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EFFECTS OF CONTINUOUS MEDIAN BARRIERS ON HIGHWAY SPEEDS, EMERGENCY RESPONSE TIMES, AND TRANSPORT TIMES ON NORTH CAROLINA HIGHWAYS

by

Raghavan Srinivasan, Ph.D., Senior Transportation Research Engineer
University of North Carolina Highway Safety Research Center
730 Airport Road, CB # 3430, Chapel Hill, NC 27599-3430
Phone: (919) 962 7418; Fax: (919) 962 8710
Email: srini@unc.edu

Kevin Lacy, P.E., Systems Safety Engineer
North Carolina Department of Transportation
122 N. McDowell Street, 1561 Mail Service Center
Raleigh, NC 27699-1561
Phone: (919) 733 3915; Fax: (919) 733 2261
Email: jklacy@dot.state.nc.us

John Feaganes, Ph.D., Senior Statistician
University of North Carolina Highway Safety Research Center
730 Airport Road, CB # 3430, Chapel Hill, NC 27599-3430
Phone: (919) 843 5333; Fax: (919) 962 8710
Email: John_Feaganes@unc.edu

William Hunter, M.C.E., Senior Research Scientist
University of North Carolina Highway Safety Research Center
730 Airport Road, CB # 3430, Chapel Hill, NC 27599-3430
Phone: (919) 962 8716; Fax: (919) 962 8710
Email: bill_hunter@unc.edu

UNIVERSITY OF NORTH CAROLINA HIGHWAY SAFETY RESEARCH CENTER

CHAPEL HILL, NC 27599-3430

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16. Abstract

In 1998, the North Carolina Department of Transportation started introducing positive barriers on many freeway segments to reduce across-median crashes. Unless emergency crossovers are provided, the lack of breaks in the median barriers reduces the opportunity for law enforcement to turn around to apprehend a speeder. The objective of this study was to assess the effect of different types of median barriers on speeding, speed related crashes, and emergency response times. Spot speed data were collected during off-peak periods from 51 freeway segments in North Carolina with four types of medians: traversable medians with no barriers, continuous median barriers with frequent crossovers, continuous median barriers without crossovers or infrequent crossovers, and non-traversable medians. Statistical models were developed to study the effect of median barrier type on average speeds and the propensity to exceed the speed limit. The results do not support the hypothesis that continuous median barriers without crossovers lead to speeding. Statistical models were also developed to study the effect of median barrier type on the frequency of speed related crashes. Consistent with the results obtained from the speed models, the results from the models estimated for crash frequency do not support the hypothesis that sections with continuous median barriers are associated with a larger number of speed related crashes compared to other median types.

In order to assess the effect of median barriers on response times, several emergency operators in cities and counties across North Carolina were contacted. Most emergency operators indicated that data on response times were not recorded on a consistent basis. However, the emergency operators also mentioned that the continuous median barriers did lead to delays in responding to events. Some did acknowledge that these barriers prevent severe across-median crashes and reduced their call volume.

The study also surveyed several neighboring States to study their policies regarding median crossovers. None of the agencies were aware of problems due to illegal use of these crossover openings. This was confirmed by limited observations in 4 locations in North Carolina.

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The authors thank Thomas Meadows and Charles Hamlett at the Highway Safety Research Center (HSRC), for collecting spot speed data in 51 sites in North Carolina. The authors also thank Eric Rodgman at HSRC and several NCDOT staff for their invaluable help in extracting the necessary crash data. This work would not have been possible without their efforts. Finally, the authors thank the members of the Steering Committee for their input and guidance in this effort.

SUMMARY

In 1998, NCDOT implemented a program to prevent across median crashes by providing positive barriers on all freeways with medians 70 feet or less. In many cases, the NCDOT utilized cable barrier; however, there is extensive use of other barrier types. The continuous nature of these barriers reduces the opportunity for law enforcement to turn around to apprehend a speeder traveling in the opposite direction. Sections without breaks in the median barrier limit the locations where emergency vehicles can turn around to approach a crash or to transport an injured motorist to the hospital. The objectives of this study were to: (1) assess the effect of different types of median barriers on speeds and speed related crashes, (2) study the effect of continuous median barriers on emergency response times, (3) review the policies used by neighboring States regarding median crossovers, and (4) determine the level of unauthorized use of existing median crossovers.

Effect of median type on speed

Speed data were collected from a total of 51 sites consisting of four types of median barriers: (1) continuous median barriers with frequent crossovers, (2) continuous median barriers without crossovers or infrequent crossovers, (3) traversable medians with no barriers, and (4) non-traversable medians with no barriers. Speed data were collected using a Light Detection and Ranging System (LIDAR) during off-peak periods for 50 vehicles in each lane of the freeway, on both sides of the median. Data were collected for a vehicle only if its speed was not impeded by the vehicle in front of it. Vehicle speed, vehicle type, directional of travel, lane of travel, type of median, and information about the location of the site were recorded.

In order to assess the effect of median barrier types on operating speed, two sets of statistical models were developed to study the effect of median type and other variables on driver speed. The first set of models studied the effect of median type on average speed. The second set of models studied the effect of median type on the proportion of drivers exceeding the speed limit by different values. The results do not support the hypothesis that continuous median barriers are associated with speeding.

Effect of median type on speed related crashes

With help from NCDOT staff, data on speed related crashes were extracted for a 3-year period for the 51 sites where speed data have been collected. Statistical models were estimated with crash frequency as the dependent variable, with ADT, segment length, type of median barrier, speed limit, and terrain, as independent variables. Consistent with the results obtained from the speed models, the results from the models estimated for crash frequency do not support the hypothesis that sections with continuous median barriers are associated with a larger number of speed related crashes, compared to other median types.

Policies used by neighboring States

Pennsylvania DOT, South Carolina DOT, Tennessee DOT, Georgia DOT, Virginia DOT, and New Jersey Turnpike Authority were contacted through fax, email, and phone, to obtain

information regarding their policies on crossovers. All agencies except Tennessee DOT responded to the survey.

All agencies except Georgia DOT provide emergency crossovers. The spacing between crossovers generally varies between 2 and 4 miles. Some agencies have guidelines on sight distance at these sites usually based on AASHTO. None of them use gates or chains at the crossovers. South Carolina provides flexible delineator posts at the crossover openings. There is no evidence that safety or illegal use of the crossovers is a significant problem.

Emergency response

Emergency operators in Counties and Cities across North Carolina were contacted and data were requested on emergency response times. Most agencies indicated that they do not record response time data. Even the few agencies that do record response time information, do not consistently record the location of the incident and route followed by the emergency vehicle. However, most agencies argued that the continuous barriers did lead to increase in response times. Some operators did acknowledge the benefit of having these barriers in preventing severe across-median crashes and reducing their call volume. Some emergency operators have started dispatching emergency vehicles to both sides of highway simultaneously to assure adequate patient access and transport. This leads them to tie-up two units for every call.

Observation of illegal use of crossovers

Four crossover openings on Interstate routes were observed for two hours to determine the extent of illegal and legal use. Two of these openings were in rural areas and two were in metropolitan areas. In over eight hours of observation, only four vehicles used the crossovers and one of them was an official use. Realizing that the desired illegal usage is zero, a total of three illegal uses is not significantly high. It is also important to note that we do not know how often vehicles turned around in the medians before the barriers were installed. These observations, when considered together with the results of the survey of other State agencies, seem to indicate that illegal usage of crossovers is not a significant problem.

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INTRODUCTION

In 1995, the federal government repealed the national maximum speed limit and many states immediately increased the posted speed limit on many of their highways. North Carolina chose to take a more cautious approach and study the highway segments on which engineers believed the increased speed limits would not impact safety. In August 1996, the NCDOT increased the speed limits on selected interstate highways to as high as 70 mph. In October of 1996, the NCDOT increased speed limit on selected full control access facilities that were not interstates to as high as 65 mph.

In 1998, NCDOT implemented a program to prevent across median crashes by providing positive barriers on all freeways with medians 70 feet or less. In many cases, the NCDOT utilized cable barrier; however, there is extensive use of other barrier types. The barrier, regardless of the type, nearly seals off the median with limited openings for maintenance personnel and transitions near bridge piers in the cases where cable is installed. The continuous nature of these barriers reduces the opportunity for law enforcement to turn around to apprehend a speeder traveling in the opposite direction. Sections without breaks in the median barrier limit the locations where emergency vehicles can turn around to approach a crash or to transport an injured motorist to the hospital. In both cases, the respective agencies claim that the barriers adversely affect their ability to perform their duties[1].

The true impacts of the barriers on the ability of these agencies to perform their duty are unknown, as are the effects of providing median openings for their use. Members of the law enforcement community have expressed their concern that the barriers erode driver respect for their presence. Anecdotal evidence says that a driver speeding in the opposite direction of a patrol officer is not in jeopardy of receiving a ticket, because it takes too long for the officer to turn and pursue. Some law enforcement officers believe that median crossovers help resolve this issue, while others believe that median openings would not help in enforcement but would allow quicker response to crash scenes[2]. The law enforcement community is also in a dilemma -- while believing continuous barrier may impede speed enforcement, they also know the barrier saves lives and averts serious injuries (see Hunter et al., 2001).

Emergency response agencies such as the emergency medical service and fire departments are also claiming negative impacts, although these groups also acknowledge the positive impacts of the barriers. Buncombe County EMS and fire department lobbied the NCDOT for median openings using records showing increased response times as proof of the adverse effects. In response to this request, NCDOT has provided, or plans to provide, crossovers in selected sections of roadway. In addition to providing new median crossovers, NCDOT is also improving the crossing surface at two other locations without median barriers.

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[1] M. Roberts, "Highway guardrails, while good, have critics", WRAL Online, http://www.wral-tv/news/wral/2000/0402-highway-guardrail/, July 1, 2000
[2] M. Roberts, "DOT may place safety breaks in medians", WRAL Online, http://www.wral-tv/news/wral/2000/0721-highway-barriers/, June 21, 2000

Previous Research

Very little work has been conducted to document the effects of median barriers on driver behavior and the performance of law enforcement or emergency response organizations. Keese and Pinnell (1960) completed a study in late 1950s on how different median types affected driver behavior. The study originally planned to evaluate effects of different median types on volume, speed, and lane compliance. However, the researchers dropped speed from the project due to other factors that influenced speed such as speed limit.

More recently, Parham et al. (1999), from the Texas Transportation Institute (TTI) conducted a study for the Texas Department of Transportation, to support the development of geometric design guidelines to accommodate incident management strategies. The study included a literature review, a survey of organizations and individuals involved in incident management, and on-site visits to existing locations that have implemented certain incident management strategies.

They mailed a survey to 158 city and transportation agencies and fire, police, and other emergency response agencies within the United States. The objective of the survey was to determine types of incident management techniques that responding agencies use and determine the effectiveness of these techniques. Twenty-eight city/state transportation agencies and 25 emergency response agencies responded to the survey. The responses also included information about emergency crossovers and access barrier gates in some areas. Researchers also conducted on-site meetings and/or made on-site visits in the following locations: Los Angeles, Las Vegas, Dallas, Houston, Chicago, Washington D.C., Atlanta, Maryland, Virginia, Winston-Salem, and Charlotte.

Based on the survey and site visits, the study produced the following recommendations regarding emergency crossovers and barriers gates in Texas:

> "Permit crossings in suburban areas as needed when spacing (between interchanges) exceeds the current rural standard."
>
> "Install a sign at the crossovers for the use of authorized vehicles only."
>
> "Continue the practice of using a designated sign only – do not install advanced signing." Advanced signing may encourage some illegal use by the public.
>
> "Install an improved surface at the crossing."
>
> "Use powered gates for breaks in median barriers that are compliant with current crash-test requirements."

The latest issue of the AASHTO green book (AASHTO, 2001), indicates that emergency crossovers on rural freeways "are normally provided where interchange spacing exceeds 8 km (5 mi)", and "between interchanges, emergency crossovers are spaced at 5 to 6.5 km (3 to 4 mi) intervals". The green book also mentions that: (1) sufficient stopping sight distance should be available at these locations, (2) width of the crossovers should be sufficient to allow safe turning movements of vehicles, and (3) it should be depressed below shoulder level to be inconspicuous to traffic.

None of these studies have studied driver behavior including speeding and illegal issue of these emergency crossovers. In addition, very little information is available on the effect of these crossovers on emergency response and transport times.

Study Objectives

The purpose of the median barrier is to prevent an errant vehicle from crossing the median and potentially striking another vehicle traveling in the opposite direction. If the median barriers are contributing to higher incidences of speed-related crashes and increasing the response time of critical emergency services, then these factors need to be considered when comparing median barrier costs and benefits.

The specific objectives of this study were to:

<u>Determine the effects of different types of median barriers on vehicle speeds and speed related crashes</u>. Many of the locations where the NCDOT increased posted speed limits have, or will have, median barriers installed. NCDOT conducted various speed studies on some of these sections. This data, along with additional data collected in this project, will help determine the impacts that different types of median barriers have had on vehicle speeds on sections where NCDOT installed median barriers. In addition, crash studies on selected sections can also determine the impacts of the median barrier on speed related crashes.

<u>Determine the effects of different types of median barriers on emergency response and transport times</u>. Some emergency agencies put forward that the median barriers impede their ability to quickly respond to crashes on highways with such barriers. One of the objectives of this study is to contact these agencies to obtain the necessary data and assess the extent to which this is occurring.

<u>Determine the level of unauthorized use of existing median crossovers</u>. Some engineers are concerned that median crossovers are being illegally used by the general public, and this can lead to unsafe maneuvers and accidents. We propose to monitor a sample of existing median crossovers to measure the level of authorized and unauthorized use of these facilities.

<u>Review policies used by neighboring States to mark median crossovers</u>. The majority of the median crossovers are unmarked. Typically, marked locations contain a sign stating that the openings are for use by authorized vehicles only. This study will survey neighboring States to study the policies and signs that they use to mark these crossovers.

COLLECTION OF SPEED DATA

In order to study the effect of continuous median barriers on vehicle speeds, speed data were collected from a total 51 sites consisting of four different types of median barriers:

1. *Continuous median barriers with frequent crossovers*. These are locations where there are median barriers with frequent crossovers that can be used by law enforcement and emergency responders. These crossovers are not necessarily purposefully installed; they may include areas around bridge piers.

2. *Continuous median barriers without crossovers or infrequent crossovers*. These are locations where there are continuous median barriers with no crossovers or infrequent crossovers.

3. *Traversable medians with no median barriers*. These locations offer the maximum level of freedom of movement for law enforcement and emergency response services. There are no median barriers and the medians are relatively flat without much impedance to a vehicle attempting a controlled crossing. If the type of median barrier has an effect on vehicle speeds, then, the average speeds in a traversable median may be similar to those with continuous barriers and frequent crossovers.

4. *Non-traversable medians with no median barriers*. Although these locations do not have any median barriers, the medians are considered non-traversable due to the presence of large trees, a ditch, or other factors that would prevent a vehicle from using it. Again, if the type of median barrier has an effect on vehicle speeds, then the average speeds in a non-traversable median may be similar to those with continuous barriers without crossovers or infrequent crossovers.

Speed data were collected using a Light Detection and Ranging System (LIDAR) from a total of 51 limited access freeway segments in North Carolina. Speed data were collected during off-peak periods for 50 vehicles in each lane of the freeway, on both sides of the median[3]. Data were collected for a vehicle only if its speed was not impeded by the vehicle in front of it. In most cases, the data collectors were positioned on overpasses and collected speed data on receding vehicles. Vehicle speed, vehicle type, directional of travel, lane of travel, type of median, and information about the location of the site were recorded.

Tables 1 through 5 show statistics about the number of sites with a particular median barrier, speed limit, terrain, and type of area. Overall, the most common speed limit was '65 mph', the most common area type was 'rural', the most common terrain was 'level', and the most common median type was 'continuous barriers without crossovers or infrequent crossovers'.

The speed limit of 60 mph is not common in North Carolina and that limited the total number of sites to four in that category. In addition, non-traversable medians (without a barrier) are

[3] All sites had equal number of lanes on both sides of the median. Spot speed data were collected for a total of 11400 vehicles. Appendix A shows some basic information about the sites including the location of the site, speed limit, type of median, and total number of lanes.

typically found only in rural areas that have higher speed limits (i.e., 65 mph or 70 mph). Similarly, the 55 mph speed limit is more common in urban areas where interchanges are more closely spaced, and at these locations, it is more common to find continuous barriers without crossovers or infrequent crossovers. In addition, the limited width of medians in urban areas may not always provide sufficient space to provide a crossover opening that can be safely used by an emergency vehicle.

Table 1: Number of sites by type of median and speed limit

Speed Limit (mph)	**Type of Median**				**Total Number of Sites**
	No barrier and traversable	Continuous median barrier with frequent crossovers	Continuous median barrier without crossovers or infrequent crossovers	Non-traversable, but no barrier	
55	1	0	5	0	6
60	0	1	3	0	4
65	13	7	10	2	32
70	1	1	3	4	9
Total Number of Sites	15	9	21	6	51

Table 2: Number of sites by type of median and terrain

Terrain	**Type of Median**				**Total Number of Sites**
	No barrier and traversable	Continuous median barrier with frequent crossovers	Continuous median barrier without crossovers or infrequent crossovers	Non-traversable, but no barrier	
Level	10	5	13	4	32
Mountains	3	3	6	0	12
Rolling	2	1	2	2	7
Total Number of Sites	15	9	21	6	51

Table 3: Number of sites by type of median and area type

Area Type	Type of Median				Total Number of Sites
	No barrier and traversable	Continuous median barrier with frequent crossovers	Continuous median barrier without crossovers or infrequent crossovers	Non-traversable, but no barrier	
Rural	10	5	11	6	32
Urban	5	4	10	0	19
Total Number of Sites	15	9	21	6	51

Table 4: Number of sites by speed limit and area type

Area Type	Speed Limit (mph)				Total Number of Sites
	55 mph	60 mph	65 mph	70 mph	
Rural	1	2	20	9	32
Urban	5	2	12	0	19
Total Number of Sites	6	4	32	9	51

Table 5: Number of sites by speed limit and terrain

Area Type	Speed Limit (mph)				Total Number of Sites
	55 mph	60 mph	65 mph	70 mph	
Level	3	1	22	6	32
Mountains	3	3	6	0	12
Rolling	0	0	4	3	7
Total Number of Sites	6	4	32	9	51

ANALYSES OF SPEED DATA

Two sets of statistical models were developed to study the effect of median type on driver speed. The first set of models studied the effect of median type on average speed. The second set of models studied the effect of median type on the proportion of drivers exceeding the speed limit by different values. These models are discussed below.

Effect of type of median barrier on average speed

A linear model was estimated with vehicle speed as the dependent variable and the following independent variables: speed limit, type of median barrier, area type, terrain, lane position (represented by whether the vehicle was in the left lane or another lane), vehicle type, and the ratio of ADT to the total number of lanes. The site number was included as a random factor. The model was estimated using a statistics/econometrics package called LIMDEP (Greene, 2002). The specific details of the model are discussed in Appendix B. Following is a summary of the results from the model:

1. The hypothesis of interest, i.e., type of median barrier does not influence mean vehicle speed, is not rejected. In other words, the type of median barrier does not seem to be significantly associated with driver speed.
2. As expected, vehicles travel slower if the speed limit is lower. Based on the model, compared to the average speeds on 70 mph freeways, average speeds are 9 mph lower on 55 mph roads, 3.6 mph lower on 60 mph roads, and 2.4 mph lower on 65 mph roads.
3. Vehicles traveling in the left lane travel approximately 4 mph faster than vehicles traveling in other lanes
4. Cars, SUVs, vans, and pickups, travel approximately 2 to 3 mph faster than the truck/trailer/buses group.

Effect of type of median barrier on the propensity to exceed the speed limit

In order to study the effect of median type on the propensity to exceed the speed limit, the speed data were divided into that those are speeding (i.e., exceeding the posted speed limit) and those that are not. Similarly, vehicles were assigned the speeding characteristic for exceeding the posted speed limit by 5, 10, or 15 mph. Four logit models were developed to study the following cases:

1. Probability of exceeding the speed limit
2. Probability of exceeding the speed limit by 5 mph or more
3. Probability of exceeding the speed limit by 10 mph or more
4. Probability of exceeding the speed limit by 15 mph or more

In general, classical logit models assume that observations are independent of one another. However, in our case, observations within a site will be correlated, and this cannot be ignored. The models were estimated using SAS %GLIMMIX MACRO[4], which explicitly accounts for this correlation. The estimation algorithm uses the principle of quasi-likelihood procedure repeatedly fitting a linear mixed model to a pseudo response (see Chapter 11 of Littell et al. 1996). The logit model for the first case, i.e., probability of exceeding the speed limit, is discussed in Appendix C.

The results from the logit models are consistent with the results obtained from the average speed models, i.e, type of median barrier does not significantly influence the probability of drivers exceeding the speed limit by 0 mph, 5 mph, 10 mph, or 15 mph. The probability of drivers

[4] http://ftp.sas.com/techsup/download/stat/glmm800.html

exceeding the speed limit is related to the speed limit; compared to 70 mph roads, a higher percentage of drivers exceed the speed limit in roads posted at 55 mph, 60 mph, or 65 mph. In addition, drivers tend to exceed the speed limit more often in level terrain compared to rolling or mountainous terrain.

Speeding Citations

One way to further study the effect of median barrier types on speeding is to compile data on speeding citations in these roadway segments. Data on speeding citations are available in the driver history records. However, the location information that is available in this database is limited to the County where the incident occurred and the citation was given[5]. No information about the road/intersection/milepost is recorded. One way to get further information is to manually review hard copies of the citations that are probably stored in the Administrative Office of the Courts in Raleigh. The limited resources in this project did not permit this activity.

ANALYSES OF SPEED RELATED CRASHES

Extraction of relevant crashes

With help from NCDOT staff, crash data were extracted for a 3-year period from the Traffic Engineering Accident Analysis System (TEAAS), a crash reporting system maintained by NCDOT, for the 51 sites where speed data have been collected. In order to select speed related crashes that occurred on limited access freeways, the following variables were reviewed:

Driver contributing circumstances. Three contributing circumstances are coded for each driver who was involved in the crash. Only those crashes where at least one of the contributing circumstances for at least one driver was coded as 6 (exceeded authorized speed limit), 7 (exceeded safe speed for conditions), or 8 (failure to reduce speed), were extracted.

Roadway contributing circumstances. Two roadway contributing circumstances are coded for each crash. If either one of the roadway contributing circumstances was coded as 4 (i.e., work zone related), these crashes were excluded from the analysis.

Traffic control device. Only crashes where the traffic control device was coded as 0 (i.e., no control) were extracted.

Road feature. Crashes related to different types of intersections (codes 7 through 12), driveways and alley intersections (codes through 4 through 6), railroad crossings (code 22), and interchanges (codes 16 through 18 and 20, 21), were excluded.

A total of 3205 crashes for a 3-year period in the 51 sites were selected for further analyses.

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[5] Based on personal communication with Eric Rodgman, Senior Database Analyst at HSRC

Analyses

Crashes are count data (i.e., they are non-negative integers) and have to be analyzed using appropriate statistical procedures. Negative binomial regression models were estimated using LIMDEP with three-year crash frequencies as the dependent variable. The independent variables included speed limit, type of median barrier, log of the product of ADT and segment length, and terrain. Details of the models are presented in Appendix D.

As expected, the log of the product of ADT and segment length was statistically significant, indicating that a longer segment with more traffic will have more crashes, other things being equal. Type of median was not significantly related to crash frequency. Based on the parameter estimates and p values, there is some evidence that compared to 70 mph zones, 55 mph zones have a slightly higher number of speed related crashes. This may be because drivers exceed the speed limit more often in 55 mph zones compared to 70 mph zones, leading to a larger speed variance on these road segments, and possibly more crashes as a result of that.

REVIEW OF POLICIES USED BY OTHER STATES

A survey was prepared to query States regarding their policies on median barriers. Following are the list of questions that are included in the survey:

1. Which office in your Department is responsible for approving median crossovers on full control access facilities?

2. Do you have a policy for investigating requests for median crossovers for emergency vehicle and law enforcement use on full control facilities? If so, please send us your policies / guidelines, or tell us where we can find them on-line.

3. Do you have requirements for minimum distances between crossovers? Interchanges? If so, what are they?

4. Do you provide crossovers at political and jurisdictional boundaries, i.e. County Lines, EMS jurisdictions?

5. Do you have written considerations for sight distance, grade between opposing travel lanes and other geometric and operational characteristics (ADT)? If so, can we get a copy of them?

6. Do you provide signs at the crossover? (Official Use Only, Authorized Vehicles Only, etc.)? If so, do you have a standard design?

7. Do you provide advance warning or notification signs for the median crossovers? If so, what standards do you use? Why do you or do you not provide advance notification?

8. Do you use gates or other means to restrict use of the crossovers? (e.g., gates, chains)

9. Do you provide auxiliary lanes or wider paved shoulders for the crossovers?

10. Are you aware of any specific safety problems in your state or jurisdiction with median crossovers on full control access highways?

11. Are you aware of problems with unauthorized use of median crossovers on full control access highways?

The following agencies were contacted through fax, email, and phone: Pennsylvania DOT, South Carolina DOT, Tennessee DOT, Georgia DOT, Virginia DOT, and New Jersey Turnpike Authority. All agencies except Tennessee DOT responded to the survey. A summary of the responses from these agencies is given below:

New Jersey Turnpike Authority

- Median U-turns for official vehicles (fire apparatus, first aid squads, and state police) are created irrespective of political boundaries.
- Median U-turns are spaced about 2 miles apart. Interchanges are spaced from as little as 2 miles to as large as 12 miles.
- No written criteria for sight distance, but have about ¼ mile sight distance for on-coming traffic.
- Standard diagrammatic “no U-turn” signs. Provide a small “ U 1000’ ” sign, 1000’ before the U-turn.
- No gates in these areas.
- About 11’ of paved shoulder is provided for the entire length of the Turnpike, and can be used by police and emergency vehicles.
- Not aware of any problems with safety or unauthorized use.

Georgia DOT

- Georgia does not allow median crossovers on interstate type highways.
- There are areas where the median is flat and easily traversable and thus emergency vehicles use this area to cross because it is near a state or county line, but Georgia DOT does not condone such use.

Pennsylvania DOT

- Median crossovers can be used on Interstate and other Limited Access Freeways when the median width is greater than 10 m (33 ft).

- Median crossovers constructed on Interstate highways shall be approved by the Federal Highway Administration (FHWA).

- Median crossovers can be located as follows:

    - Where the distance between the ends of speed-change tapers for adjacent interchanges is less than 4 miles, one median crossover may be provided. This crossover should be constructed at a suitable location between the interchanges, but not closer than 450 m (1500 ft) from the end of a speed-change taper or structure.

    - Where the distance between the ends of speed-change tapers for adjacent intersections is greater than 4 miles, two or more median crossovers may be provided. These crossovers shall be provided at no less than 3 mile intervals, but not closer than 450 m (1500 ft) from the end of a speed-change taper or structure.

    - One set of dual crossovers may be located at or near a State or County line if the proximity of the nearest interchange or median crossover is greater than 1 mile. The intent is to allow for the safe operation winter maintenance activities, eliminating the need for winter maintenance vehicles to back up to a crossover after plowing or spreading materials beyond the crossover.

- The location of median crossovers should be coordinated with proposed or existing median drainage systems to eliminate exposed pipe end sections that could present an obstacle to errant vehicles.

- In order to limit usage to emergency and other authorized vehicles, appropriate signage and delineation shall be used (see Figure 1).

- When eliminating existing crossovers, they should be coordinated with local emergency management officials to ensure their operations are not significantly impacted.

- Not aware of any safety problems or illegal use of crossovers.

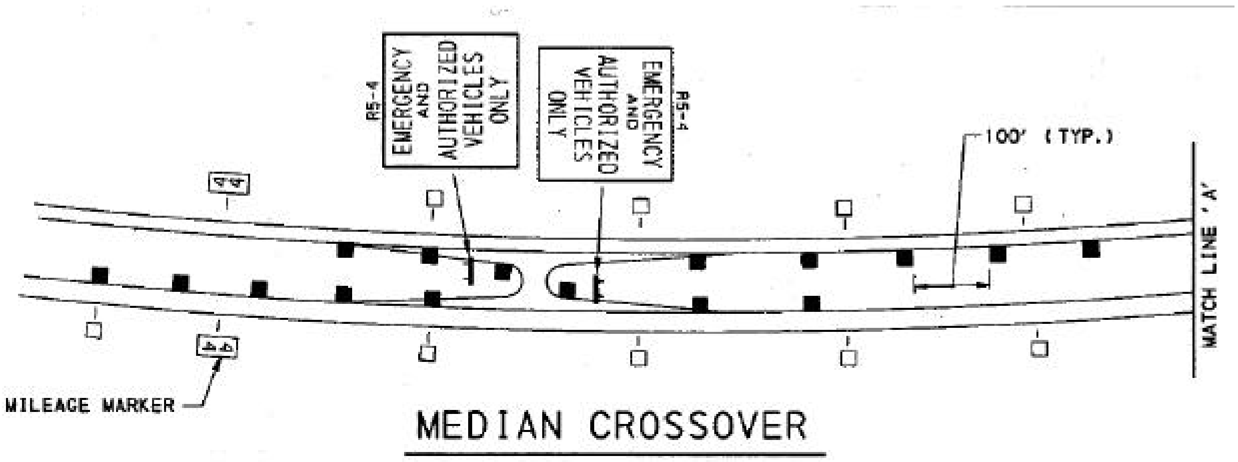

Figure 1: Signage used in Pennsylvania to mark crossovers

Virginia DOT

- Location of median crossovers are approved by VDOT's Transportation and Mobility Planning Division in coordination with FWHA, VDOT district and residency offices, and local law enforcement and emergency personnel.
- Maintenance crossovers are typically provided at district boundaries and at the end of interchange acceleration/deceleration lane tapers.
- Written considerations are available for crossovers in non-limited access highways. No written guidelines seem to be available for emergency and maintenance crossovers.
- Written considerations are available for sight distance and other geometric and operational characteristics. Most of these guidelines are written for crossovers in non-limited access highways.
- No advance warning or notification signs are provided for the median crossovers. However, a reflector post is provided at the crossovers.
- Not aware of safety problems or illegal use of maintenance and emergency crossovers.

South Carolina DOT

- Use the AASHTO green book for investigation requests for median crossovers and for determining the minimum distance between crossovers and interchanges
- Use AASHTO green book for sight distance issues, but do not have any written policies regarding ADT or other geometric / traffic factors

- No signs (including warning signs) are provided at the crossovers to prevent the public from using them

- Flexible delineator posts are used at the crossover openings

- Not aware of any safety problems with these crossovers, although there has been some anecdotal evidence regarding illegal use by the public

Summary of policies in other States

- All the agencies (except Georgia DOT) that were surveyed provide emergency crossovers.

- The spacing between crossovers generally varies between 2 and 4 miles.

- Some have guidelines on sight distance, usually based on AASHTO.

- Some provide advance signing, while others do not, in order to prevent the general public from using them.

- Among the agencies that were surveyed, none of them used gates or chains at the crossovers. South Carolina provides flexible delineator posts at the crossover openings.

- There is no evidence from these agencies that safety or illegal use of the crossovers is a significant problem.

EMERGENCY RESPONSE ISSUES

Some emergency agencies have argued that the median barriers impede their ability to quickly respond to crashes on highways with such barriers. In order to quantify whether continuous barriers have resulted in delayed emergency response to events, it would be important to obtain information about emergency response times and routes taken by emergency vehicles before installation of barriers and after installation of barriers. To accomplish this, research was conducted to determine if there were any databases that could provide such data. In addition, emergency operators in the different counties and cities were contacted and data were requested on emergency response times.

Databases with response times

The research revealed information about a database called Prehospital Medical Information System (PreMIS) (www.premis.net). This database does provide information about travel times between the origin and the location where the event occurred. Location information is provided through a 'grid number', which is defined in a different way for each provider: some have larger grids than others. In some cases, the closest intersection to the site is coded in the database. However, there is no information in the database about the route followed by the provider, which would be difficult to record.

Contacts with Emergency Operators

The research team tried to reach the emergency operators by contacting the following agencies: Statewide Incident Management Interagency Team, County Emergency Management Directors, and the National Emergency Number Association:

Statewide Incident Management Interagency Team. This team consists of individuals from North Carolina Department of Transportation (NCDOT), North Carolina Division of Motor Vehicles (NCDMV), North Carolina Emergency Managers (NCEM), North Carolina State Highway Patrol (NCSHP), Federal Highway Administration (FHWA), Office of Emergency Medical Services, Office of State Fire Marshalls, Office of State Medical Examiners, North Carolina Trucking Association, North Carolina Association of Rescue and Emergency Management Systems, North Carolina Fireman's Association, North Carolina Sheriff's Association, and North Carolina Association of Police Chiefs. This team meets every quarter to discuss issues related to emergency response and management. Dr. Srinivasan attended their meeting in Raleigh on February 12, 2003, and presented a one-page summary of this project (see Appendix E) and enquired about the possibility of obtaining emergency response data. Rob Stone from NCDOT who chaired the meeting asked the attendees to forward the summary to their local representatives.

County Emergency Management Directors. The County Emergency Management Directors in North Carolina were contacted to enquire about the possibility of obtaining emergency response data.

National Emergency Number Association (NENA). NENA's mission is to foster the technological advancement, availability, and implementation of a universal emergency telephone number system. In carrying out its mission, NENA promotes research, planning, training and education. NENA has Chapters in different States. The Officers of the North Carolina Chapter and the representatives at the County level were contacted to enquire about the possibility of obtaining emergency response data.

Appendix F gives the responses that were received from different emergency operators. Two Counties indicated that they record emergency response information. County of Forsyth does record when the response provider was dispatched, and when the provider arrived at the scene. However, with regard to the location of the incident, in most cases, only the route number and the direction are recorded.

Lee County provided some information on response times to motor vehicle accidents that occurred on US#1, but excluded calls inside the city limits of Sanford (Table 6). Data from a total of 25 events are included in this calculation: information on the specific number of events before and after the installation of barriers was not available. Continuous median barriers were installed on November 2002 on US#1. Based on this data, there was almost a 6 minute increase in the average response times for EMS/Rescue after the installation of barriers, but very little change in the response times for Fire. Further information about these events was not available.

Table 6: Average response times in Lee County

Average response times	Before Median Barrier	After Median Barrier
EMS / Rescue	11 minutes 54 seconds	17 minutes 18 seconds
Fire	8 minutes 34 seconds	8 minutes 28 seconds

Many of the other Cities and Counties who responded to the request for response time data, indicated that they did not record such data, but were indeed delayed by the continuous barriers if there are no crossovers. Below is a summary of the comments received from the different emergency operations and police personnel. Further details are available in Appendix F.

- Many agencies argue that continuous barriers increase response times. They argue that if no crossovers are present, this will add at least 6 to 8 miles to any call, resulting in an increase in the response time.

- Many callers to 911 are not completely sure of the direction of travel and sometimes provide incorrect information to the 911 operator. One operator (Jim Pharr, Gaston County) feels that markers should be included every tenth of a mile indicating the position and the direction of travel. Mr. Pharr also feels that drivers should be educated to expect emergency vehicles traveling in the shoulder in the opposite direction following collisions on divided highways.

- Some operators do acknowledge the benefit in having these barriers, i.e., preventing severe head-on collisions, and reducing the call volume.

- Some emergency operators have started dispatching emergency vehicles to both sides of highway simultaneously to assure adequate patient access and transport. This leads them to tie-up two units for every call.

- Medic units in Mecklenburg County are provided with GPS units with on board mapping and routing devices, and can be routed around these barriers if necessary.

- One operator (Dan Summers, New Hanover County) feels that some crossover openings are not wide enough for emergency vehicles, and sometimes the ground is so poorly maintained that heavy fire and rescue vehicles can get stuck in the mud. In addition, Mr. Summers feels that signs are necessary so that the responders know where the next opening is located.

STUDY OF ILLEGAL USE OF MEDIAN CROSSOVERS

One of the concerns of transportation officials is that the availability of emergency median crossovers on full control access facilities encourages illegal and inappropriate use by drivers. This is of special concern because the use of these crossovers violates driver expectancy. Drivers do not expect to see a vehicle turn in front of them on a freeway. In addition, these crossovers are not designed for public use. For reasons such as these and others, the NCDOT has established specific guidelines for determining the placement of official crossovers.

Compared to other States, there are few official emergency vehicle crossovers in North Carolina. However, many locations throughout the state have unofficial crossovers at the end of a section of cable barrier where it transitions to W-beam guardrail that shields bridge piers. These openings vary in width with many large enough to permit a vehicle to turn around. They also have a special concern because the structure can also hide a vehicle that is turning around, legally or illegally.

It is obvious from visual inspection that both official and unofficial crossovers are being used. To understand how often these facilities are used, four crossovers on interstate routes were observed for two hours each. Being a small sample, it was not intended to be a definitive measure of emergency crossover usage, but merely a summary of observations. Two crossovers, one official and one unofficial, were in a rural setting, and the other two were located on the fringe of a metropolitan area on major commuter routes. Table 7 summarizes the observations of the crossovers.

Table 7: Summary of Emergency Crossover Usage Observations

Crossover	Legal Usage	Illegal Usage
Rural Official Crossover	0	0
Rural Unofficial Crossover	0	0
Commuter Official Crossover	1	1
Commuter Route Unofficial Crossover	0	2

During the observation period, the crossovers were used a total of four times, all in the commuter routes. On rural interstates, trips tend to be long, and drivers may not be aware of alternate routes during congestion, or have a reason to turn around. However, in more urbanized areas, drivers are probably more familiar with alternate routes and may be aware of the availability of crossovers.

In over eight hours of observation, only four vehicles used the crossovers and one of them was an official use. Realizing that the desired illegal usage is zero, a total of three illegal uses is not significantly high. It is also important to note that we do not know how often vehicles turned around in the medians before the barriers were installed. In addition these data appear to support the findings in others States that illegal usage is not a significant problem.

CONCLUSIONS AND RECOMMENDATIONS

In order to investigate the association between speeds and barrier types, this study collected spot speed data from 51 freeway segments in North Carolina during off peak periods. Random effects linear models were estimated to study the effect of median type on average speed; random effects logit models were estimated to study the effect of median type on the propensity to exceed the speed limit. As expected, in general, motorists drove faster if the speed limit was higher. In addition, motorists traveled faster in the left lane. A higher percentage of drivers exceeded the speed limit on 55 mph, 60 mph, and 65 mph roads, compared to 70 mph roads. However, despite anecdotal evidence about the effect of continuous median barriers on speeds, the data collected from this study do not seem to support the hypothesis that continuous median barriers lead to speeding.

Data on speed related crashes were extracted for a 3 year period for the same sites where speed data were collected. Negative binomial regression models were estimated to study the effect of median barrier type and other site characteristics on speed related crashes. As expected, a longer segment with more traffic was associated with more crashes. However, consistent with the results obtained from the speed models, the results from the models estimated for crash frequency do not support the hypothesis that sections with continuous median barriers are associated with a larger number of speed related crashes compared to other median types.

The emergency response issue is more complicated. Many emergency operators argue that continuous barriers without emergency crossovers do lead to an increase in response times because of the additional distance that emergency vehicles have to travel to get to the scene. Some agencies have started dispatching two units in opposite directions of the highway at the same time to ensure timely arrival at the scene. This increases their cost and also reduces the number of vehicles that are available to deal with emergencies that may occur simultaneously.

Very little data are available on response times. Even agencies that record response times and are willing to provide the information do not consistently record the location of the incidents and the routes followed by emergency vehicles. The lack of data makes it very difficult to make a quantitative assessment of the impact of continuous median barriers on emergency response and transport times. As global positioning systems (GPS) become more prevalent, better data may become available. Appendix G provides examples of data elements that need to be collected by emergency operators in order to facilitate the quantitative assessment of the impact of continuous barriers on emergency response and transport times.

Based on the results of the survey of other States and limited observations in North Carolina, illegal use of these crossovers does not seem to be a significant problem. One way to address the illegal use is to have gates that can be quickly opened by emergency vehicles, or flexible delineator poles, as in South Carolina.

Advance signing is not recommended at crossovers as this may increase illegal use. However, at the crossovers, a sign indicating that it is ‘for authorized vehicles only’ may be useful. Based on the responses from the emergency operators, it is clear that it will be worthwhile to explore ways that will make it easier for drivers to identify their location when they call 911.

Investigating Requests for New Median Crossovers

Several factors should be taken into account while investigating requests for new median crossovers:

Presence of other crossovers, interchanges, and other structures. Crossovers can be provided if distance between interchanges exceeds 5 miles. Spacing between crossovers can be between 2 and 4 miles. In addition, AASHTO (2001) recommends that “maintenance or emergency crossovers generally should not be located closer than 1500 feet to the end of a speed-change taper of a ramp or to any structure".

Sight distance. It is important that sufficient sight distance is available at locations where median crossovers are going to be located. AASHTO (2001) recommends that crossovers "be located only where above-minimum stopping sight distance is provided and preferably should not be located on superelevated curves."

Crossover width and surface. It is important that the width of the median is sufficient to allow a fire truck to use the opening when one is provided. Its surface should be designed and maintained as to be capable of supporting maintenance equipment that is used on it (AASHTO, 2001).

Traffic Volume. It is important to consider the traffic volume because high volume facilities are less likely to provide an available gap for a vehicle to reenter the traffic stream. While an emergency vehicle should have their lights operating, illegal usage of the potential crossover may create a safety hazard.

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APPENDIX A

Spot speed locations

Site	County	Route	Spot Speed Location	Speed Limit	Median type	Total # of lanes
1	Stokes	US 52	Overpass of SR 1106	65	2	4
2	Surry	US 52	Overpass for SR 2097	65	3	4
3	Surry	I 74 (previously NC 752)	Mile markers 8, 9 and 10.5	65	1	4
4	Surry	I 77	mile marker 91	70	4	4
5	Surry	I 77	mile marker 96	70	4	4
6	Surry	I 77	A point 0.1 mile north of mile marker 92	70	3	4
7	Haywood	I 40	Overpass SR 1220	60	2	4
8	Bumcombe/Madison	US 19-23	0.1 mile north of Buncombe/Madison County Line	55	3	4
9	Buncombe	US 19-23	Overpass for SR 1720	55	1	4
10	Haywood	I 40	0.5 mile west of mile marker 27	60	3	4
11	Buncombe	I 240	Martin Luther King & Town Mountain Road Overpass	55	3	4
12	Buncombe	I 40	SR 2748 Overpass	65	2	4
13	Buncombe	I 26	Mile Marker 3.5 (south-eastbound Only) Mile Marker 9 (North-westbound Only)	60	3	4
14	Henderson	I 26	Overpass 1793	65	3	4
15	Polk	I 26	Approx 0.1 miles SE of Mile Marker 30	65	3	4
16	Cleveland	US 74	Approx 1.7 miles east of US 74 Business-Moss Lake Interchange	65	1	4
17	Rutherford	US 74	3.4 Miles East of NC 120 Interchange	65	2	4
18	Polk	US 74	At Mile Marker 168	65	1	4
19	Nash	US 264	Overpass for SR 1108	65	4	4
20	Nash/Wilson	US 264	Overpas For SR 1945	65	1	4
21	Nash	I 95	Milemarker 131	70	4	4
22	Halifax	I 95	Overpass for SR 1210	70	2	4
23	Halifax	I 95	Overpass for SR 1600	70	3	4
24	Wake	I 440	Overpass for Glen Eden Road	60	3	6
25	Orange	I 40	Overpass for SR 1725	65	2	4
26	Davie	I 40	Overpass for SR 1407	70	1	4
27	Forsyth	I 40	Lexinton Road Overpass	65	3	6
28	Forsyth	I 40	HanesMall Blvd Overpass	65	1	6
29	Forsyth	I 40	Overpass for SR 2678	65	2	4
30	Mecklenburg	I 77	Overpass for Pressely Road	55	3	6

Site	County	Route	Spot Speed Location	Speed Limit	Median type	Total # of lanes
31	Iredell	I 77	Overpass for SR 1100	65	2	4
32	Warren	I 85	0.4 miles south of Milemarker 225	65	1	4
33	Vance	I 85	Overpass for SR 1369	65	3	4
34	Granville	I 85	0.2 miles south of Milemarker 201	65	1	4
35	Wake	I 540	Overpass for SR 3444	65	1	6
36	Wake	I 40	Overpass for SR 1795	65	3	8
37	Wake	I 40	Overpass for Avent Ferry Road SR-1321	65	1	6
38	Wake	I 40	Overpass for SR 2703	65	2	4
39	Wake	US 1	Overpass for SR 1153	65	4	4
40	Lee	US 1	Overpass for SR 1426	65	1	4
41	Wake	US 64	Overpass for SR 2407	65	3	4
42	Nash	US 64	Overpass for SR 1137	65	1	4
43	Martin	US 64	Overpass for SR 1300	70	4	4
44	Wake	Wade Avenue	Between I 40 and I 440	55	3	4
45	Mecklenburg	I 277	Elizabeth Street Overpass	55	3	4
46	Orange	I 85	Overpass SR 1713/MT Herman Church	65	3	6
47	Alamance	I 85	Overpass 1154	65	3	8
48	Craven	US70	Overpass SR 1224	65	1	4
49	Pinder	I 40	SR 1318	70	3	4
50	Montgomery	US 220	Milemarker 41	65	1	4
51	Wake	I 540	0.25 miles West of US 1	65	3	6

Median Types:
1 –Traversable
2 – Continuous barriers with frequent crossovers
3 – Continuous barriers without crossovers or infrequent crossovers
4-Non Traversable

Note: All sites had equal number of lanes on both sides of the median. Spot speed data were collected for 50 vehicles in each lane for a total of 11400 vehicles.

APPENDIX B

Regression type models for average speed

Mixed models for Average speed

The objective is to generalize the results of the speed analyses to the population of all similar sites in North Carolina. To accomplish this, the effect of the observed sites on observed mean vehicle speeds was included as a random effect, i.e., the sites were treated as a random draw from the population of all possible sites.

A random effects model can be expressed in this form:

$$y_{ij} = a + b^{'} x_{ij} + x_{ij} + u_i$$

where,

y_{ij} is the observed vehicle speed by vehicle j at site i. u_i is the site effect assumed to be a normally distributed random variable with mean = 0, and its variance equal to some value (say, s_u^2). In a random effects model, Cov(u_i, x_{ij}) = 0. a is the overall mean, x_{ij} is the vector of independent variables that includes variables that are characteristic of the vehicle (e.g., vehicle type, lane of travel), and variables that are characteristics of a site (e.g., speed limit, type of median barrier, area type, and terrain). $b^{'}$ is a vector of parameter estimates for the independent variables. For a given i (i.e., a site), the disturbances from different vehicles are correlated.

This model is estimated using generalized least squares. In this model, the categorical variables (speed limit, type of median, lane of travel, area type, vehicle type, and terrain) were input as indicator variables, with one of the levels within each factor as a reference variable. In addition, ADT divided by the number of lanes was included as a covariate. The results from the model are shown below.

The p-values in the table indicate the following:

1. The hypothesis of interest, i.e., type of median barrier does not influence mean vehicle speed, is not rejected.
2. As expected, in general, vehicles travel slower if the speed limit is lower. Based on the model, compared to the average speeds in 70 mph freeways, average speeds in 55 mph roads are 9 mph lower, average speeds in 60 mph roads are 3.6 mph lower, and average speeds in 65 mph roads are 2.4 mph lower.
3. Vehicles traveling in the left lane are approximately 4 mph faster than vehicles traveling in other lanes
4. Cars, SUVs, vans, and pickups, travel approximately 2 to 3 mph faster than truck/trailer/buses.

A similar model was estimated for 65 mph speed limit sections, which had at least two sites with each of the four different types of barriers. The results were similar.

Variable	Description	Coefficient	S.E.	T value	P value
LIMIT55	Indicator variable, 1 if speed limit =55, 0 otherwise	-9.11318	1.30736	-6.97	< 0.0001
LIMIT60	Indicator variable, 1 if speed limit =60, 0 otherwise	-3.60793	1.36504	-2.64	0.0082
LIMIT65	Indicator variable, 1 if speed limit =65, 0 otherwise	-2.44159	0.81902	-2.98	0.0029
LIMIT70	Indicator variable, 1 if speed limit =70, 0 otherwise; Reference variable				
CROSS	Indicator variable, 1 if continuous barrier with crossovers, 0 otherwise	0.73971	0.86115	0.86	0.3903
NOCROSS	Indicator variable, 1 if continuous barrier without crossovers, 0 otherwise	0.47668	0.71562	0.67	0.5053
NONTRAV	Indicator variable, 1 if non-traversable median, 0 otherwise	0.15425	1.00281	0.15	0.8778
TRAV	Indicator variable, 1 if traversable median, 0 otherwise, Reference variable				
LEFTLANE	Indicator variable, 1 if vehicle was in left lane, 0 otherwise	4.30962	0.08743	49.29	< 0.0001
LEVEL	Indicator variable, 1 if terrain was level, 0 otherwise	2.39479	0.77090	3.11	0.0019
ROLLING	Indicator variable, 1 if terrain was rolling, 0 otherwise	1.00769	1.00542	1.00	0.3162
MOUNTAINS	Indicator variable, 1 if terrain was mountains, 0 otherwise, Reference variable				
URBAN	Indicator variable, 1 if urban area, 0 otherwise	-0.64432	0.77222	-0.83	0.4041
CAR	Indicator variable, 1 if vehicle is a Car, 0 otherwise	2.64226	0.12238	21.59	< 0.0001
SUV	Indicator variable, 1 if vehicle is a SUV, 0 otherwise	2.99665	0.15682	19.11	< 0.0001
PICKUP	Indicator variable, 1 if vehicle is a Pickup, 0 otherwise	2.31410	0.16483	14.04	< 0.0001
VAN	Indicator variable, 1 if vehicle is a Van, 0 otherwise	2.09989	0.16113	13.03	< 0.0001
MCYCLE	Indicator variable, 1 if vehicle is a Motorcycle, 0 otherwise	2.33268	1.35356	1.72	0.0848
TRUCK	Indicator variable, 1 if vehicle is a truck/bus/trailer, 0 otherwise, Reference variable				
ADTBYLAN	ADT divided by the number of lanes	-0.00007	0.00009	-0.83	0.4096
Constant	Intercept term	66.94874	1.11139	60.24	< 0.0001

Number of observations = 11400; Lagrange Multiplier test *versus* Model estimated using OLS without random effect = 10072.08 (1 df, $p < 0.000001$)

Mixed model for vehicle speed – including all sites

Variable	Description	Coefficient	S.E.	T value	P value
CROSS	Indicator variable, 1 if continuous barrier with crossovers, 0 otherwise	0.90867	1.01084	0.899	0.3687
NOCROSS	Indicator variable, 1 if continuous barrier without crossovers, 0 otherwise	0.53619	0.83132	0.645	0.5189
NONTRAV	Indicator variable, 1 if non-traversable median, 0 otherwise	0.16936	1.44771	0.117	0.9069
TRAV	Indicator variable, 1 if traversable median, 0 otherwise, Reference variable				
LEFTLANE	Indicator variable, 1 if vehicle was in left lane, 0 otherwise	4.52483	0.11065	40.892	<0.0001
LEVEL	Indicator variable, 1 if terrain was level, 0 otherwise	2.48760	0.89237	2.788	0.0053
ROLLING	Indicator variable, 1 if terrain was rolling, 0 otherwise	0.68005	1.21320	0.561	0.5751
MOUNTAINS	Indicator variable, 1 if terrain was mountains, 0 otherwise, Reference variable				
URBAN	Indicator variable, 1 if urban area, 0 otherwise	-1.04504	0.86876	-1.203	0.2290
CAR	Indicator variable, 1 if vehicle is a car, 0 otherwise	2.40680	0.15175	15.860	<0.0001
SUV	Indicator variable, 1 if vehicle is a SUV, 0 otherwise	2.79956	0.19506	14.352	<0.0001
PICKUP	Indicator variable, 1 if vehicle is a PICKUP, 0 otherwise	2.22243	0.21069	10.548	<0.0001
VAN	Indicator variable, 1 if vehicle is a VAN, 0 otherwise	1.98009	0.20003	9.899	<0.0001
MCYCLE	Indicator variable, 1 if vehicle is a Motorcycle, 0 otherwise	-1.79704	2.00997	-0.894	0.3713
TRUCK	Indicator variable, 1 if vehicle is a truck/bus/trailer, 0 otherwise, Reference variable				
ADTBYLAN	ADT divided by the number of lanes	-0.00001	0.00011	-0.059	0.9527
Constant	Intercept term	64.14654	0.99070	64.748	<0.0001

Number of observations = 7300; Lagrange Multiplier test *versus* Model estimated using OLS without random effect = 5536.6 (1 df, $p < 0.000001$)

Mixed model for 65 mph zones

APPENDIX C

Logit models to study the probability of exceeding the speed limit

A logit model can be expressed in this form:

$$P_{ij} = \frac{e^K}{1 + e^K}$$

where, P_{ij} is the probability that vehicle j at site i will exceed the speed limit.

The above equation can be transformed into the following generalized linear mixed model:

$$\log\left(\frac{P_{ij}}{1 - P_{ij}}\right) = K = \quad a + b' x_{ij} + x_{ij} + u_i$$

where, u_i is the site effect that is assumed to be random factor. a is the overall mean, x_{ij} is the vector of independent variables that includes variables that are characteristic of the vehicle (e.g., vehicle type, lane of travel), and variables that are characteristics of a site (e.g., speed limit, type of median barrier, area type, and terrain). b' is a vector of parameter estimates for the independent variables. For a given i (i.e., a site), the disturbances from different vehicles are correlated.

In this study, the models were estimated using SAS %GLIMMIX MACRO[6]. The estimation algorithm uses the principle of quasi-likelihood procedure repeatedly fitting a linear mixed model to a pseudo response (see Chapter 11 of Littell et al. 1996). Following are results of collective significance of the fixed effects using the F ratios.

Effect	**Numerator DF**	**Denominator DF**	**F Value**	**Pr > F**
Speed Limit	3	39	10.61	< 0.0001
Number of Lanes	2	39	2.40	0.1037
Type of Median	3	39	0.07	0.9738
Terrain	2	39	9.29	0.0005
Urban/Rural	1	39	1.46	0.2335
Vehicle Type	5	207	45.77	< 0.0001
Lane of travel (left lane or other)	1	49	706.77	< 0.0001

The parameter estimates, T statistics, and p values are shown in the next page. The results are consistent with those obtained from the models that were developed for average speed. Models that were developed to study the probability of drivers exceeding the speed limit by 5 mph, 10 mph, or 15 mph, yielded similar results. In the models, the dependent variable = K = $\log\left(\frac{P}{1-P}\right)$, where P is the probability of exceeding the speed limit, and the number of observations = 11400.

[6] http://ftp.sas.com/techsup/download/stat/glmm800.html

Variable	Description	Coefficient	S.E.	T value	P value
LIMIT55	Indicator variable, 1 if speed limit =55, 0 otherwise	2.04790	0.45400	4.51	<0.0001
LIMIT60	Indicator variable, 1 if speed limit =60, 0 otherwise	2.50890	0.48110	5.22	<0.0001
LIMIT65	Indicator variable, 1 if speed limit =65, 0 otherwise	1.07150	0.29310	3.66	0.0008
LIMIT70	Indicator variable, 1 if speed limit =70, 0 otherwise; Reference variable				
CROSS	Indicator variable, 1 if continuous barrier with crossovers, 0 otherwise	-0.05584	0.39110	-0.14	0.8872
NOCROSS	Indicator variable, 1 if continuous barrier without crossovers, 0 otherwise	0.08459	0.34920	0.24	0.8099
NONTRAV	Indicator variable, 1 if non-traversable median, 0 otherwise, Reference variable				
TRAV	Indicator variable, 1 if traversable barrier, 0 otherwise	0.01922	0.35840	0.05	0.9575
4LANES	Indicator variable, 1 if total number of lanes is 4, 0 otherwise	0.19940	0.56540	0.35	0.7263
6LANES	Indicator variable, 1 if total number of lanes is 6, 0 otherwise	-0.53000	0.51850	-1.02	0.3130
8LANES	Indicator variable, 1 if total number of lanes is 8, 0 otherwise, Reference variable				
LEFTLANE	Indicator variable, 1 if vehicle was in left lane, 0 otherwise	2.07100	0.07790	26.59	<0.0001
LEVEL	Indicator variable, 1 if terrain was level, 0 otherwise, Reference variable				
ROLLING	Indicator variable, 1 if terrain was rolling, 0 otherwise	-0.65140	0.28580	-2.28	0.0282
MOUNTAINS	Indicator variable, 1 if terrain was mountains, 0 otherwise	-1.09420	0.27210	-4.02	0.0003
URBAN	Indicator variable, 1 if urban area, 0 otherwise	-0.33630	0.27790	-1.21	0.2335
CAR	Indicator variable, 1 if vehicle is a car, 0 otherwise	0.75140	0.80430	0.93	0.3513
SUV	Indicator variable, 1 if vehicle is a SUV, 0 otherwise	1.06560	0.80800	1.32	0.1887
PICKUP	Indicator variable, 1 if vehicle is a PICKUP, 0 otherwise	0.65170	0.80630	0.81	0.4199
VAN	Indicator variable, 1 if vehicle is a VAN, 0 otherwise	0.77700	0.80750	0.96	0.3371
MCYCLE	Indicator variable, 1 if vehicle is a Motorcycle, 0 otherwise, Reference variable				
TRUCK	Indicator variable, 1 if vehicle is a truck/bus/trailer, 0 otherwise	-0.15660	0.80480	-0.19	0.8459
Constant	Intercept term	2.09770	1.03160	2.03	0.0489

APPENDIX D

Models to study speed related crashes

Model for speed related crash data

Crashes are count data (i.e., non-negative integers) that have to be modeled using appropriate statistical procedures, the most popular of which are poisson and negative binomial regression models (Washington et al., 2003). In a poisson regression model, the probability of site i having y_i crashes per year is given by:

$$P(y_i) = \frac{e^{(-l_i)} l_i^{y_i}}{y_i!}$$

where l_i is the poisson parameter for site i, which is equal to the expected number of crashes per year at site i, E(y_i). Poisson regression models are estimated by specifying the Poisson parameter l_i as a function of explanatory variables, which may include traffic volume, speed limit, terrain, etc. The most common relationship between explanatory variables and the Poisson parameter is the log-linear model,

$$l_i = e^{bX_i},$$

Where X_i is a vector of explanatory variables and b is a vector of estimable parameters. This model can be estimated by standard maximum likelihood methods.

One assumption in the poisson model, is that the mean and variance are equal, i.e.,
E(y_i) = Var(y_i)

If this equality does not hold, the data are said to be under-dispersed or over-dispersed, and the parameter estimates will be biased if corrective actions are not taken. Over-dispersion is quite common with crash data, and the negative binomial regression allows the variance to differ from the mean.

With a negative binomial model, for each observation (say, site) i,

$$l_i = e^{(bX_i + e_i)},$$

where e^{e_i} is a gamma-distributed error term with mean 1 and variance a^2. The addition of this term allows the variance to differ from the mean as below:

$$Var(y_i) = E(y_i) + a[E(y_i)]^2$$

a is called as the over-dispersion parameter. The poisson model is regarded as a limiting model of the negative binomial model as a approaches zero. Cameron and Trivedi (1990) have provided a test for over-dispersion and the results of this test can be used to decide on whether to use the poisson or the negative binomial model.

In our case, the test revealed that a negative binomial model was more appropriate, and that is presented below.

Variable	Description	Coefficient	S.E.	T value	P value
Constant	Intercept	-9.8514	1.5842	-6.218	<0.0001
LIMIT55	Indicator variable, 1 if speed limit =55, 0 otherwise	0.6344	0.2809	2.258	0.0239
LIMIT60	Indicator variable, 1 if speed limit =60, 0 otherwise	0.2781	0.3276	0.849	0.3958
LIMIT65	Indicator variable, 1 if speed limit =65, 0 otherwise	0.0756	0.2022	0.374	0.7086
LIMIT70	Indicator variable, 1 if speed limit =70, 0 otherwise; Reference variable				
TRAV	Indicator variable, 1 if traversable barrier, 0 otherwise	-0.2208	0.1753	-1.260	0.2078
CROSS	Indicator variable, 1 if continuous barrier with crossovers, 0 otherwise	-0.0977	0.1999	-0.489	0.6249
NOCROSS	Indicator variable, 1 if continuous barrier without crossovers, 0 otherwise, Reference Variable				
NONTRAV	Indicator variable, 1 if non-traversable median, 0 otherwise	-0.3301	0.2779	-1.188	0.2349
LEVEL	Indicator variable, 1 if terrain was level, 0 otherwise	0.5833	0.2510	2.324	0.0201
MOUNTAIN	Indicator variable, 1 if terrain was mountains, 0 otherwise	0.2481	0.2823	0.879	0.3795
ROLLING	Indicator variable, 1 if terrain was rolling, 0 otherwise, Reference Variable				
LG_ADTLN	Log(ADT * Segment Length)	1.0700	0.1193	8.969	<0.0001
a	Dispersion Factor	0.1779	0.1039	1.711	0.0870

Log likelihood = -211.13
Restricted log likelihood = -334.46

Negative binomial regression model for speed related crashes

APPENDIX E

Project summary presented at Statewide Incident Management Interagency Team meeting on February 12, 2003

Evaluating the effects of continuous median barriers on freeways speeds and emergency response service times

Dr. Raghavan Srinivasan (Srini), Highway Safety Research Center (HSRC), UNC-Chapel Hill

Background:

- Funded by NCDOT
- Focus on limited access roads
- Initiated by Kevin Lacy when he was working for HSRC. Mr. Lacy now works for NCDOT
- The project started in July 2001. I have been working on this effort since September 2002
- Speed data has been collected at 51 sites consisting of four types of medians, i.e., no barrier but traversable medians, no barrier and non-traversable medians, continuous barrier with no crossovers, and continuous barrier with crossovers
- Conducted a survey of neighboring states regarding their policies on median crossovers

Emergency Response:

- The objective is to try to *quantify* the effect of continuous median barriers and median crossovers on emergency response times
- A database called PreMIS (http://www.premis.net/). This system does record response time data, but does not provide information about the routes followed by the emergency vehicles / ambulance.
- Questions:
  - Is it possible to get data on: (i) response time, and (ii) routes traveled, before and after continuous median barriers were introduced? If this information is available, it can be compared with situations that were not affected by median barriers, or locations with median crossovers.
  - If this information is available, how can I get it?

If you can provide input, please contact Dr. Raghavan Srinivasan (Srini) at (919) 962 7418; or srini@unc.edu

APPENDIX F

Responses from emergency operators

EMERGENCY OPERATORS IN CITIES

Charlotte Fire Department

Marcia Simmons, Charlotte Fire Communications, msimmons@ci.charlotte.nc.us

The Charlotte Fire Department does not have the data you requested. However, we did have to change our response procedure on Interstates with continuous barriers to include dispatching one company in each direction on the Interstate. This change was necessary to ensure a quick response regardless of the direction of travel, particularly since most callers to 911 are not 100% sure of the direction of travel.

Weddington, NC

Steven R. Carow, Chief, Providence Volunteer Fire Department
5025 Hemby Road, Matthews, NC 28104, Phone: 704-846-1111

Jeff, I am Chief of the Providence VFD located in Weddington, NC. My fire district encompasses a stretch of I-485 around Southern Mecklenburg County, covering from approximately the 56 mile marker to the 58 mile marker. When responding to calls on I-485 between exit 52 and exit 57 on the westbound lanes, we are forced to travel all the way from exit 57 to exit 52, and then return. Although I don't have a history of detailed incidents, it is easy to see how adding 6 to 8 miles to a call can create an extended response time. Only under the most dire conditions do I have trucks stop on the eastbound side and pull hoses and equipment across the median and westbound travel lanes. This requires completely shutting down the westbound travel lanes, and if SHP is not on the scene to do so, creates a very dangerous condition for my members and all responders. Although I have never encouraged driving any fire or rescue equipment across the grass median due to potential damage to the truck, the installation of the cables has eliminated any possibility of ever doing that. As an interesting side note, we have had a number of instances where cars have actually traveled under the bottom cable without completely being stopped. Please feel free to contact me if I can be of any further help. My voice mail at the station is 704-844-2206.

EMERGENCY OPERATORS IN COUNTIES

Buncombe County

Jerry VeHaun, Jerry.VeHaun@buncombecounty.org

We do not keep any stats here in Buncombe County regarding the two questions you asked, but we have had a problem with these barriers since they were installed. We did manage to get DOT to place some crossovers at certain places for us, but we did not get enough of them. These barriers definitely cause us problems with response times in that we sometimes have to travel to the next exit, cross over to the other lanes and then go back to the incident scene. In addition, once we are headed in the opposite direction, we sometimes have to again reverse directions to get to the hospital.

When we met with DOT, it was obvious that common sense was not a part of their agenda. The engineers kept telling us that it was very dangerous to just cross over the median to change directions, even though we had been doing it for over thirty years without problems.

The bottom line is that these barriers definitely cause delays to incidents, and this problem will only get worse in coming years.

Chowan County

Douglas L. Belch, Director, Chowan County Emergency Services, 208 W. Hicks St.
Edenton, NC 27932, Phone: 252-482-4365, Fax: 252-482-7940, Pager: 252-338-7073
Mobile: 252-312-9827, E-mail: doug.belch@ncmail.net

Chowan County only has one (1) four lane highway passing through it. That is Hwy 17. This section of highway is approximately 7-8 miles long. We do not have any median barriers or median crossovers on that section of highway.

Dare County

William R. "Skeeter" Sawyer, Director, Dare County Department of Public Safety, Dare County Emergency Medical Services, Dare MedFlight Helicopter
252-475-5712 (office), 252-441-1847 (fax)
wsawyer@co.dare.nc.us

It was a pleasure to talk with you this morning regarding the question of continuous median barriers and emergency response. As you will recall, we did not have any of those sort of barriers prior to the construction of the Virginia Dare Bridge on Highway 64 spanning the Croatan Sound.

Since the opening of the new bridge in August 2002, we have only had a few responses to emergency calls on the bridge. The average response time to those calls has been five minutes. This is within the target response time that Dare County EMS maintains for emergency response. The problem still remains with dealing with the barrier after arrival on scene, as we discussed, and the necessity to send ambulances from each end of the bridge simultaneously to assure adequate patient access and transport.

If I may be of further assistance, please contact me at your convenience.

Duplin County

Jimmy Pate, jimmyp@duplincounty.org

We do not keep a database on response time on the interstate. We have had to send two (2) EMS units or two fire dept. to every call on I-40: one on the east side, and one on west side of an accident. We have to tie up 2 units on every call.

Forsyth County

Rick Plunkett, Deputy Fire Marshal, Forsyth County
336 727 8084, plunkers@vulcan.co.forsyth.nc.us

Forsyth County Fire Department has some limited data on response times. This data is recorded in Logics Incident Reporting Software. However, unfortunately, the precise location of the event is not recorded in this database and this makes it difficult to determine the impact of median barriers.

Gaston County Emergency Management

Jim Pharr, Gaston County Emergency Management, (704) 866-3265, jpharr@gcps.org

Sorry, we do not have the data from previous years that I know of.

The issue of travel time is valid, however one should simultaneously examine the root issue, that of reasons for having crossover problems.

In the past, when no barriers were present, we could cross medians but more often we encountered body recovery rather than initiating life saving measures. Median walls prevent crossover wrecks that produce grievous injury in most cases.

Many responders complain about inability to cross, however they do not recall problems associated with crossover collisions. An alternative to providing crossover access to divided highway collisions is that of reverse travel in the collision direction. If we educate the drivers to EXPECT emergency vehicles traveling in opposing shoulder lanes following collisions on divided highways, the novelty of such actions would diminish and become acceptable. Often at collisions we significantly reduce or stop traffic in the lanes, thus opposing response is an acceptable alternative.

Smart traffic systems that incorporate cameras to detect traffic movement that is connected to communications centers in each county would prove helpful in routing emergency responses and may prove more helpful to quickly accessing collisions.

Another item of import is that of clearly marking roads in a manner that facilitates motorist recognition of landmarks. We suggest markers each tenth of a mile that indicate the position in tenths of a mile and the direction of travel. With this system we can query callers as to their position and simply ask what is written on the wall or sign. Such a system would reduce time wasted in locating incidents.

Bottom line, the real issue is not crossing through barriers but working around them.

Lee County

Pat Garner, Communications Supervisor
Sanford Police Department, Phone: 919-775-8268; Fax: 919-774-4036
pat.garner@sanfordnc.net

Received some information on response times in Lee County. The response times were to motor vehicle accidents which occurred on US#1 inside Lee County and excluded calls inside the city limits of Sanford (inside the city limits medians have always caused a problem with response times. Data from a total of 25 events are included in this calculation.

Continuous Median Barriers were installed on November 2002 on US #1

Response Time Data	Before Median Barrier	After Median Barrier
EMS / Rescue	11 minutes 54 seconds	17 minutes 18 seconds
Fire	8 minutes 34 seconds	8 minutes 28 seconds

Mecklenburg County

Barry Bagwell, BARRYB@MEDIC911.com

Mecklenburg EMS tracks our response times and reviews all responses that we do not reach the incident within our contractual requirements. However, we do not have information specific to continuous median barriers and how they impact our response. Medic units are equipped with GPS and on board mapping and routing devices, which utilize impedance data to determine the best route of access. If the barrier information is a part of the data, crews would be automatically routed around these barriers.

If you have any additional questions, please contact Monroe Hicks, GIS Coordinator for Medic, at monroeh@medic911.com

New Hanover County

Dan Summers, Director, Emergency Management, New Hanover County, NC
dsummers@nhcgov.com

I usually don't reply to unknown e-mail addresses, but I feel strongly about this issue.

First, I have seen the benefit of the barriers first hand watching road conditions along I-40 in eastern NC deteriorate rapidly as a freak snow and ice event occurred and I watched trucks and cars go into various slides and loose control.
Short!!.. We need more..

Now for the bad news. On the long stretches of highway, the barriers are a real problem for responders. In most cases where there is a break in the barriers it is at the next overpass, those breaks are often not wide enough for emergency vehicles or they ground is so POORLY maintained that heavy fire and rescue vehicles can get stuck in the mud due to poor soil conditions and lack of drainage or hard surface.

Summary:
Barriers ...Great... need more.
Current design lacks adequate signage for responders as to next opening.
And ability to "open" for emergency vehicles without having to drive many miles for turn-around!

Polk County

Sandra G. Halford, Polk County Emergency Services, sghalford@alltel.net

No data is being kept by any agency in Polk County.

Because of the media barriers, two fire departments that have coverage of I-26 have worked together to cover the steep grade and the barrier issue. Columbus Fire Department covers West bound I-26 from the Columbus Exit to the Saluda Exit, Saluda Fire Department covers East bound from the Saluda Exit to the Columbus Exit. In this instance, there is no delay. Polk County EMS has a delay if the accident is East bound between the Columbus and Saluda Exit.

I know this wasn't what you were hoping for, but if there is anything we can do to help let us know.

Rowan County

Frank Thomason, Director, Rowan County Department of Telecommunications
232 N Main Street, Suite 202, Salisbury, NC 28144, Phone: 704-638-3121, Fax: 704-638-3119
thomasonf@co.rowan.nc.us

Sorry - I have no data specific to the criteria you mention.

Scotland County

Roylin Hammond, Scotland County Emergency Services
rhammond@scotlandcounty.org

We have no database in Scotland County that would address this specific issue. We do recognize the fact that the barriers play a significant role in reducing the possibility of vehicle crossovers resulting in head on collisions. In Scotland County, NCDOT tracks the number of accidents, which have occurred where median barriers were damaged and prevented a vehicle crossover. Unfortunately, they are closed today but can be reached Tuesday, April 22, 2003 at 910-369-2645. Bill McClendon is the person to get the information from.

From an EMS prospective, the barriers in our county do not cause any unreasonable response times but they (the barriers) are only located on a portion (8 to 10 miles) of Hwy 74 and there is room at each bridge overpass for an ambulance to pass through.

Stokes County

Ricky Tuttle, rtuttle@co.stokes.nc.us

In Stokes County, the continuous barriers on US 52 definitely causes a delay in response. Callers often report the wrong lane (North or South) and location. With only 1 crossover between King and Pinnacle, emergency vehicles have to drive past the accident to turn around to get the personnel and equipment to the accident scene. NCDOT did help us by installing the crossover and I understand their position that the barriers stop vehicles from crossing over to the other lane.

In Forsyth Co, a fatality occurred when a person with diabetes was traveling North in the South lane. A Deputy Sheriff with lights and siren was in the North lane trying to get the attention of the driver. The Deputy could not cross over to get behind or in front of the other car. A head on accident occurred, killing the driver.

OTHER EMERGENCY OPERATORS AND POLICE

Cabarrus Rescue Squad

Douglas Bickerstaff – CTC, dbicker751@ctc.net

The only problems we have with the continuous barriers is that cars and small trucks get stuck in them sometimes. The Emergency vehicles usually do not cross the median due to the steepness going into and out of the median. We (Cabarrus Rescue Squad) do not keep any records of this and if there are any problems, we will forward to you. I think the longest distance between exits is about 3 miles so it does not pose a problem as of right now.

Medic99

Richard Dean, RICHARDD@MEDIC911.com

We are not tracking incidents of response time delays created by median barriers. While I'm certain that they occasionally cause some delay they probably reduce many more serious crashes and actually lower our call volume (or at least severity).

In the case of the cable type barriers - they have little effect on preventing the delivery of medical care. Paramedics can just step across the cable to render care. It is more likely to delay rescue/extrication service due to the need to get the rescue vehicle close to the trapped victim. But in Charlotte / Mecklenburg there are so many rescue vehicles we have them respond from multiple directions on interstate crashes so they aren't routinely delayed by the barriers - traffic maybe - but not median barriers.

Mitchell's Towing Service, Raleigh, NC

Woody Mitchell, Owner, Mitchell's Towing Service, Inc.
504 Woodland Road, Raleigh, NC 27603, Mobile Phone: 919-422-3720,
WECANTOW4U@aol.com

I don't have any stats, maybe communications personnel with SHP could come up with something.

Another problem could be by not having crossovers closer is that folks try to use bridge overpasses (not sure of spelling), which could be dangerous, pot holes, etc. Could be interesting if these crossings have caused any accidents, i.e., around bridge areas. My vote would be to provide a cross over for emergency vehicles every 3 miles if there were not intersections within that approximate mileage.

Morrisville, Police

John A. Crone, Chief of Police, jcrone@ci.mooresville.nc.us

Certainly an argument can be made that continuous barriers reduce the potential for head on crashes. However, motorist also know that police officers using moving radar not only can't turn around on a violator, they also can't get a description of the speeding car for later pursuit. Because of this, motorists feel secure in driving much faster which probably negates any benefit from the reduction in head-on crashes. That is my opinion in addition to the difficulty in accessing accident scenes.

Two years ago on Easter weekend, I witnessed an intoxicated female motorist southbound on Interstate 77. She abruptly pulled in front of me from the shoulder in bumper to bumper traffic southbound on the interstate around exit 30. I was in my personal car with my family and observed she had two small children in her car not in any child restraints. I called the Highway Patrol for assistance and told them she was going to kill somebody. The traffic was only moving 5mph and was stopping frequently.

Once she struck the car in front of her. That driver called the police also. I continued to keep her in sight waiting for the SHP who was Northbound on I-77. Twice, I ran out into the Interstate trying to get to her stopped and detain her. Each time the traffic again started moving and I had to get out of the Highway. Finally, the driver that had been struck earlier told the female that the SHP was on the way. She panicked and pulled out onto the shoulder and accelerated to 60mph beside the traffic standing about still on the roadway. She drove about a mile and crashed into a car that a tow truck driver had been working on with the hood up. The tow truck driver's arm was severed and he died at the scene. She received minor injuries and I got the children out of the vehicle and they seemed okay.

I can't say for sure that accessibility to that moving scene would have saved that truck driver's life. I will say that the barricade prevented the SHP from getting to her in time. The SHP passed me going Northbound before she had run into the Tow Truck.

Sorry about the detail story, but I'm still a little upset that we couldn't get her stopped in the 15 minutes that all this took before the crash. I know accessibility limited by the continuous barricades played a part in the effort to apprehend her.

North Carolina State Highway Patrol

Nolan C. Beam, nbeam@NCSHP.ORG

Median cable barriers hamper our efforts in speed enforcement as well as restricting our efforts in vehicle removal at collision scenes. The median cable barriers however, do prevent some head on collisions on the interstate system preventing serious injury. We would like to see these barriers with crossovers for police/EMS/ Fire responding to calls on the interstate system. We do not keep any data bases that reflect any information concerning response times. However, rather than cables, our officer think that a guardrail system provides better protection. Additionally, these guardrails/barriers need to be placed further off of the roadway on the left shoulder in order to maximize travel lanes in case of an emergency.

APPENDIX G

Recommended List of Variables for Emergency Operators

In order to assess the effect of median barriers, emergency crossovers, and other parameters on response times, it is important that sufficient data are collected on response times and the routes followed by emergency vehicles for each incident. Following are examples of data elements that would allow this assessment:

- Date of incident
- Time of incident (may have to be estimated)
- Location of Incident (street address, route number, and/or milepost, city, county, State, ZIP)
- Emergency vehicle dispatch location (street address, route number, and/or milepost, city, county, State, ZIP)
- Location of destination (street address, route number, and/or milepost, city, county, State, ZIP): destination may include a hospital where a patient is taken for treatment
- Incident location type: home, street or highway, office complex, etc.
- Type of vehicle responding to incident: fire, ambulance, etc.
- Date and Time when emergency responder started moving in response to a call
- Date and Time when emergency responder arrived at the scene
- Date and Time when emergency responder left the scene
- Date and Time when emergency responder arrived at destination with patient
- Beginning mileage of responding vehicle
- Mileage of responding vehicle when it arrives at the scene
- Mileage of responding vehicle at the destination
- Route followed by emergency vehicle from origin to the scene
- Route followed by emergency vehicle from the scene to the destination
- Reasons for delay in transport to the scene (this applies if the emergency operator feels that there was a delay in reaching the scene): Vehicle crash, traffic congestion, road closure, wrong directions, etc.
- Reasons for delay in transport to the destination (this applies if the emergency operator feels that there was a delay in reaching the destination): Vehicle crash, traffic congestion, road closure, wrong directions, etc.