – one PJC every 3 years per insurance policy is allowed – in 2006-2007 judges granted 56,000 in speeding cases, including 2,800 to defendants charged with speeding 90 mph or more and 226 to defendants charged above 100 mph
- In 1990 legislators turned to improper equipment and speedometers as ways to circumvent speeding tickets

Laws – a powerful state legislator made an attempt to change laws as a result of the newspaper article:

- To allow DMV to record improper equipment – speedometer, on driver record
- To limit improper equipment pleas to 2 in a 5-year period
- To prohibit judges from granting PJC in high-speed cases
- the NC Senate approved 49-1 May 23, 2007
- On July 28, 2007 a House committee strengthened the Senate bill by preventing drivers charged with speeding more than 25 mph over limit to plead improper equipment, speedometer (Senate version was 30 mph over) – then the full House defeated the bill on Aug 1, 2007 – then compromised to pass the law by eliminating the feature that limited drivers to 2 pleas of improper equipment in 5 years – the bill was applied after Dec. 1, 2007
- The State Senate was to study insurance surcharges levied on drivers convicted of speeding and other traffic offenses (Aug 8, 2007) – then a legislative study commission was to convene at start of 2008, with findings by May 2008

(Note: The N.C. General Assembly recently passed a law that increased the penalty for speeding in school zones and on school property from $25 to $250. Five insurance points will also be assessed on the violator's driver's record. No action was taken on a bill that would have enable automated speed enforcement in school zones and work zones.)

Workshop - Summary of Problems and Recommendations

With the objective of identifying important strategies to help North Carolina achieve the greatest possible reductions in speeding and speed-related crashes and injuries in future years in mind, a one-half day Speed and Safety Symposium was held on October 11, 2011 at the North Carolina Museum of History in Raleigh. The Symposium featured presentations by international experts on best speed management practices worldwide, as well as presentations on the crash problem and other issues in North Carolina (NC). On October 12, a full-day panel meeting was convened involving NCDOT, UNC-Highway Safety Research Center project team members, the speed and safety experts who also presented on October 11, and officials and representatives from nine other NC agencies and one legislative task force with interests or roles in traffic safety in the State. (A full list of participants in the panel meeting is included in Appendix 2.) The expert consultants, HSRC project team members, and a NCDOT representatives also met on October 13 to continue discussion about potential speed management strategies and research needs.

Prior to these meetings, the University of North Carolina Highway Safety Research Center had been tasked to undertake a review of effective speed management practices and countermeasures and perform a problem assessment regarding the speeding-related safety issues in the State. A summary of the information compiled was provided in advance to all of the participants in the panel meetings. The panelists were also asked to attend the Symposium on October 11 in order to hear the presentations from the experts on some of the best speed management strategies and practices from around the world. The NC meeting participants were able to quickly focus on key issues that need to be addressed in order for North Carolina to continue improving speed management practice and help the State progress toward zero fatalities and serious injuries resulting from inappropriate speed.

The sections following summarize the discussions and recommendations emerging from the panel meetings.

Speed Limits, Design Speed and Speed Limit Credibility

Principles and key points emphasized during this discussion (and the symposium) include the following:

- It is not an effective, proven safety measure to set speed limits based on existing, prevailing speeds.
- A number of safer countries have used safety principles to set speed limits to minimize trauma to the most vulnerable users for that roadway type and design.
- Enforcement is enhanced as needed to ensure drivers comply with the limits (including before changes can be made to the roadway).
- A credible speed limit may be a limit within which a majority of drivers operate, but is not necessarily reflective of a generally safe speed limit for the conditions.
- Road design, enforcement and other communications must work together to convey the well-established, safe maximum speed of a roadway.

Discussion highlighted the difficulty in agreeing on what credible speed limits are, and that credible speed limits are not necessarily safe speed limits (until efforts are made to bring them together). There was wide agreement, however, that speed limits need to be reflective of the roadway and environment to be enforceable and understood by drivers, and that drivers will do what the road tells them to do (although there may be some variation among drivers in their responses). The 85th percentile speed has often been assumed, in practice, to be a credible speed limit, but since we know that drivers will exceed speeds that even they perceive of as safe, it should not be interpreted to be a safe speed unless the road operates with few serious crashes at such speeds. If such is the case, then a speed limit adjustment may be warranted. (But see cautions about raising speed limits below.)

A number of countries with better safety track records have established safe speed limits based on the function and users (purposes) of the roadway, with a focus on providing a high degree of safety (minimal risk of being killed or seriously injured in the event of a collision) for the most vulnerable users, and considering the design and extent of separation of different weight and speed of users. In an example from the Netherlands (represented by Letty Aarts from SWOV), the functionality, context and users are assessed as part of the network-based provision of safe access and mobility. For example, urban and potentially other local streets that serve all destinations and modes would tend to have very low speed limits (based on research showing the relationship between increasing speeds and fatality risk to pedestrians). When speed limits are lowered to better-match the uses of the roadway, the Netherlands uses enhanced enforcement (until the road design can be changed). Higher speeds are appropriate for other roads that serve primarily through motorized traffic and have high design standards (design consistency and minimal conflict potential). Design and infrastructure changes are made to the roadway to achieve operating speeds in line with established speed limits (or shift uses/functions to other network roads).

Safe speeds may also mean different things to different types of stakeholders such as engineers, planners and law enforcement than they do to drivers. For example, drivers don't perceive the importance of width of the shoulder as engineers do and therefore, may not adjust speeds downward even when insufficient paved shoulder exists. And while engineers may think that adding an advisory limit sign should be enough to alert drivers about a sharp curve or other unexpected feature, drivers may not understand the reason for the sign (or even notice it). Drivers may also not perceive the risk of a bicyclist, child, or car emerging from rural driveways and adapt their speed accordingly, although engineers would understand that many connections to the roadway may warrant a speed zone or lower speed limit. Therefore, design changes or other added cues and/or enforcement may be needed in such circumstances to properly convey the speed limit which should in turn reflect desired operating speeds.

Conversely, people are very sensitive about children and drivers will likely obey a lower limit around schools or other obvious child activity area, even if the road design doesn't fully convey the reasons.

Researchers Conclusions: A significant number of drivers don't necessarily perceive what is a safe speed, at least not in all circumstances. Furthermore some drivers may choose their speeds for selfish reasons (e.g., perceived time savings, enjoyment), others due to learned habits or by adopting the speeds of those around them. These reasons for speed selection are not in the broader public safety interest. There may also be very legitimate reasons to set lower speed limits than the road environment (as currently built) conveys (to most drivers) such as level of access, land/community uses, school zones, high conflict areas, high pedestrian areas, and others. Therefore, relying on 85th percentile speed to set limits is a very imperfect way to set appropriate speed limits for the roadway function and users served. According to the experts, using such practices (based on prevailing speeds) for speed limit setting is how we got where we are now. When reviewing whether current speed limits are appropriate and what to do about discordance between limits, operating speeds, and design and function of the roadway, note that care should be taken in raising limits, since most prior evidence suggests that severe and fatal crashes are likely to increase when speed limits are raised (if travel speeds also go up, as they are likely to do over time). Other options are described below under Solutions.

(From the literature synthesis: Note that in the U.S., the term rational speed limit has come into greater use, and may incorporate more safety through the use of such tools as U.S. Limits. The U.S. Limits Tool provides a structured approach to reviewing speed limits that incorporates crash histories and specific roadway attributes, but the prevailing speed distribution still has most weight in the recommended speed limits generated by the models.)

NC-specific issues - Speed Limits, Design Speed and Speed Limit Credibility

- Default urban speed (within city limits) limits are 35 mph by statute and must be changed by local and State concurrency ordinances (for State-managed roads; local ordinance only for local streets).
- Design speeds are often significantly higher than the intended operating speed of the roadway, particularly in urban areas. Such roads may contribute to a misperception on the part of drivers about safe operating speeds and a challenge to enforcement.
- There may be diversity of opinion about the purposes of specific roadways.
- Many different practices currently exist for setting/changing speed limits from default maximums in cities and towns around the State.

- Default rural speed limit maximums are 55 mph outside municipal limits by statute. These default limits are not required to be posted, and some questioned whether drivers even know what the default limits are.
- Many (if not most) of the 55 mph statutorily set, two-lane roads are not designed for that speed, but it requires a statutory change to change the default maximum statewide, or a speed limit review and engineering study for every section of roadway in order to implement a speed zone.
- There have not yet been any specific guidelines or triggers for speed-limit review, with these usually being triggered by the public, the business community, or various political leaders/bodies.
- Speed limit review and engineering practices are not standardized across the State, as there are no standardized methodologies for establishing speed zones.
- The NC State maximum limits are 70 mph on Interstates or “any part of a controlled access highway (either inside or outside the corporate limits of a municipality).” (It is not known how this limit was determined, but most likely for political/mobility/economic reasons rather than safety reasons.)

Municipalities can raise limits to a maximum of 55 mph, and lower limits from the default 35, on locally-operated roads, but State and local concurrent ordinances are required to change limits on State-maintained roadways within municipalities. Signs are required when limits are different than default limits. (Different practices may prevail among municipalities when raising and lowering limits. Presumably, most conduct traffic and speed studies, but speed limits are also raised or lowered on local and sometimes State-owned streets by political pressure.)

There have not yet been any specific guidelines or triggers for speed-limit review, with these usually being triggered by the public, the business community, or various political leaders/bodies. For this and other reasons, there is a diversity of speed-limit setting practices across the geographic regions of the State which vary extensively in topography as well as development and roadway infrastructure. Some of the other reasons include a diversity of practices among all the cities, engineering judgment (across different NCDOT regions/divisions) employed to set speed limits, and the historical legacy of diverse-aged roads, some of which were not ‘designed’. The result is that roadways with similar function and design may currently have very different limits, and roadways with the same limits may also look and operate very differently.

Rural two-lane highways. Another specific key issue in relation to speed limits and design speed was raised. According to a design engineer with the western region of NC DOT, “Many of the 55 mph statutorily set roads are not designed for that speed, but it requires a statutory change to change the limit. We deal with this a lot.” A speed limit review and traffic engineering study is currently required for any speed limit reduction (or increase) on any section of the many miles of State Secondary roadways. So, while each section could be studied and limits reduced if warranted, the resources required to study each section to institute a speed zone are likely prohibitive.

State secondary roads accounted for 37% of all fatal crashes, 52% of fatal speeding-related crashes and 43% of all speeding-related crashes in NC. These roadways also comprise the largest number of roadway (centerline) miles in the State (64,000), although most have low volumes.

Urban corridors. A State DOT representative mentioned that cities and towns often perceive the uses and functions of State roads within their borders differently (access to businesses and properties) than does the State DOT (throughput); the implications could also affect speed limit setting and design practices.

There was discussion of possible adverse speed and safety effects of the high design standards of DOT-owned roads in urban areas. State-owned arterials and other corridors may have design speeds of 55 mph. Default urban speed limits are 35 mph, but some urban roads have higher speed limits (changed through ordinances).

About 20% of fatal crashes and 28% of all crashes involving speeding occurred in urban areas over the past six years. In addition, 27% of all fatal crashes occurred in urban areas. DOT officials indicated that a majority of speeding problems in cities are on urban arterials. The top 12 counties with the greatest numbers of speeding-related crashes are all urbanized counties and account for 38% of the State's total speeding-related crashes, so addressing speeds in urban areas would be a way to target a significant number of fatal and speed-related crashes.

There was no direct discussion about speed limit and design issues on other types of State roadways.

Solutions identified - Speed Limits, Design Speed and Speed Limit Credibility

Design, limits, and enforcement must work together. The experts each mentioned that when the road design fails or cannot for some reason be changed, then (road managers) have to set the speed limit to a safe limit, AND it must be enforced.

- ☐ Establish appropriate speed limits for intended use and function of the roadway. In European countries such as the Netherlands, speed limits have been established based on the type of road users, functions and design of the roadway as part of the "safe systems" approach. Safety for the users is a key consideration in establishing the limit. For example, urban streets that provide access to homes or businesses and serve pedestrians and cyclists would be posted at speeds expected to be survivable by the vast majority of pedestrians (most vulnerable users) should they be involved in a collision (more on this below).

The importance of collecting and analyzing more data to gain more understanding of the problem and potential solutions was highlighted.

Other speed management recommendations included the following:

- ☐ Collect travel speed data to enhance our understanding of speed and speeding issues in relation to road types and other risk factors.
- ☐ Collect data on what drivers think or perceive about different speed issues, potentially including, but not limited to whether drivers know what default speed limits are in rural and urban areas, whether drivers think speed/speeding is a problem and want actions taken, perspectives on enforcement and automated enforcement and potentially others.
- ☐ Good compliance with speed limits requires that road users always and everywhere know what speed limit is in force, including on unposted (default limit) roadways. Clear information must be provided (Organization for Economic Co-operation and Development, 2006).
- ☐ Review existing speed limits on all roads on a regular basis. Although this recommendation did not emerge directly from the panel meetings, the research team recommends that the current practice of reviewing limits only when some stakeholder or other requests it should be changed to a more systematic schedule, prioritization, and regular process for reviewing speed limits on all roads.

Having guidance already in place about what speed limits are appropriate for different types of roads should go along with speed limit review.

- ☐ A subset of speed limit review would be to assess whether current default maximums are appropriate. A lower versus higher default speed limit profoundly affects risk, as even small reductions in mean speeds reduce crashes and injuries and resultant costs to the State and its citizens. It will be a long-while before the 60,000 miles of rural state secondary roads can be improved, but there may be other measures available, potentially, lower default speed limits. A demonstration example is provided in Appendix 3 of expected crash reductions if average operating speeds can be lowered by even small amounts on state secondary roads. However, there is a need for further data to understand the speeds that drivers are currently driving in relation to current limits, as well as whether there is comprehension of default speed limits before particular measures are undertaken. Additional needs may follow this step.
- ☐ Assess roadways function and use. DOT mentioned that A Complete Streets policy has been adopted by the State Board of Transportation. There is a Complete Streets document currently under development (version 1 now finalized) by NCDOT that should provide additional guidance on assessing roadway function as well as selecting speed limits and designing for appropriate speeds on various functional types of corridors and streets. This guide could be a common tool for establishing safer speed limits.
- ☐ Design for safe speeds. The experts provided guidance on roadway and design cues that affect drivers' speed choice in both particular and general circumstances. Design for urban areas and roadways that are not access-controlled should follow principles that suggest lower and safer speeds. For example urban, multi-function streets should use narrower lanes, smaller number of lanes, tight turn radii, street trees, or street furniture close to the street, and facilities, markings, and signals for transit, pedestrians and cyclists that illustrate that the streets are used by all modes. Divided roadways and other access-controlled measures as well as wider lanes should typically be reserved for roads serving as connectors and primarily through-put traffic.

Other primary cues for slowing speeds (affecting driver perception and speed choice) include:

- Guardrails that affect visual perception, especially those close to the road that give less tolerance.
- Closed versus open roadsides/environment (buildings, trees close to roadway versus few buildings trees, open "periphery").
- Curves versus straight roads.
- Perceptual narrowing techniques such as using paint for transverse markings at decreasing distances, different colored shoulders, etc.
- Increased cues for "blind" curves. The less drivers can see of the curve on the approach, the less the driver perceives the sharpness of the curve. Those unfamiliar with the road will need added cues in such situations.
- In general, signing alone is weak and overused.

Proven speed-related engineering treatments for reducing crashes:

- Roundabouts to replace both stop-controlled and signalized intersections.
- Traffic calming measures – particularly speed humps and tables.
- Transverse rumble strips on intersection approaches.

- Road diets which change a road from four lane undivided to 3-lanes (with middle lane being a two-way left turn lane). The crash reduction effects have been larger in more rural/suburban type areas (where speeds were likely initially higher than in urban areas). These have been tried extensively in Iowa and Washington States.
- *Chevrons and warning paint on curves. The chevron/pavement marking curve delineations are useful for the curves that are not "self-explaining." Enhanced delineation of curves has achieved crash reductions in quality U.S. studies. But, there was a caution that if curve delineation is over-used, drivers may start to ignore these treatments as well.
- Shoulder rumble strips also help to prevent road departure crashes, which are often speeding-related. It is not yet clear whether shoulder rumble strips help to reduce speeds.

*NCDOT is working on a systematic approach to delineating curves that are further down from the "highest priority list." A delineation "template" will be provided to make the curves look like the template. DOT is also committed to evaluating this approach.

Other resources are available and currently being developed that will assist the State in identifying speed and crash-reducing countermeasures and prioritizing design and retrofit remedies.

Enforcement of Speed Traffic Laws and Driver Sanctions

As mentioned several times, design, limit setting, and enforcement must work together. If limits are not enforced or at least perceived to be enforced, they will not be obeyed.

Speed management principles include the following:

- Drivers must have a high perceived risk of being caught and punished for speeding at any time or location for speeding enforcement to have a widespread deterrent effect.
- The goal of an enforcement program should be for most drivers to believe that they will be caught and punished.
- Enforcement alone is insufficient for population-wide deterrence of speeding. Publicity about the enforcement is needed to provide sufficient deterrence.
- Automated technologies are the most cost-effective way to increase real risk of being caught speeding (specific deterrence) as well as to increase general deterrence (especially if widely-publicized).
- Consistent and certain punishment is more important than degree of punishment for most drivers. The goal should be to make certain that punishment will occur certainly, consistently and (reasonably) swiftly, even if fine amounts and penalties must be somewhat lower to accomplish greater certainty.
- Drivers must believe that speeds are enforced close to the threshold (and perhaps see others around them obeying the limits) to believe those limits.

NC (Specific) Issues - Enforcement of Speed Laws and Sanctions of Speeders

- It is very difficult if not impossible to achieve crash reductions using traditional enforcement alone.
- Automated speed enforcement has been documented to reduce crashes and injuries in at least one North Carolina (Charlotte) program (now discontinued) and from many other national and international studies.

- High enforcement tolerances further erode belief in North Carolina's speed laws, there was considerable discussion about large enforcement tolerances currently often practiced by law enforcement (and which may also relate to the court situation. High enforcement tolerances above the posted limit serve to create a "de facto" speed limit much higher than the actual limit. This wide tolerance sends the message to the driving public that speeding 11 to 15 mph above the limit is acceptable. If drivers believe speed limits are not enforced, or that there is a wide tolerance, they may adapt their speeds accordingly. When a majority of drivers exceed by even a few miles above the limit, significant increases in the severity and number of crashes are expected.
- Municipal enforcement. Issues mentioned relating to challenges for municipal speed enforcement include funding for local police agencies to cover the costs of personnel, equipment and training for traffic enforcement, better data or methods of identifying locations where speeding is of particular safety concern, and convincing the public that speed enforcement is worthwhile. The way funds from enforcement are currently legislatively allocated, there are no funds available from citations to cover traffic enforcement costs or to go towards additional safety efforts in cities. This policy seems to serve as a disincentive for at least some cities to aggressively enforce speed limits. This issue was also brought out in interviews and discussions with local enforcement agencies prior to the panel meeting.
- Political support. Need to convince may levels of government and jurisdictions that speed enforcement is an important safety issue.
- The current court system for adjudicating speeding and other traffic citations is broken. Linkage of vehicle insurance with driver license points currently serves as a major financial incentive for arrested drivers to contest speeding penalties, clogging the court system and affecting the swiftness, consistency, and certainty of punishment.

There was considerable discussion of the fact that there is not enough traditional enforcement to achieve the widespread deterrence needed in NC (or elsewhere) and little chance of that changing significantly any time soon. The public may actually have a higher perception of the odds of getting a ticket than really exists, similarly to what was recently demonstrated in a Norwegian study (Elvik, CIT. needed). Even when high crash areas are targeted, some enforcement officials indicated, it has been hard to observe an impact on vehicle speeds. Just giving tickets, even in concentrated areas, isn't effective without publicity, because not enough drivers know about it to result in the widespread deterrence needed.

Enforcement Solutions

- ☐ Technologies such as ASE should be used to enhance the actual and perceived risk of being caught.

Automated speed enforcement (ASE) is widely used in Europe and Australia to enhance enforcement presence and reduce injury crashes. ASE is cost-effective and can be employed on a wide scale, or to target particular hazardous situations or locations difficult to enforce by traditional means. It is likely that ASE works by both increasing actual and perceived risk of detection. Along with publicity of the programs, ASE may provide extensive deterrence of speeding. Fatal and injury crash reductions of a Charlotte, NC mobile speed enforcement program and publicity were about 25% (Hummer and Moon, 2010). About 10% of the crash reduction effects were attributed to associated media publicity and about 15% to the enforcement in the Charlotte program. Estimated reductions in injury and fatal crashes of

48% were obtained on a principal urban arterial/freeway loop road (Scottsdale, AZ, Shin et al., 2009). Crash reductions may vary depending on the implementation.

Ways to overcome the barriers to ASE were discussed:

- Strong public/private partnerships including health and wellness leaders, business leaders, insurance, legal professionals, and others are needed to pursue the needed enabling legislation for ASE.
- Communications strategies should be carefully planned both in seeking legislative approval and in establishing and maintaining programs. Adopting a strong public health message that speed is the #1 killer on the road, paired with the objective to make NC a safer place for everybody could be a way to frame the efforts.
- The State could assess what the public thinks through surveys. Such knowledge is important to know where you stand, and may be useful in selling the idea.
- Communicating that "There is good evidence that if we don't go ahead then you can expect this (continuing fatalities and injuries and costs to the public) to happen" may be another way of framing the issue.
- Administration, cost recovery, and other vital aspects and principles of a good program should be carefully planned before legislative changes are sought.

To sustain ASE programs:

- Maintain a program focus that the reason for the ASE is safety.
- Do not tie numbers of citations issued to payment to vendors and follow other best practices.

Montgomery County, MD has had a successful ASE program in place for many years. It has been methodically and carefully sustained by maintaining a focus that the safety evidence supports camera use for enforcement. NHTSA has guidelines for camera programs and ASE, and in time, the continued use with good communications gains acceptance. The public is not opposed to efforts to reduce speeding and improve safety, but it is also the case that everyone doesn't have to be convinced. (Note that the level of public support, although in the majority, has not substantially increased in the U.K. over many years, but a strong ASE program continues to be implemented)

- ☐ Tighten enforcement thresholds to increase respect for established limits and publicize.

When a majority of drivers exceed by even a few miles above the limit, significant increases in the severity and number of crashes are expected. Small reductions in mean speeds can have large impact on crashes and severity. Australia has had additional success toward further bringing down crashes by tightening enforcement thresholds to basically within the margin of error of measuring devices and, widely publicizing these efforts. These efforts have not always been popular, but leadership has been strong in maintaining support for speed enforcement measures.

- Again, additional data are needed on current operating speed distributions and the effects of lowering enforcement tolerances (with and without other changes).
- Adjudication changes may be needed before lowering enforcement tolerance is tried and evaluated.

As a result, it has been difficult to recover the costs of operating programs and most have folded, including a Charlotte ASE program that was successful in reducing crashes. Some programs have also been discontinued because they were badly design and not supported by decision-makers. In some of these cases, the public and decision-makers objected to the fact that revenues to the operating companies were tied to numbers of citations issued.

Adjudication

There was much discussion about the current traffic citation adjudication system which is undermining enforcement efforts further by failing the principle of swift and certain punishment. North Carolina's traffic laws and punishments for speeding, especially when considering the linkage between driver penalty points and insurance costs, have led to the situation in which it is cost-effective for cited drivers to contest penalties, especially for drivers with the most to lose (prior convictions). Courts officials describe that the resulting clogged courts have tied prosecutors' hands and suggest that most speeding infractions need to be taken out of the courtroom for more consistent and better adjudication outcomes.

Prosecutors also say they cannot look up driver records for speeders when 1000s come to court to contest their citations. This situation has led to widespread pleas to lesser charges, dismissals, and prayers for judgment continued (PJCs) that for the most part do NOT show as speeding convictions on drivers' license histories. Driver histories are therefore not reflective of risk that may be posed by repeat speeders. And, even egregious speeders slip through the system. Consequently, nothing meaningful can be done to address repeat and egregious violators or even determine who they are. The current situation also breeds general disrespect for North Carolina's speed laws as even unintentional or infrequent speeders realize that they can easily escape conviction for speeding.

Reporting and research for a State newspaper and the on-going courts situation strongly indicates that recent legislative attempts to close some loopholes have not solved the problems. According to a later communication by the reporter, "Those tough penalties enacted by the General Assembly are easily evaded by using one of several loopholes which legislators also enacted. Speeders show up on their court date, stand in line with all the other unlucky souls, pay the cost of court even though they don't actually go to court, plus a small fine, and go their merry way. North Carolina's speed laws are a joke, and almost everyone knows it."

As mentioned above, drivers' prior records are not readily available to court personnel (due to time, staffing, and funding constraints). This situation also limits court officials' abilities to identify and treat repeat offenders differently. The NC Executive Committee Speed Group had suggested that every violation, including the initial charge and the disposition, should be on drivers' license records. Although initial charges are not currently reflected, the project team learned that some local traffic enforcement officers assume that PJCs, convictions for faulty equipment, and lower level speeding convictions are likely reflective of initial charges of speeding and higher level speeding, and will indicate these on citations at the time of a stop to assist in prosecution of repeat offenders. However, the perception of HSRC participants in traffic records coordinating committee is that accurate driver histories are not readily available to officers at the time of a stop and significant effort will be required to coordinate such information systems.

Potential adjudication solutions include:

- ☐ Provide improved data on driver histories to courts' officials.
- ☐ Another potential improvement that could be used in the interim, or if effective, as a long term solution to assist courts officials in prosecuting and adjudicating cases under the current structures was suggested. The suggestion was made that the State Highway Patrol (SHP) print out the driver's prior record or write in the notes part of the citation if there are prior speeding convictions. Given the current lack of knowledge about the initial charges, any prior convictions

that could relate to initial speeding charges could be noted. Since it was thought that the SHP can access drivers' records at the time of the stop, it was thought that such notations could be made at the time citations are issued. Such a change could help prosecutors and the courts recognize repeat and flagrant violators and be better able to treat such violators differently. However, the records available through law enforcement and DMV resources may not be complete.

- ☐ To increase the consistency, certainty, and swiftness of punishment, move a majority of lower-level speeding citations from district court to administrative handling and eliminate pleas. Fines and court costs should be kept relatively low, could be scaled to the offense, but there should be no linkage to insurance points. The expectation is that most drivers would then not find it worth their while to contest the administrative penalties, would pay their fines, which should be levied immediately, and more serious speed crimes may then be dealt with in district court. Court costs should be designed in such a way to pay the costs to operate the system, with fees being used for other public priorities (potentially still schools, but possibly for traffic safety efforts).

Expert legal, policy, and research work will be needed to develop sound legislative proposals. Many of the same of the same issues and strategies that are needed to change policies and overcome barriers for automated enforcement may be applicable here and it may be feasible to pursue the objectives of enabling legislation for ASE and creating a civil penalty code and administration for most speeding infractions (and covering the costs of each) together.

- Public and private partners are needed to pursue and follow through on the legislative changes needed.

Using an example for DWI: "we did not get there by convincing people one on one not to drive drunk. We changed the laws so we changed the way life is lived – people came in line."

- There must be top-down policies and support for effective strategies.
- There is a need to convince legislators that speeding is a problem and that policies and laws should be changed to allow more effective ways to deal with speeding.

<u>Publicity</u>

- ☐ Publicity should be widely employed to support enforcement efforts and enhance the perceived risk of detection.

Australia has had success by employing publicity efforts, both through paid conventional media and, more recently also using social media, that relate to and emphasize the enforcement effort underway. Some Australian States have, more recently, also developed campaigns targeting the social acceptability of speeding. However, it may be most important for NC to focus early efforts on magnifying the effects of enforcement to increase the perceived risk of being caught speeding. Attacking the social acceptability of speeding could follow or supplement, but all campaigns must be carefully developed, tested, and implemented.

APPENDIX III – Network Screening

One of the recommendations to emerge from the problem identification process was to develop a proactive and systematic approach to identify corridors that may benefit from speed limit and safety review. Phase 2 of this project therefore focused on developing several approaches to network screening that might be used to prioritize routes for review. Other potential triggers include:

- Changes in roadway function or uses,
- Significant changes in traffic volume
- Changes in development extent or type,
- Changes in use of the roadway due to implementation of other roads (alternate routes or nearby corridors).

The next sections describe the approaches used and summarize a few of the outcomes, focusing on outcomes for rural, two-lane corridors. Results for all the route types screened were provided as Excel workbooks directly to the NCDOT Mobility and Safety Unit. Many options are available for ranking the corridors within each list.

Corridor Screening Approaches

In collaboration with NCDOT, it was determined to adopt a corridor-focused network screening approach to identify routes with potential speeding-related crash and injury problems. Defining a corridor is not a straight-forward endeavor. To some, a corridor could be a highway that traverses several counties or passes from county (rural) into urban jurisdictions. To others, a corridor provides a continuous route between origins and destinations. The route numbers may sometimes change. However, roadway inventory data do not identify which route numbers are considered by local engineers or drivers to be the same corridor. Route numbers had to be used to uniquely identify corridors at the highest level. The cross-section of a corridor might change several times as well. There may also be corridor-wide influences on safety, including the traffic that uses the road, design issues between the transitions, and others. However, road sections with significantly different designs and traffic volumes are likely to have different average safety performance functions.

The research team attempted to balance the need to compare similar sections of roadway to determine when a section is performing poorly with the desire to identify corridor-level speeding problems. Therefore, the team considered only fairly high-level changes in design or changes such as urban-rural transitions, and a few other major cross-section, volume, and design category changes to minimize breaks in ‘corridors.” to. The approach combined segments and adjacent intersections into corridors defined by similarity of key roadway characteristics, defined below.

Identification of Corridors

The first step in the screening of the network was to identify corridors that may need further investigation to identify appropriate countermeasures. The following variables were used to determine when a corridor would end and a new corridor would begin:

- County route
- Area type (rural versus urban)
- Mile-posting gap of more than 0.005 miles

- Access control (partial versus no access control). These two categories were ultimately combined due to low numbers of partially-controlled roads.
- Route subcategory (2L, 4L, DCL, SVR, RMP, or 'other')
- AADT category (Unknown, $\leq$1499, 1500 – 4999, 5000 – 14999, 15000 – 23999, $\geq$24000)

Corridors shorter than 0.1 mile were not included in the network screening. Since sufficient data were not available for service roads and ramps, the screening was conducted for corridors that belonged to the following six roadway types:

- Rural 2 lane
- Rural multilane undivided
- Rural divided
- Urban 2 lane
- Urban multilane undivided
- Urban divided

Roads with full access control were, however, not included because NCDOT indicated that they were not high priority for screening for speeding related crashes. Wholly federally-owned roads (such as National Park roads) also were not included.

Screening Methods

There are many ways to screen a network to identify corridors or sections that may need safety treatment. The more advanced methods make use of safety performance functions (SPFs) and the empirical Bayes (EB) method. These advanced methods are intended to address potential bias due to regression to the mean (RTM). To use such methods, there is a need for traffic volume data. Not all roadway segments in North Carolina have traffic volume information. Hence, these advanced methods could not be applied to the whole network.

Other methods include examining the trends in crashes to identify corridors that have seen a larger increase in crashes in recent years compared to the average for that roadway type. Another method involves identifying corridors where the proportion of crashes (e.g., proportion of speed-related or severe injury crashes) is higher than the average for that roadway type. Further discussion of these methods is provided below.

Method 1: Use of SPFs and the EB Method

The empirical Bayes (EB) methods refer to a suite of screening methods that are based on estimating the *long-term* expected crash frequency for a location. These methods have been adopted for the *Safety Analyst* software which, among other analyses, performs network screening. It is also documented as a preferred methodology in the recently published Highway Safety Manual.

The empirical Bayes estimate of expected crash frequency for a location is a weighted combination of the prediction from a safety performance function (SPF) and the observed crash count for the location. The weights (*w* and *1-w*) are calculated based on the EB procedure that makes use of the overdispersion parameter that is an outcome of the SPF development using negative binomial regression.

Sites are ranked in descending order of the expected crash frequency (E) or, alternatively, the expected excess crash frequency, which is the difference between E and the SPF prediction.

> *Estimate of Expected Crashes for a site (E) = w × (SPF prediction) + (1 – w) × (Observed crash frequency)*
>
> where: $0 \le w \le 1$
>
> *Estimate of Expected Excess Crashes for a site (EE) = (Estimate of Expected Crashes for a site) – (SPF Prediction)*

Here is an example that illustrates how E and EE can be estimated for a particular corridor. Here are the details about a hypothetical corridor:

Roadway type:	Rural 2 lane
Length:	3.5 miles
Average AADT:	2500
Observed speeding-related crashes in 5 years:	6

Based on Appendix IV, the SPF for speeding-related crashes for rural two lane roads is the following:

Y = exp[-5.4342 + 0.5339*ln(AADT)]; k = 0.6084

Where, Y is the predicted number of crashes for a 1 mile corridor per year (k is the overdispersion parameter). The SPF prediction for 3.5 mile section for 5 years will be the following:

5*3.5*exp[-5.4342 + 0.5339*ln(2500)] = 4.979.

The EB weight $w = \frac{1}{1 + k * (SPF\ prediction)} = \frac{1}{1 + 0.6084 * (4.979)} = 0.248$

Estimate of Expected Crashes for a site (E) = w(SPF prediction) + (1-w)*(observed crash frequency)*

*= 0.248*4.979 + (1-0.248)*6 = 5.747. E per mile will be 5.747/3.5 = 1.642.*

Estimate of Expected Excess Crashes for a site (EE) = (Estimate of Expected Crashes for a site) – (SPF Prediction) = 5.747 – 4.979 = 0.768. EE per mile will be 0.768/3.5 = 0.219.

Screening may be conducted for all crash types or for specific crash types and severities. Screening may also be done by weighting the expected crash frequency using relative unit cost estimates for crashes of various severity and the expected crash frequencies by severity.

Is it better to rank by the expected or excess crash frequency? There has been some debate in the safety community on this topic without any clear consensus. There are advantages and disadvantages for both these methods. The use of expected crashes is embedded in the concept of Collision Modification Factors (CMFs) since the benefit of a treatment can be expressed as the product of the expected crashes with (CMF – 1). On the other hand, there is no way to directly apply CMFs to expected excess crashes. However, using expected excess is attractive and intuitive because it "rests on the belief that if a site has more crashes than what is normal at similar sites, there must be site-specific causes that explain the excess, and that if causes are identified, they could be remedied, and the excess reduced" (Hauer et al., 2002). Further discussion of these methods can be found in Lan and Persaud (2011).

In this study, screening was done with both Expected (E) and Expected Excess (EE) methods. The following steps were used for each roadway type separately:

1. Estimated SPFs for different crash types. 10 different crash types were considered. Not all crash types were subsequently used – the reasons for excluding the crash types along with the discussion of SPFs can be found in APPENDIX IV - Safety Performance Functions
2. A. Using the EB method, estimated E per mile, and

   B. Using the EB method, estimated EE per mile for the following crash types for each corridor:

   1) Speed-related crashes
   2) Injury (KAB) crashes
   3) Weighted KABC crashes
   4) Lane departure crashes
3. Ranked the corridors in decreasing order (separately for E per mile and EE per mile)
4. Among the top ranked corridors for speed-related and Injury (KAB) crashes, we determined the list of common corridors. We then ranked these 'common' corridors two ways: in decreasing order of KAB crashes, and by adding the resulting ranks for the KAB and speed-related crashes and ranking in increasing rank order of the "additive" rank.

As discussed earlier, this method could only be applied to corridors with AADT data available for every segment.

Method 2: Trends in Crash Counts

Safety Analyst incorporates a methodology for identifying for investigation those sites that experience a gradual or sudden increase in mean collision frequency (Hauer, 1996a; and Hauer, 1996b). In this study, we decided to examine whether there has been a significant increase in crashes in the last two years of the five year period from 2007 to 2011. Here are the steps that we undertook to identify corridors based on trends (for each roadway type):

1. Selected corridors that had at least 5 total crashes during the 5 year period. In addition, for a particular crash type (speed-related, KAB, lane departure), only selected corridors with at least 3 crashes of that type during the 5 year period.
2. For each of the 3 crash types discussed in the previous step, ranked the corridors in decreasing order of the ratio of the number of crashes in the last 2 years (2010 and 2011) to the number of crashes in the five year period from 2007 to 2011. If corridors had the same ratio, then they were ranked by crash rate (of that particular type) per mile; if the corridors had the same ratio and the same rate per mile, they were ranked based on the total number of crashes (of that type).
3. Among the top ranked corridors for speed-related and KAB crashes, we determined the list of common corridors. We ranked these 'common' corridors two ways: in decreasing order of KAB

crashes, and by adding the resulting ranks for the KAB and speed-related crashes for an "additive" rank.

Since this method does not make use of AADT, all the corridors were included.

After further reflection, the team decided not to report the results of this method. We thought that five years of data were insufficient to determine changes in trends. However, we report the method here, as it may be useful to use in conjunction with more years of data. The method may be useful to identify areas that are experiencing changes in the type or severity of crashes due to speeding or inappropriate speeds due to other issues (such as changes in development type, traffic volume, or other factors) that may warrant speed limit and safety review.

Method 3: Proportion of Crashes of Particular Types

The method of screening based on high proportions identifies and ranks locations that have a proportion of a specific crash type relative to the total crashes that is higher than some average or threshold proportion value for similar road types. Here are the steps that we undertook to identify sites based on high proportions of a particular crash type (for each roadway type):

1. Selected corridors that had at least 5 total crashes during the 5 year period. In addition, for a particular crash type (speed-related, KAB, lane departure), only selected corridors with at least 3 crashes of that type during the 5 year period.
2. For each of the 3 crash types discussed in the previous step, ranked the corridors in decreasing order of the proportion of that crash type. If corridors had the same proportion, then they were ranked by crash rate (of that particular type) per mile; if the corridors had the same ratio and the same rate per mile, they were ranked based on the total number of crashes (of that type).
3. Among the top 2000 ranked corridors for speed-related and for KAB crashes, we determined the list of common corridors. As with the previous two screening methods, we used two methods to rank these 'common' corridors: in decreasing order of KAB crashes, and by adding the ranks from the KAB-list and the speed-related list.

Similar to method 2, since this method does not make use of AADT, all the corridors were included.

Comparison of Results from Different Methods

Screening for crash types that were also speeding-related, or on crashes weighted by severity could also be useful for identifying treatable, speeding-related crash problems. However, the models based on crash type combinations including speeding and rear-end, and speeding and intersection combined, were determined to be suboptimal for screening because of small numbers of such crashes. The weighted by severity types were deemed unsuitable because of high variability, likely associated with the weights. Thus, these models are not recommended for screening.

To facilitate discussion of the remaining screening and ranking methods and crash types described above, results for rural two-lane screening are discussed. For this discussion, the focus is predominantly on three different methods of identifying corridors that had (or were expected to have) both high speeding-related (speeding-related) and high severe crashes. In these cases, recall that we screened individually for speeding-related and severe crashes, and then identified the common corridors found in the top of each list. Arguably, this combined method accounts for the potential contribution of speeding, but also considers severity in prioritizing which roads to review first since a primary goal is to reduce fatal and serious injury crashes.

Due to the subjective determination of whether speeding was a contributing factor in a crash, one could also argue for screening based only on more severe crashes. Since severity is highly dependent on pre-crash speed, an excess or high or proportion of severe crashes on a corridor could suggest that speeds are inappropriately high for the design, limits, and/or other conditions present compared to other corridors of the type. The remaining issues involve the screening approach as discussed above: whether using expected crashes, excess crashes, or simple proportions of the crash types to total crashes are more effective at identifying problem corridors.

Table 38 shows the distributions of (approximately 1000) corridors by average annual daily traffic categories that were identified by three different screening approaches. From left to right in the table, the method using Empirical Bayes methods to estimate safety performance functions and to estimate expected crashes (M1-E = Expected) identified very few corridors with low traffic volume (0.5 percent); most (61 percent) were in the mid-range of AADT (5000 to 14,999). The method based on SPFs and using excess crashes (M1-EE = Excess) to screen identified many more corridors with low volumes (26 percent) and moderately low volume (53 percent) for 80 percent of the total. In contrast, nearly 94 percent of the corridors identified by Method 3 (M3 = Proportions method), were either in the lowest volume category (36.6 percent), next lowest (34.6 percent), or unknown volume (22.5 percent), the latter which are also likely to be low volume (since not measured). No corridors in the highest volume category were identified by Method 3.

Table 38. Distribution by AADT Categories of Rural Two-lane Corridors Identified by Different Screening Methods using both Speeding-related and Severe Crashes.

	M1–Expected (M1-E)		M1–Excess (M1-EE)		M3–Proportion	
AADT cat	Frequency	Percent	Frequency	Percent	Frequency	Percent
1_1499	5	.5	221	26.5	385	36.6
1500_4999	261	23.8	447	53.5	364	34.6
5000_14999	668	60.9	148	17.7	65	6.2
15000_24000	139	12.7	15	1.8	1	.1
>24000	24	2.2	4	.5	--	--
Unknown	--	--	--	--	237	22.5
Total	1097	100.0	835	100.0	1052	100.0

Further characteristics of the corridors identified, and crash types are provided below (Table 39, Table 40, and Table 41). In general, the average corridor lengths were lowest among the corridors identified by M1–E, intermediate by M1–EE, and longest among those identified by M3. The mean number of observed severe (killed, K; disabling injury, A; or evident injury, B type) crashes was highest in Method –EE (7.6), next highest in Method 1–E (6.8), and lowest in Method 3 (6.6). This latter finding may not be surprising since the corridors identified by Method 3 (M3) tended to have significantly lower volumes, although they were also of greater average length. The mean number of speeding-related crashes was also highest in M1–EE (9.7), but second highest in M3 (8.5), and third highest in M1-E (6.5). Also, because M1-E relies in part on weighted prediction for the corridor type, 36 corridors that actually experienced no crashes in the prior five years were identified within the top 1097 corridors.

Table 39. Descriptive Statistics for Corridors Identified using Method 1-Expected crashes. (Corridors in top 2000 of both high speeding-related and high-severity (KAB) crash lists.)

Method 1–E					
	Minimum	Maximum	Mean	Std. Deviation	Means for all Corridors with AADT & > =0.1 mi
Corridor length	.10	22.73	1.82	2.332	1790.7
avg_aadt	411	34000	8800.23	5374.843	2032.76
min_aadt	340	34000	8332.45	5373.209	1891.38
max_aadt	790	39000	9388.44	5503.642	1.58
KAB	0	136	6.75	8.870	0.85
KAB per mi	.00	44.44	4.10	4.01	1.73
Spd-Rel	0	127	6.52	8.805	0.96
Spd-Rel per mi	.00	26.50	3.67	3.05	11.88
Total	0	582	48.19	61.160	7.05
Total per mi	0	671.11	35.97	44.63	1.62
Valid N	1097				18,923

Table 40. Descriptive Statistics for Corridors Identified using Method 1-Excess Crashes ranking method. (Corridors in top 2000 of both high speeding-related and high-severity (KAB) crash lists.)

Method 1-EE					
	Minimum	Maximum	Mean	Std. Deviation	Means for all Corridors with AADT & > =0.1 mi
Corridor length	.10	22.73	2.64	2.647	1.62
avg_aadt	154	33749	3494.08	3511.398	1790.7
min_aadt	80	30000	3233.58	3381.279	2032.76
max_aadt	310	39000	3858.08	3780.482	1891.38
KAB	1	136.00	7.63	7.97	1.58
KAB per mi	.94	44.44	4.15	3.44	0.85
Spd-Rel	1	127.00	9.68	9.26	1.73
Spd-Rel per mi	1.43	33.42	4.81	3.09	0.96
Total	1	342.00	39.87	43.69	11.88
Total per mi	2.99	671.11	21.49	32.70	7.05
Valid N	835				18,923

Table 41. Descriptive Statistics for Rural Two Lane Corridors Identified using Method 3 (proportion of total crashes). (Corridors in top 2000 of both high speeding-related proportion and high-severity (KAB) proportion crash lists.)

Method 3					
	Minimum	Maximum	Mean	Std. Deviation	Means for all corridors > = 0.1 mi
Corridor length	.17	28.17	3.49	2.945	0.93
KAB	3	136	6.56	6.227	0.61
KAB per mi	.22	21.66	2.46	1.843	0.39
Spd-Rel	3	127	8.47	7.390	0.71
Spd-Rel per mi	.25	24.08	3.17	2.486	0.47
Total	5	193	27.34	23.753	4.53
Total per mile	.71	61.66	9.718	6.98	3.21
Valid N	1052				60,760

Table 42 shows the results from comparing the actual lists of top corridors identified by each method, M1-Expected, M1-Excess, and M3-proportions for KAB and Speeding additive, the same methods applied to KAB and Spd-Rel crash types individually (top 1000 corridors in each), and M1-EE for Ln Departure (top 1000). Since the number of corridors found in both top 2000 for the additive methods varies, the numbers of corridors identified varies. For the individual crash types, the top 1000 were used in comparisons.

M1-EE method identified more total corridors in common with the M3-proportions list overall than did M1-E. However, there is very little overlap for either EB method with M3, when only the top 100 corridors identified were compared. When the top 100 corridors for the three methods were compared, only 1 corridor identified by M1-E was also identified by M3. Only 9 corridors identified by M1-EE were also in the top 100 for M3.

Table 42. Overlap in identification of Rural, Two—lane Corridors with Potential Speeding-related Crash Problems.

Rural 2 Lane (full list)	Column1	M1_EE KAB_Spd-Rel	M1_E KAB	M3 KAB_Spd-Rel	M3 KAB	M3 Spd-Rel	M1_EE Ln_Dep
	no. corridors	835	1000	1052	1000	1000	1000
M1_E_KAB_Spd	1097	385	673	207			
M1_EE_KAB_Spd-Rel	835			463			405
M1_EE_Spd-Rel	1000					319	579
M1_EE_KAB	1000	481			306		409
M1_E_Spd-Rel	1000					167	
M1_E_KAB	1000		122		122		

While many further comparisons could be made, the real test of screening methods will come with field review by an experienced engineering team and perhaps other stakeholders such as law enforcement, or others experienced in identifying roadway and behavioral safety issues. A potential approach for field validation of screening and ranking approach is described in the next section. Note that within each method, NCDOT can choose from among alternate ranking methods to prioritize corridors for review.

Field Validation

Results for the three screening methods (M1-E, M1-EE, and M3-proportions) were provided separately to the NCDOT Mobility and Safety unit for use in testing and further development of the speeding-related crash screening methods. Corridors uniquely identified by one method and not the others could be the focus of efforts to assess whether one method proves more efficient at identifying corridors that have speed limit or speeding issues that could be contributing to crash and injury problems. Potentially, that each method has strengths that are useful, as past literature has shown. It is also possible that a combined method that focuses on the top corridors that are identified by all of the methods 1-E, 1-EE, and method 3 might be used. In addition, many potential ranking methods are available. The project team illustrated some of these methods in the results provided to NCDOT. Speed-related crash screening methods may ultimately be incorporated into other safety screening performed by NCDOT.

For field validation of methods and ranking one approach would be to identify a reasonable number of corridors– for example the top 20 corridors – that are identified by each approach that are not identified by the other methods, and conduct field reviews. Ideally, the unidentified lists would be provided to teams for speed limit and safety field review, with review results used to help inform decisions about the efficacy of each method.

As a precursor, the project team selected the top five rural two-lane corridors (from the KAB and speeding-related combined lists) that were identified by only one of each of the three prime methods. Using Google maps, it was determined that several of the high volume corridors in the top 5 list using M1-E method were not, in fact, two-lane corridors. Thus, errors in the data may result in misleading results by affecting the safety performance functions and predictions obtained. The number of corridors selected for review may also need to be adjusted to account for such errors. Although these errors in classification may affect the priority list of corridors identified, it is not expected that the errors in classification would affect the safety performance functions or average proportions of crashes very much.

Next Steps

Following field validation, the next step will be to conduct the speed and safety reviews. The State may wish to conduct further investigation into alternate speed limit setting methods, including the injury minimization approach, or encourage use of the US Limits Tool (http://safety.fhwa.dot.gov/uslimits/) as an additional check when speed zoning is applicable. More information is available on alternate speed limit setting methods in *Methods and Practices for Setting Speed Limits: An Informational Report* available at FHWA's website (http://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa12004/).

Steps include the following:

- Assess the limit.
    - The limit may be raised, lowered, or left the same.
- Assess whether design changes are needed to the roadway in support of the recommended limit or to reduce specific speeding-related crash problems.
- Assess whether enforcement improvements are needed to support the recommended limit.
- Develop a corridor plan - Plan and implement the recommended changes to limits (if any), to the roadway, and to enforcement.

Although NCDOT is primarily interested in identifying speeding issues that may be treated with engineering countermeasures, speeding is also very much a behavioral issue, and engineering treatments should not be considered in isolation.

Sometimes engineering treatments will not be available or sufficient to correct the problems, at least not until major road re-design may be undertaken. Thus, a comprehensive approach will seek improvements to enforcement to supplement engineering, when needed. Design changes have the greatest and longest-lasting impact on speeds, but may take a longer time to develop, fund, and implement. Therefore, enforcement or spot improvements may also be needed to reduce crashes in the interim before major roadway changes can be implemented.

Additional discussion may be warranted on what speed limit setting approaches are to be considered when reviewing the locations. Statutory limits, speed zones as well as corridor-wide limits may be in effect. Elsewhere in this report, an injury minimization approach has been suggested as one potential way to gain more uniformity in speed limit setting when speed zones or corridor limits are considered. NCDOT's Complete Streets Guidelines and approach to working with communities could also be utilized as either part of an injury minimization approach to speed zones, as well as in reviewing and changing statutory limits through ordinances established by NCDOT in concurrency with town and city ordinances.

References for Appendix III

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APPENDIX IV - Safety Performance Functions

This Appendix documents the Safety Performance Functions (SPFs) that were used in the network screening (i.e., in method 1). SPFs were estimated for the following 6 roadway types and 10 crash types:

Roadway types

- Rural 2 lane
- Rural undivided (more than 2 lanes)
- Rural divided
- Urban 2 lane
- Urban undivided (more than 2 lanes)
- Urban divided

Crash types

- Total crashes
- Total Injury crashes (KABC)
- Total Injury crashes (KAB)
- Weighted Injury crashes (W-KABC): weights are based on economic cost of different severity levels. Based on NCDOT guidelines, the relative weight of K & A crashes (relative to PDO) is 76.8 and the relative weight of B & C crashes are 8.4 (relative to PDO). For the SPF estimation, B & C crashes were given a weight of 1.0 and the K & A crashes were given a weight of 76.8/8.4 = 9.14 (rounded to 9) (in other words, the relative weight of K & A crashes are 9 relative to B & C crashes).
- Weighted Injury crashes (W-KAB): As discussed above, the weight of K & A crashes was 9 and the weight of B crashes was 1.0.
- Weight total (W-total): For this crash type, since PDOs are included, K & A crashes were given a weight of 77 (rounded value of 76.8), B & C crashes were given a weight of 8 (rounded value of 8.4), and PDO crashes were given a weight of 1.0.
- Speed-related crashes: this includes crashes where the driver contributing circumstances for at least one of the drivers was exceeding authorized speed limit or exceeded safe speed for conditions.
- Speed-related crashes at intersection: this includes crashes that are *speed-related* and occurred at intersection (this was based on the Road Feature variable in the crash report and included Four-way intersection, T-intersection, Y-intersection, Five-point or more, and Related to intersection)
- Speed-related rear-end crashes: this includes crashes that are speed-related and also rear-end (based on first harmful event and includes rear end, slow or stop and rear end, turn)
- Lane departure crashes: based on first harmful event and includes Ran off road – right, Ran off road – left, Ran off road – straight, Fixed object, Head on, and Sideswipe, opposite direction

For each crash type, the following statistics are provided:

- Minimum AADT
- Average AADT

- Maximum AADT
- Minimum corridor length
- Average corridor length
- Maximum corridor length

The SPFs are of the following form:

$$Y = L \times \exp[a + b \times \ln(AADT)] = L \times e^{a} \times (AADT)^{b}$$

Where, Y is the predicted number of crashes for a L mile corridor per year (L is the length of the corridor), a is the intercept term, and b is the coefficient of ln(AADT). This functional form is the most common and is used in Safety Analyst as well (there has been extensive discussion about appropriate functional forms for SPFs – see Kononov et al., 2011, and Hauer, 2004, for further discussion).

SPFs were estimated using negative binomial regression based on data from 2007 until 2011. For each SPF, the following information is provided:

- Estimate of a (Intercept term) along with its standard error (S.E.)
- Estimate of b (coefficient of ln(AADT)) along with its standard error (S.E.)
- Estimate of k (overdispersion parameter); k is needed for any analysis involving the empirical Bayes (EB) method
- Number of crashes used in the estimation

A high value of k indicates a large amount of variability in the data. SPFs for W-Total and W-KAB had much higher k values compared to the other SPFs. Hence, the crash types resulting in high k values were not used in the network screening. In addition, for many of the roadway types, SPFs for speed-related intersection and speed-related rear end crashes were based on a relatively small sample of crashes. Hence, these crash types or combinations were also not used in network screening.

For example, for speed-related crashes on rural 2 lane roads, coefficient a = -5.4342 and b = 0.5339. So, for a corridor that is 1.5 miles long with an AADT of 3000, the average predicted crashes per year based on the SPF will be the following:

$= 1.5 \times e^{-5.4342} \times (3000)^{0.5339}$ $=$0.47 crashes per year

If NCDOT chooses to use these SPFs in the future as part of network screening, they need to be calibrated with future data. The calibration procedure will yield a calibration factor which is essentially the ratio of the total number of observed crashes (of a particular type) to the total number of predicted crashes from the SPF for the same crash type. Further discussion about calibration can be found in a recent NCDOT report (Srinivasan and Carter, 2011).

References for Appendix IV

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Kononov, J., Lyon, C., and Allery, B.K. (2011), Relationship of Flow, Speed, and Density of Urban Freeways to Functional Form of a Safety Performance Function, *Transportation Research Record* 2236, pp. 11-19.

Srinivasan, R. and Carter, D. (2011), *Development of Safety Performance Functions for North Carolina*, Report FHWA/NC/2010-09, Submitted to NCDOT, December 2011.

SPFs for Rural Two Lane Roads

Variable		Total		KABC		KAB		W-KABC		W-KAB	
		Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
Intercept		-5.5214	0.0337	-7.0518	0.0462	-6.9485	0.0570	-6.2051	0.0583	-6.1193	0.0808
ln(AADT)		0.7906	0.0046	0.8460	0.0062	0.7134	0.0075	0.7963	0.0081	0.7214	0.0114
k		0.3204		0.3443		0.2946		1.1436		2.3340	
Observed Crashes		224728		75770		29869		122826		76925	
		W-Total		Speed related		Speed-related at intersection		Speed-related rear-end		Lane Departure	
Intercept		-4.0196	0.0568	-5.4342	0.0610	-9.4683	0.1688	-15.8966	0.4061	-5.0818	0.0445
ln(AADT)		0.8043	0.0082	0.5339	0.0084	0.7165	0.0217	1.3376	0.0481	0.5970	0.0061
k		1.7320		0.6084		0.7829		0.8102		0.3793	
Observed Crashes		1160976		32680		2337		638		76075	

AADT	Min	10
	Average	1891
	Max	58,000
Corridor Length (mi)	Min	0.10
	Average	1.62
	Max	33.54
Total Length of Corridors (mi)		30,576
Number of Corridors		18,923

Variable		Total		KABC		KAB		W-KABC		W-KAB	
		Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
Intercept		-4.4423	0.9306	-6.8644	1.0252	-9.5330	1.1312	-5.2825	1.0422	-5.7860	1.3740
ln(AADT)		0.6963	0.0981	0.8381	0.1077	0.9848	0.1182	0.7063	0.1097	0.6829	0.1447
k		0.6300		0.5357		0.2833		0.6689		1.1139	
Observed Crashes		9265		3312		1100		5128		2916	
		W-Total		Speed related		Speed-related at intersection		Speed-related rear-end		Lane Departure	
Intercept		-1.7250	1.0056	-5.2682	1.4658	-12.3833	3.0969	-12.5179	3.9490	-3.9032	0.9543
ln(AADT)		0.5732	0.1064	0.4621	0.1543	1.0185	0.3215	0.9632	0.4101	0.4089	0.1005
k		0.8967		0.6385		0.5794		0.5354		0.2893	
Observed Crashes		48112		580		86		48		1300	

AADT	Min	1500
	Average	14070
	Max	37000
Corridor Length (mi)	Min	0.10
	Average	1.21
	Max	12.80
Total Length of Corridors (mi)		273
Number of Corridors		225

SPFs for Rural Multilane Undivided Roads

Variable		Total		KABC		KAB		W-KABC		W-KAB	
		Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
Intercept		-7.8329	0.5043	-9.9751	0.6323	-9.0024	0.6646	-8.6713	0.6644	-7.7722	0.8475
ln(AADT)		1.0164	0.0531	1.1240	0.0663	0.8997	0.0694	1.0299	0.0700	0.8699	0.0895
k		0.6371		0.6924		0.4422		0.9019		1.3648	
Observed Crashes		27496		9109		2938		13653		7482	
		W-Total		Speed related		Speed-related at intersection		Speed-related rear-end		Lane Departure	
Intercept		-6.0568	0.6168	-8.2574	0.6943	-15.2620	1.5444			-6.4718	0.5426
ln(AADT)		0.9949	0.0655	0.7844	0.0725	1.2772	0.1586			0.6763	0.0568
k		1.1406		0.4257		0.5259		No valid SPFs		0.3189	
Observed Crashes		130451		2234		236		190		4523	

AADT	Min	540
	Average	14271
	Max	68000
Corridor Length (mi)	Min	0.10
	Average	1.57
	Max	13.03
Total Length of Corridors (mi)		959
Number of Corridors		611

SPFs for Rural Divided Roads

Variable		Total		KABC		KAB		W-KABC		W-KAB	
		Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
Intercept		-8.5557	0.1371	-10.2095	0.1685	-10.1770	0.2044	-8.6281	0.1677	-7.7097	0.2157
ln(AADT)		1.1482	0.0161	1.2060	0.0194	1.0549	0.0231	1.0571	0.0196	0.8574	0.0254
k		1.2475		1.0744		0.7286		1.6203		2.8316	
Observed Crashes		106322		34382		8871		43590		18079	
		W-Total		Speed related		Speed-related at intersection		Speed-related rear-end		Lane Departure	
Intercept		-5.8131	0.1492	-6.1546	0.1997	-10.4599	0.4203	-17.8974	0.6487	-5.9013	0.1533
ln(AADT)		0.9960	0.0181	0.5445	0.0231	0.8450	0.0469	1.6330	0.0701	0.6372	0.0179
k		2.6888		1.0349		0.7624		0.9442		0.9162	
Observed Crashes		426415		5001		951		808		14692	

AADT	Min	30
	Average	5574
	Max	53000
Corridor Length (mi)	Min	0.10
	Average	0.71
	Max	9.13
Total Length of Corridors (mi)		4207
Number of Corridors		5963

SPFs for Urban Two Lane Roads

Variable		Total		KABC		KAB		W-KABC		W-KAB	
		Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
Intercept		-7.4729	0.4855	-8.2414	0.5141	-8.5131	0.5753	-7.6371	0.5193	-7.2081	0.6550
ln(AADT)		1.0821	0.0506	1.0483	0.0534	0.9204	0.0593	1.0062	0.0540	0.8561	0.0681
k		0.8609		0.7161		0.5094		0.7983		1.1530	
Observed Crashes		64557		21945		4919		26809		9783	
		W-Total		Speed related		Speed-related at intersection		Speed-related rear-end		Lane Departure	
Intercept		-5.3067	0.5247	-10.0278	0.7207	-11.4709	1.1417	- 19.3933	1.4402	-6.7299	0.5670
ln(AADT)		1.0011	0.0549	0.9807	0.0738	0.9843	0.1159	1.7997	0.1451	0.7364	0.0587
k		1.1441		0.4650		0.4334		0.6750		0.5652	
Observed Crashes		260124		1947		461		610		4597	

AADT	Min	410
	Average	16392
	Max	62000
Corridor Length (mi)	Min	0.10
	Average	0.86
	Max	7.40
Total Length of Corridors (mi)		589
Number of Corridors		683

SPFs for Urban Multilane Undivided Roads

Variable		Total		KABC		KAB		W-KABC		W-KAB	
		Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
Intercept		-6.0479	0.5371	-6.8157	0.5717	-6.9036	0.6274	-6.2985	0.5774	-6.1302	0.7215
ln(AADT)		0.9171	0.0555	0.8832	0.0589	0.7410	0.0641	0.8528	0.0595	0.7367	0.0743
k		1.0536		0.9742		0.6869		1.0831		1.5385	
Observed Crashes		54886		18181		4055		22197		8071	
		W-Total		Speed related		Speed-related at intersection		Speed-related rear-end		Lane Departure	
Intercept		-4.1171	0.5858	-9.2136	0.7533	-8.2328	1.1208	-18.6670	1.4262	-5.9394	0.5781
ln(AADT)		0.8628	0.0607	0.8874	0.0761	0.6466	0.1128	1.6946	0.1409	0.6473	0.0591
k		1.3960		0.5179		0.5750		0.4896		0.5170	
Observed Crashes		216791		1760		412		532		4050	

AADT	Min	480
	Average	18242
	Max	68000
Corridor Length (mi)	Min	0.10
	Average	0.73
	Max	7.72
Total Length of Corridors (mi)		514
Number of Corridors		708

SPFs for Urban Divided Roads

Summary statistics for all Rural, Two-Lane Roads (length > 0.1 mi)									
Variable	Label	N	N Miss	Minimum	Maximum	Sum	Mean	Median	Std Dev
corrlngth	Corridor Length	60760	0	0.1	33.54	56710.49	0.93	0.49	1.37
tot5	Total	60760	0	0	655	275064	4.53	0	16.42
tot5_mi	Total per mile	60760	0	0	671.11	194737	3.21	0	9.73
inj5	Injury crashes (KABC)	60760	0	0	212	91747	1.51	0	5.83
inj5_mi	Injury per mi	60760	0	0	202.22	62693.35	1.03	0	3.42
kab5	KAB	60760	0	0	136	36966	0.61	0	2.31
kab5_mi	KAB per mi	60760	0	0	44.44	23738.25	0.39	0	1.23
wtot5	Weighted (Wtd) Total	60760	0	0	5322	1418233	23.34	0	90.41
wtot5_mi	Wtd Total per mi	60760	0	0	2086.67	928063.2	15.27	0	48.43
winj5	WtdInjury	60760	0	0	625	149827	2.47	0	9.79
winj5_mi	Wtd Injury per mi	60760	0	0	202.22	96835.11	1.59	0	5.29
wkab5	Wtd KAB	60760	0	0	600	95046	1.56	0	6.73
wkab5_mi	Wtd KAB per mi	60760	0	0	105.77	57879.99	0.95	0	3.81
spd5	Speed-related (Spd-Rel)	60760	0	0	127	43003	0.71	0	2.38
spd5_mi	Spd-Rel per mi	60760	0	0	33.42	28705.59	0.47	0	1.31
ln_dpt5	Lane Departure	60760	0	0	138	98738	1.63	0	5.1

ln_dpt5_mi	Lane Departure per mi	60760	0	0	88.17	68094.46	1.12	0	2.43
spd_int5	Both Spd-Rel & Intersection	60760	0	0	10	3118	0.05	0	0.29
spd_int5_mi	Both Spd-Rel & Intersection per mi	60760	0	0	19.05	2918.46	0.05	0	0.4
spd_re5	Both Spd-Rel & Rear end	60760	0	0	5	710	0.01	0	0.13
spd_re5_mi	Both Spd-Rel & Rear end per mi	60760	0	0	7.69	479.29	0.01	0	0.13
pb5	Ped or Bike	60760	0	0	7	2225	0.04	0	0.24
pb5_mi	Ped or Bike per mi	60760	0	0	18.47	1991.96	0.03	0	0.31