Final Report

# ANALYSIS OF CROSS-MEDIAN CRASHES ON ALABAMA DIVIDED PARTIAL CONTROL OF ACCESS ARTERIALS

Prepared by

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Civil Engineering
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**Abstract**

This report summarizes the activities and conclusions of a study conducted on cross-median crashes on non-Interstate divided partial access controlled arterials in Alabama with speed limits of 45 mph (72 km\hr) or greater. The Critical Analysis Reporting Environment (CARE) was used to identify roadway segments experiencing cross-median crashes. Hard copies of the crash reports and measurements of site characteristics were obtained for fifty-eight segments. Analysis included determining if a correlation exists between site characteristics, and cross-median crash frequency and/or crash rate could be established. A strong correlation could not be established between cross median crashes and site data. Site specific crash experience was determined as being the best factor for identifying segments that should be investigated for remedial countermeasures. Analysis of both crash frequency and crash rate were conducted but the relatively small range of crash frequency did not result in meaningful results. Analysis results of crash rates indicated that two way left turn (TWLT) arterials should be investigated for cross median countermeasures when the crash rate exceeds 14.1 crashes per 100 million vehicle miles (100 MVM) (160 MVKM) of travel. Similar considerations should be applied on divided arterials with partial access control when the cross median crash rate exceeds 8.3 median crashes per 100 MVM (160 MVKM) of travel.

# 1 - INTRODUCTION

## Background

Highway agencies consistently apply safety concepts as a guiding principle when designing roadways. These efforts have been effective since, while the number of fatalities remains relatively constant at approximately 42,000 persons per year, the fatality rate has been decreasing. Nationwide vehicle miles traveled increased 8.5% from 1998 to 2002 while the fatality rate decreased from 1.58 to 1.51 fatalities per 100 million vehicle miles (100 MVM) (160 MVKM) [1]. During the same time period in Alabama, the fatality rate decreased from 1.94 to 1.80 fatalities per 100 MVM (160 MVKM). The decreasing trend of the National fatality rate, since 1980, is presented as Figure 1.

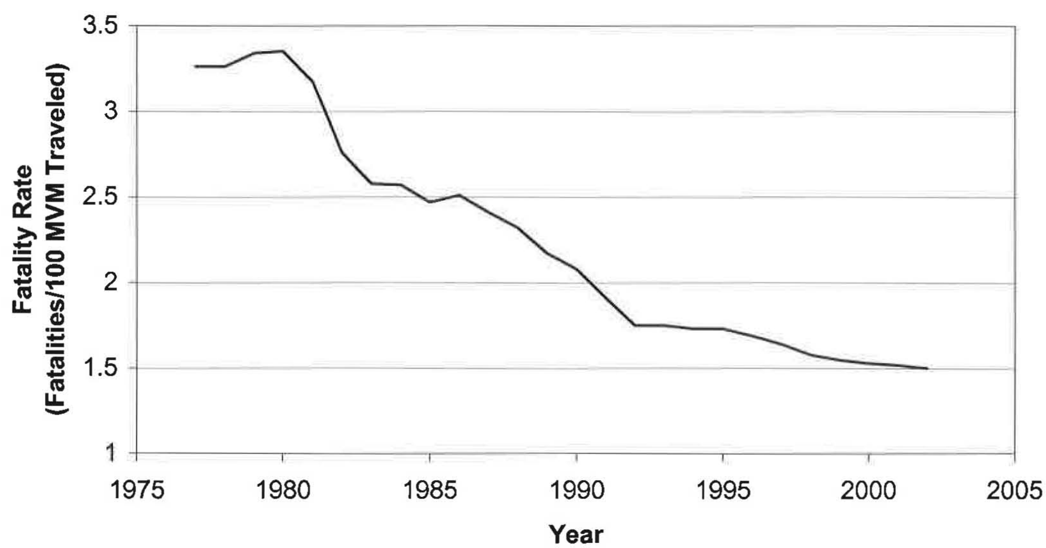



Figure 1 - Fatality rate by year [1].

Certain crashes, because of their characteristics, tend to result in a higher crash severity. One such type of crash is the cross-median crash, which involves the collision of vehicles traveling on divided routes in opposing directions. The potential for cross-median crashes can be reduced by the installation of median barriers and by providing a sufficiently wide median to allow drivers an opportunity to recover before entering the opposing travel lanes. Median width is defined as the distance between the left edges of opposing traveled ways, including the left shoulders.

Median width is affected by many factors, including available right-of-way, and land availability and cost. These factors can result in narrow medians which may require the installation of longitudinal barriers to prevent an errant vehicle from crossing the median. Variables considered in the determination of barrier need can include median width, median design, design speed, average daily traffic (ADT), and crash history. A set of guidelines to help determine the need of median barrier needs, or warrants, for high speed roadways is provided in the AASHTO Roadside Design Guide (RDG) [2]. A study sponsored by the National Cooperative Highway Research Program (NCHRP), Improved Guidelines for Median Safety, is currently underway to develop more comprehensive median barrier warrants. In addition, some states have conducted in-depth studies on median barrier needs, resulting in State specific installation guidelines.

When median barriers are required, there are many different barriers that can be utilized. The type of median barrier appropriate for a particular location is dependent upon the physical characteristics of the site, crash history, barrier maintenance needs, barrier operational characteristics, and service life cost. Physical characteristics include the median width, roadway curvature, median slopes, and physical obstructions within the median. For example, concrete barriers have a high initial cost but have a relatively low maintenance cost when compared to semi-rigid systems such as W-beam. However, since the concrete barrier is a rigid system it performs best when placed in narrow medians. When the distance between the barrier and travel lanes increases there is an increased potential of large-angle impacts. The large angle impacts, due to the exposure of more vehicle frontal area, have the potential of being more severe than shallow angle impacts. W-beam barrier, while more forgiving of large-angle impacts than concrete barrier, can be installed away from the travel way but as a general rule should not be installed on slopes steeper than 10:1 (1V:10H). Severe slopes and elevation differences on the approach to W-beam barriers can result in vehicles under riding, or vaulting over the barrier. Cable barriers can be installed on slopes as steep as 6:1 (1V:6H) but some systems can have a deflection distance up to 11 ft (3.4 m). Semi-rigid or flexible systems are frequently not installed on narrow medians because the barrier can deflect, upon impact, into the opposing traffic stream.

**Statement of the Problem**

The probability of a cross-median crash is dependent upon a vehicle completely crossing the median at the same time that an opposing vehicle is present. Depending upon the median width and ADT, the probability of this type of crash can be low, but the resulting severity very high. The problem arises in determining the appropriate median width that allows for vehicle recovery without the installation of a median barrier. Guidance must consider the cost of a barrier and related maintenance activities. A median requiring a barrier should utilize the proper type of median barrier installation for the given site.

Because divided roadways without full access control are the focus of this study, additional issues must be considered. Barrier installation in the median of partial control of access arterials will necessitate the installation of more barrier terminals than would be needed on a freeway segment. The presence of median openings also allow for the possibility of cross-median crashes. In addition, since many partial access controlled undivided arterials are designed for lower speeds, the geometry of these roadways can be very different from freeway facilities..

**Research Objective**

The objective of this study is to determine the need for median safety barrier, or other crash countermeasures, by analyzing crash history with physical and operational characteristics. The study was conducted on a randomly selected subset of non-Interstate divided arterials routes, having minimum speed limits of 45 mph (72 km\hr).

# 2 - LITERATURE REVIEW

A literature review was performed to determine the current state-of-the-practice of median barrier design. Information pertaining to similar studies and current State warrants for median barrier installation were studied. The literature search included publications by the American Association of State Highway and Transportation Officials (AASHTO), Federal Highway Administration (FHWA), Transportation Research Board (TRB), Institute of Transportation Engineers (ITE), and the National Cooperative Highway Research Program (NCHRP). An internet search was also conducted on relevant websites and the Transportation Research Information System (TRIS).

## AASHTO Guidelines

A guideline for high-speed facility median barrier installation and design is contained in the Roadside Design Guide, (RDG) [2]. Some States have modified the guideline to better address the specific needs of the State. The RDG guideline, presented as Figure 2, suggest that a median barrier installation is optional when a roadway site has average daily traffic (ADT) of less than 20,000 vehicles per day or a median width in excess of 30 ft (9.1 m). However, the use of these guidelines is intended for high-speed, controlled-access highways with relatively flat, traversable medians [2]. The installation of strong-post W-beam median barrier is suggested for medians with widths of at least 10 ft (3 m). Cable median barrier can be installed for widths of 24 ft (7.3 m) or more. Whenever a median barrier is installed, the installation and performance of the barrier should conform to the performance requirements of

NCHRP Report 350 [3]. NCHRP Report 350 establishes the test level standards and criteria that are used to evaluate the performance of barriers.

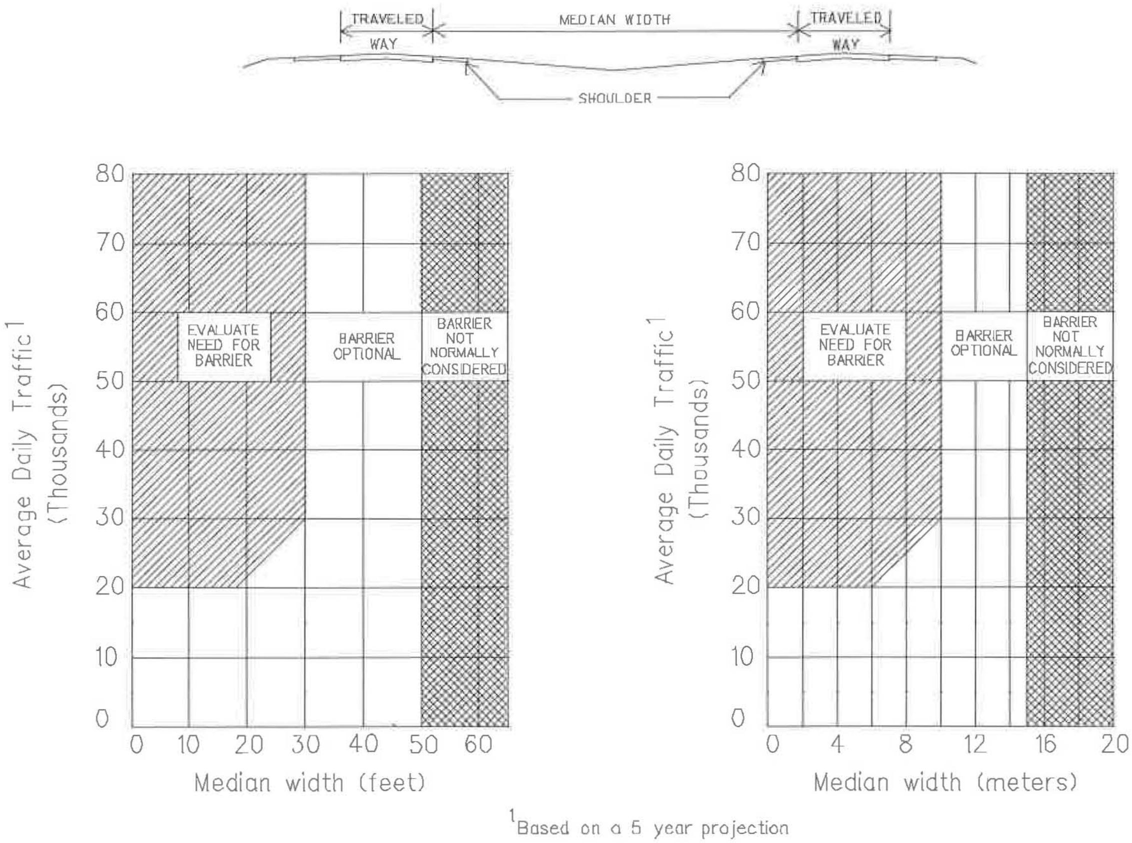



Figure 2 – Suggested median barrier guidelines of the Roadside Design Guide. [2]

## Other Guidelines

Some States have determined that the guidelines set forth in the Roadside Design Guide are not sufficient and have developed more comprehensive guidelines for determining median barrier need. California analyzed their cross-median crash data to develop a set of warrants, for freeways, that can also be used as a guide for median barrier installation on non-freeway segments. The warrant, presented in Figure 3, determines when median barrier studies should be conducted based on a site's ADT and median width. Median barriers should also be considered when, given at least three crashes in five years, a rate of 0.50 cross-median crash per mile (0.31 per km) per year of any severity or 0.12 fatal cross-median crash per mile (0.073 per km) per year exists [4]. The type of barrier suggested for use by California is determined by median width, as shown in Figure 3. It is noted that concrete barrier is specified for medians up to 36 ft (11 m) wide. Thrie beam barrier is specified for wider medians, but may be used with median widths between 20 ft (6.1 m) and 36 ft (11 m) if the potential for flooding or other special circumstances exist. Concrete barrier can be used when median widths exceed 36 ft (11 m) if it is offset from the center of the median to allow an acceptable recovery area for errant vehicles on one side of the barrier and adequate space for maintenance activities on the other [4].

Connecticut's Highway Design Manual states that median barrier is warranted on all freeway medians with widths of 66 ft (20.1 m) or less and on wider medians depending on crash history. Some judgment should be used on non-freeways, taking into account crash history, ADT, travel speeds, median width, alignment, sight distance and construction costs to determine an appropriate median barrier for installation [5]. A limited discussion of when different median barrier types should be used is presented, but the point is made that concrete median barriers should not be placed further than 12 ft (3.6 m) from the traveled way.

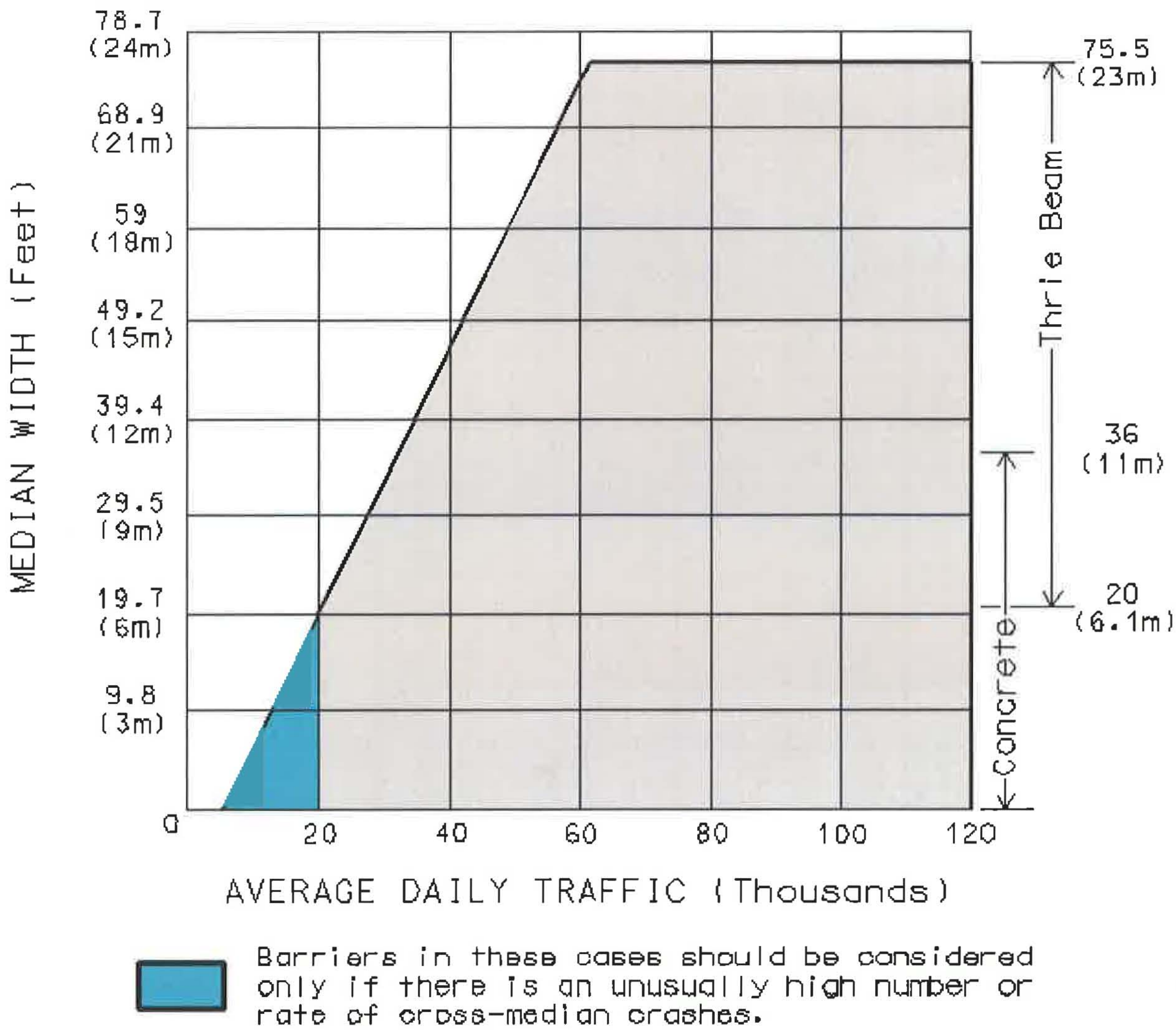



Figure 3 – California's median barrier warrants [4].

Washington's Design Manual requests that median barrier be installed on full access control, multilane highways with median widths of 50 ft (15.25 m) or less and posted speed limits of 45 mph (72 km\hr) or greater [6]. Median barrier may also be warranted when median widths are wider or posted speed limits are lower if there is a history of cross-median crashes.

The roadway design guidelines of North Carolina require median barrier on freeway projects with median widths of 70 ft (21.3 m) or less [7]. It also suggests that two rows of a semi-rigid barrier be used on median widths of 30 ft (9.1 m) and greater when median slopes steeper than 6:1 (1V:6H) exist [7]. Cable barrier can be installed when median widths are 46 ft (14 m) or greater if median slopes are than 6:1 (1V:6H) or flatter, but should be placed 4 ft (1.2 m) from the centerline of the ditch.

Although these guidelines were developed primarily for full access controlled facilities, they may also be helpful for determining median barrier needs for other lower speed and limited access highways.

## Median Width Studies

Few studies have been conducted to develop guidelines for determining the median width that warrants barrier installation. One study, performed by the Highway Safety Research Center (HSRC) at the University of North Carolina, investigated the relationship between crashes and median width [8]. The study analyzed crash data from Illinois and Utah contained in the Highway Safety Information System (HSIS) data base, which is maintained by the HSRC for the FHWA. HSIS includes crash, roadway inventory, and traffic volume data bases for five states: Illinois, Utah, Michigan, Minnesota, and Maine.

The analysis of crashes in Illinois and Utah was restricted to two-way, four-lane, rural and urban Interstate, freeway, and major highway road sections with lengths exceeding 0.07 mi (0.11 km), a posted speed limit of at least 35 mph (56 km\hr), and median width no wider than 110 ft (33.5 m) [8]. The study analyzed four years of crash data from 982 roadway sections in Utah, with an average length of 0.99 mi (1.59 km), and three years of crash data from 2,481 roadway sections in Illinois, with an average length of 0.84 mi (1.35 km). At the time of the study, four years of crash data was not available for Illinois. A log-linear regression model was developed to relate the effects of median width and other roadway variables to crash rates [8].

A small decrease in crash rate occurred when median widths increased from zero to 30 ft (9.1 m), which may demonstrate that medians do not provide a safety benefit unless they are at least 30 ft (9.1 m) wide. Also, the safety benefits of medians increased steadily until median widths reached 60 to 80 ft wide (18.3 to 24.4 m) [8]. This study analyzed all reported crashes on the segments, regardless of type. The analysis reveals that median width may affect not only cross-median crashes, but other crash types as well. This can easily be understood when the median is not only considered as a recovery area for vehicles that might be involved in cross-median crashes, but also as a recovery area for vehicles avoiding other crash types. The median width suggesting when a barrier should be installed was not determined in the study.

Washington State Department of Transportation (WSDOT) performed a study to determine the median width threshold for barrier installation by benefit/cost analysis [9]. WSDOT examined five years of data from crashes that occurred on 677 mi (1089 km) of multilane, divided highways, with full access control, that contained either depressed medians or medians without barriers [9]. The only crashes considered in the study were cross-median crashes, identified by a vehicle ending up in the opposing direction of travel; excluding wrong-way crashes. The benefit/cost analysis used the societal costs of crashes employed by WSDOT for budgeting their safety investment program and actual contract and maintenance costs for barriers. Because barrier installation is likely to increase the number of crashes, and decrease severity, it was assumed that the number of crashes after barrier installation would be equal to the number of crashes before. Cable median barrier was found to have the highest benefit/cost ratio, ranging from 2.7 to 5.5 for widths up to 50 ft (15.25 m). It was determined that barrier installation was cost effective with medians of 50 ft (15.25 m) or less. Although cable median barrier was the most cost-effective barrier in this study it is not appropriate for use in narrow medians. The deflection distance varies for different cable barrier systems. These systems have a larger deflection distance than beam and concrete barrier systems. Beam guardrail and concrete median barriers were found to be cost effective for medians with widths of 50 ft (15.25 m) or less.

**Survey of Southeastern States**

A survey was sent to ten southeastern States to determine what standards or guidelines are used when considering the installation of median barrier on high speed divided arterials, whether studies were conducted to develop the guidelines, and if cross-median crash history was a factor in the installation of median barrier at any site. The States included in the survey were Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee. While conducting this survey, presented as Appendix A, a similar survey was referenced by a respondent.

New Jersey conducted a survey of all States to determine what guidelines are used for median safety barrier installations. New Jersey received responses from 35 of the 50 states queried. Thirteen of those states referenced the RDG as their guide for determining the need to install median barrier. Six of the responding states had developed their own guidelines and the remaining states were either considering new guidelines or did not provide their standards. The results of the survey, provided by New Jersey, are summarized in Appendix B.

In this survey, only five of the ten southeastern States responded. Three of these states use the RDG as guidance for median safety barrier installations and do not consider the cross-median crash history. South Carolina has not begun to address cross-median crashes on divided, non-interstate highways, but is currently focusing on cross-median crashes on the Interstate System. The South Carolina Department of Transportation began installing cable median barrier in interstate roadway medians with widths of 60 ft (18.2 m) or less in September 2000. South Carolina reported a 67% reduction in cross-median crashes after completing these installations and has begun installing median safety barrier in interstate roadway medians with widths of 72 ft (21.9 m) or less. South Carolina studied two of their major, non-interstate divided highways and determined that the number of cross-median crashes on these types of roadways was not significant. Florida developed guidelines for median safety barrier installations from a study conducted by the Florida Department of Transportation. Cross-median crash data was compiled in this study, but no formal report was produced. The guidelines produced from their research were incorporated into Florida's Plans Preparation Manual and are presented as part of the New Jersey study responses, presented in Appendix B. Florida considers median barrier as warranted on freeways with median widths less than 60 ft (18.2 m) and design speeds of 60 mph (97 km\hr) and Interstates having median widths less than 64 ft (19.5 m) [10]

**Survey of ALDOT Divisions**

A survey of the nine Divisions of the Alabama Department of Transportation, presented as Appendix C, was conducted to identify divided partial control of access, arterials with speed limits of 45 mph (72 km\hr) or greater. The survey was necessary to identify routes with the requisite characteristics because a data base of geometric characteristics does not exist. Included on the survey were queries that were intended to obtain information of the typical type of countermeasure implemented to address "problem areas". It was not the purpose of this survey to identify specific roadway segments for analysis, but rather to obtain a stratified group of roadways from segments that could be randomly selected for project analysis.

**Median Barrier Types**

Though there are many variations of roadside barriers available, four types of median barriers are used in most situations: w-beam barrier, thrie beam barrier, concrete barrier, and cable barrier. In some instances, median width or slope can determine which type of installation will be best or may restrict the use of a particular barrier. In addition to site condition concerns, there are advantages and disadvantages to each of these barrier types.

## Semi-rigid Median Barriers

The two primary types of semi-rigid median barriers are the strong post W-beam and thrie beam systems. Strong-post W-beam guardrail is the most widely used median barrier in the U.S. It consists of strong wooden or steel posts, at 6 ft 3 in (1905 mm) spacing, with the top of the rail installed at 30 in (765 mm) when rub rail is used. It is a semi-rigid system that can deflect up to 2 ft (600 mm) upon impact and should not be used as a median barrier in situations where the median is 10 ft (3 m) or less [11]. Thrie beam barrier is a system that works in a similar manner to strong post W-beam barrier but, due to its larger cross section, has less deflection than standard W-beam barrier installations. The larger cross section also results in slightly better performance than W-beam when impacted by larger vehicles.

The advantage to semi-rigid systems is that some of the crash force is transferred to the system during deflection resulting in less force being imparted to the vehicle and its occupants. In addition the system frequently remains at least partially effective after an impact; permitting time for system repairs, while providing a degree of safety until repairs are complete. Another advantage is its relatively low cost of approximately $20 to $21 per ft ($65 to$68 per m) with a terminal length of 37.5 or 50 ft (11.5 or 15.3 m) and an approximate cost of $1500 each [11].

## Flexible Median Barriers

The two most common flexible median barriers are the weak post W-beam and cable barrier systems. The weak post W-beam system utilizes metal posts, at a spacing of 12 ft 6 in. (3810 mm). The primary function of the posts is to maintain the proper height of the rail using bolts that are designed to fail. When the barrier is impacted, the bolts release the rail from the posts permitting the guardrail to remain in contact with, and redirect, the impacting vehicle. The weak post W-beam system can deflect up to 7 ft (2135 mm) [11]. The result is that they transfer less impact energy to the vehicle occupants but are frequently not even partially effective until maintenance replaces them to their design specifications. Terminals of weak post W-beam systems are usually effected by transitioning to a rigid W beam terminal.

Cable barrier systems have been popular in some States for many years, while other States have appeared to distain their use. The systems consist of weak-posts that are placed solely to hold the cables at the proper height. When a vehicle impacts the barrier, the posts release the cables which retain contact with the vehicle. As the vehicle rides along the cables, the cables stretch, large tensile forces develop in the cables, and the vehicle is redirected.

The current emphasis on median safety has resulted in a number of new systems being developed that exhibit decreased deflection and ease of maintenance characteristics. Pre-stretched, pre-tensioned systems have the advantages of reducing the crash force imparted to vehicle occupants while causing the cables to remain upright after impact and, hence, effective until maintenance can be effected. Socket post installations result in rapid repairs reducing not only maintenance costs but also the amount of time that maintenance crews are exposed to traffic hazards. Cable barrier installations do not reduce sight distance and prevent drifting snow accumulation in areas with heavy snowfall. While the older cable systems could deflect up to 11 ft (3355 mm). New systems have been tested that have deflections of 6 ft 9 in. (2090 mm) when installed at 6 ft (1830 mm) post spacing and 9 ft 2 in (2795 mm) when installed at a post spacing of 16 ft 5 in. (5005 mm). The cost of current systems with socketed posts is approximately $12.50 ft ($41 m) with Washington State reporting an average maintenance cost of $1880 per mile ($1170 per km). Terminals for cable barrier systems are typically 50 ft (15.3 m) in length and cost approximately $2000 each.

**Rigid Median Barriers**

Rigid barriers are primarily concrete shapes that were first developed in the 1960s and evolved to the current safety shape and sloped wall designs. Concrete safety shapes are designed for narrow medians where deflection space is not available. On shallow angle impacts they result in the vehicle riding up the barrier to be redirected. The high cost of concrete median barriers, typically about $50 per ft ($164 per m) for 32 in (810 mm) barrier height, will frequently inhibit their installation but this is offset by their relatively low maintenance cost. Rigid barriers usually retain their performance level after impact, without repair. However, since these barriers do not deflect upon impact they can impart large forces on the vehicle occupants when in impacted at large angles. For this reason they should not be installed at large transverse distances from the traveled way. Tall versions of these barriers can result in sight restrictions on the inside of horizontal curves. Terminals to concrete barriers can include the use of crash cushions, transitioning to a semi-rigid barrier terminal, by flaring a sloped end out of the clear zone, or the use of a properly designed earth berm.

# 3 - CRASH AND SITE INVESTIGATION

The crash investigation was performed with the use of the Critical Analysis Reporting Environment (CARE) database. CARE was developed by the University of Alabama Computer Science Department to extract crash analysis data from police crash reports. This software has the ability to generate graphs and charts that make data easy to understand.

A search was performed using a query defined to include crashes on State highways off the Interstate System with four or more bifurcated lanes involving vehicles traveling in opposing directions. The query dismissed crashes that were intersection related, involved traffic signals, occurred on segments with speed limits less than 45 mph (72 km\hr) , or that included driver maneuvers, such as turning movements or failing to heed signs or signals, that were not consistent with a cross-median crash. The records queried included five years of data, 1998 to 2002.

The query results included 265 one-mile segments potentially having cross-median crashes on mile-posted State route roadways. These segments included 507 crashes that met the characteristics of the query. These crashes accounted for 0.07% of the 682,820 crashes that occurred throughout Alabama during the five years studied. Of the 265 total segments, 207 had one or two crashes during the five years and the other 58 segments had from three to nine crashes during the same period. It was decided that 50%, or 29, of the 58 "high crash" segments and, correspondingly, 29 of the 207 "low crash" segments would be randomly selected for site visits and in-depth analysis. The segments selected are located in the southern and central portions of Alabama.

Hard copies of the actual crash reports were obtained from the State prior to the site investigations. The narratives and the diagrams of the crash reports were studied to determine if the crash was in fact a cross-median crash. This analysis revealed that, of the 152 crashes on the 58 segments initially selected from the computerized CARE database, only 72 were actually cross-median crashes. A list of the crash sites along with the number of cross-median crashes occurring at each site utilized in this investigation is presented as Table 1.

Data collected at each of the 58 one-mile segments selected for in-depth analysis included median width, side slopes, number of lanes, posted speed limit, and the number of driveways and intersections, on both sides of the arterial, within the one-mile segment. The median width was measured using a wheel and the slope was measured by placing the bottom end of a 48 inch level in a level position on the slope and measuring the height of its opposing bottom end above the ground. A copy of the data collection sheet is presented as Appendix D with a summary of the AADT, provided by ALDOT for each of the five years 1998 – 2002, presented in Appendix E. A complete listing of the site data collected is presented in Appendix F.

**Analysis Of Operational, Environmental, And Crash Characteristics**

The statistical program MINITAB was used to identify possible relationships between crash data and physical/traffic characteristics [12]. The analysis activities

## Table 1 - Summary of All Analysis Sites for Median Crashes

| Alabama | Milepoint | | Speed | Median | | Per Mile[4.] | | Median Crashes | | | | | Average | Crash Rate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Route | Begin | End | (mph)[1.] | Slope[2.] | Width (ft)[3.] | Inter. | Dwys | Freq. | Vehicles | PDO | Fatal | Injury | ADT | (100 MVM) |
| 1 | 126.7 | 127.7 | 65 | 8.3 | 100.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15074 | 0.0 |
| 1 | 128.8 | 129.8 | 65 | 8.3 | 100.7 | 2 | 4 | 1 | 2 | 0 | 0 | 1 | 15074 | 3.6 |
| 1 | 132.6 | 133.6 | 65 | 14.6 | 94.2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 14572 | 0.0 |
| 1 | 118.7 | 119.7 | 65 | 16.7 | 53.4 | 1 | 1 | 1 | 2 | 1 | 0 | 0 | 18996 | 2.9 |
| 1 | 109.0 | 110.0 | 65 | 12.5 | 33.8 | 1 | 2 | 1 | 2 | 0 | 0 | 1 | 21244 | 2.6 |
| 8 | 122.9 | 123.9 | 65 | 33.3 | 41.2 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 13952 | 0.0 |
| 8 | 215.0 | 216.0 | 55 | 12.5 | 29.8 | 1 | 0 | 2 | 4 | 2 | 0 | 0 | 34854 | 3.1 |
| 8 | 212.8 | 213.8 | 45 | 0.0 | 12.0 | 5 | 17 | 1 | 2 | 0 | 0 | 1 | 22646 | 2.4 |
| 8 | 214.0 | 215.0 | 45 | 0.0 | 12.0 | 5 | 10 | 1 | 3 | 0 | 1 | 0 | 25832 | 2.1 |
| 13 | 23.2 | 24.2 | 65 | 12.5 | 50.8 | 5 | 13 | 0 | 0 | 0 | 0 | 0 | 12700 | 0.0 |
| 13 | 18.5 | 19.5 | 50 | 20.8 | 28.9 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 14548 | 0.0 |
| 13 | 13.4 | 14.4 | 50 | 20.8 | 28.9 | 3 | 10 | 1 | 2 | 1 | 0 | 0 | 17828 | 3.1 |
| 13 | 14.8 | 15.8 | 50 | 20.8 | 28.9 | 1 | 4 | 1 | 2 | 0 | 0 | 1 | 17302 | 3.2 |
| 13 | 17.5 | 18.5 | 50 | 20.8 | 28.9 | 2 | 2 | 1 | 2 | 0 | 0 | 1 | 14548 | 3.8 |
| 16 | 16.0 | 17.0 | 50 | 20.8 | 23.5 | 2 | 40 | 1 | 1 | 1 | 0 | 0 | 30970 | 1.8 |
| 16 | 15.0 | 16.0 | 45 | 0.0 | 12.0 | 4 | 40 | 2 | 4 | 1 | 0 | 1 | 28032 | 3.9 |
| 16 | 17.0 | 18.0 | 45 | 0.0 | 12.0 | 5 | 40 | 1 | 3 | 1 | 0 | 0 | 29830 | 1.8 |
| 16 | 18.0 | 19.0 | 45 | 0.0 | 12.0 | 5 | 50 | 0 | 0 | 0 | 0 | 0 | 32174 | 0.0 |
| 16 | 19.2 | 20.2 | 50 | 0.0 | 12.0 | 2 | 50 | 0 | 0 | 0 | 0 | 0 | 30468 | 0.0 |
| 38 | 36.5 | 37.5 | 65 | 20.8 | 53.4 | 0 | 5 | 1 | 3 | 0 | 1 | 0 | 23346 | 2.3 |
| 38 | 11.5 | 12.5 | 55 | 12.5 | 51.7 | 4 | 0 | 5 | 11 | 3 | 0 | 2 | 43998 | 6.2 |
| 38 | 12.5 | 13.5 | 55 | 12.5 | 51.7 | 2 | 1 | 2 | 4 | 1 | 0 | 1 | 27676 | 4.0 |
| 38 | 8.4 | 9.4 | 55 | 12.5 | 36.7 | 3 | 12 | 1 | 2 | 0 | 0 | 1 | 43998 | 1.2 |
| 38 | 39.0 | 40.0 | 65 | 22.9 | 29.2 | 3 | 7 | 1 | 2 | 0 | 0 | 1 | 17294 | 3.2 |

1. 1 mph = 1.6 km/hr
2. Slopes presented as horizontal run: 1 vertical rise
3. 1 ft = 0.3048 m
4. Intersections and driveways per mile include both directions of travel.

## Table 1 - Summary of All Analysis Sites for Median Crashes

| Alabama | Milepoint | | Speed | Median | | Per Mile[4.] | | Median Crashes | | | | | Average | Crash Rate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Route | Begin | End | (mph)[1.] | Slope[2.] | Width (ft)[3.] | Inter. | Dwys | Freq. | Vehicles | PDO | Fatal | Injury | ADT | (100 MVM) |
| 38 | 1.9 | 2.9 | 55 | 0.0 | 12.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 71446 | 0.0 |
| 38 | 3.0 | 4.0 | 55 | 0.0 | 12.0 | 2 | 2 | 2 | 5 | 0 | 0 | 2 | 56690 | 1.9 |
| 38 | 4.2 | 5.2 | 55 | 0.0 | 12.0 | 2 | 0 | 1 | 2 | 1 | 0 | 0 | 68184 | 0.8 |
| 38 | 5.5 | 6.5 | 55 | 0.0 | 12.0 | 3 | 2 | 2 | 4 | 1 | 0 | 1 | 68184 | 1.6 |
| 38 | 6.8 | 7.8 | 55 | 0.0 | 12.0 | 4 | 5 | 2 | 4 | 1 | 0 | 1 | 45250 | 2.4 |
| 38 | 10.0 | 11.0 | 55 | 0.0 | 12.0 | 2 | 0 | 8 | 18 | 3 | 0 | 5 | 43998 | 10.0 |
| 42 | 10.9 | 11.9 | 50 | 0.0 | 12.0 | 1 | 6 | 3 | 6 | 2 | 0 | 1 | 17212 | 9.6 |
| 42 | 12.1 | 13.1 | 45 | 0.0 | 12.0 | 2 | 28 | 4 | 9 | 2 | 0 | 2 | 23726 | 9.2 |
| 42 | 13.1 | 14.1 | 45 | 0.0 | 12.0 | 0 | 17 | 1 | 2 | 0 | 0 | 1 | 23726 | 2.3 |
| 42 | 14.2 | 15.2 | 50 | 0.0 | 12.0 | 11 | 37 | 2 | 5 | 0 | 1 | 1 | 24758 | 4.4 |
| 42 | 15.3 | 16.3 | 50 | 0.0 | 12.0 | 5 | 30 | 2 | 4 | 0 | 0 | 2 | 24758 | 4.4 |
| 42 | 17.0 | 18.0 | 50 | 0.0 | 12.0 | 3 | 8 | 1 | 2 | 1 | 0 | 0 | 23186 | 2.4 |
| 53 | 103.0 | 104.0 | 65 | 12.5 | 99.2 | 2 | 5 | 0 | 0 | 0 | 0 | 0 | 16774 | 0.0 |
| 53 | 81.5 | 82.5 | 65 | 20.8 | 53.2 | 2 | 5 | 1 | 2 | 0 | 0 | 1 | 17778 | 3.1 |
| 53 | 97.5 | 98.5 | 65 | 12.5 | 49.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15800 | 0.0 |
| 53 | 90.8 | 91.8 | 65 | 12.5 | 48.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15150 | 0.0 |
| 53 | 54.1 | 55.1 | 65 | 12.5 | 39.3 | 1 | 0 | 2 | 4 | 0 | 0 | 2 | 12824 | 8.5 |
| 53 | 55.7 | 56.7 | 65 | 12.5 | 39.3 | 3 | 4 | 2 | 4 | 0 | 1 | 1 | 12756 | 8.6 |
| 53 | 57.1 | 58.1 | 55 | 0.0 | 12.0 | 1 | 5 | 6 | 13 | 1 | 1 | 4 | 12530 | 26.2 |
| 53 | 59.0 | 60.0 | 55 | 0.0 | 12.0 | 2 | 10 | 2 | 4 | 0 | 0 | 2 | 12530 | 8.7 |
| 53 | 60.0 | 61.0 | 55 | 0.0 | 12.0 | 3 | 9 | 2 | 4 | 2 | 0 | 0 | 13186 | 8.3 |
| 53 | 62.4 | 63.4 | 55 | 0.0 | 12.0 | 3 | 10 | 3 | 6 | 2 | 0 | 1 | 14816 | 11.1 |
| 53 | 63.4 | 64.4 | 55 | 0.0 | 12.0 | 0 | 0 | 1 | 2 | 0 | 1 | 0 | 14816 | 3.7 |
| 75 | 2.5 | 3.5 | 35 | 20.8 | 31.5 | 5 | 50 | 0 | 0 | 0 | 0 | 0 | 26744 | 0.0 |
| 75 | 8.3 | 9.3 | 55 | 8.3 | 29.9 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 11642 | 0.0 |
| 75 | 3.7 | 4.7 | 35 | 0.0 | 12.0 | 9 | 50 | 0 | 0 | 0 | 0 | 0 | 12868 | 0.0 |
| 75 | 5.0 | 6.0 | 45 | 0.0 | 12.0 | 7 | 7 | 1 | 2 | 0 | 0 | 1 | 15584 | 3.5 |
| 75 | 7.2 | 8.2 | 45 | 0.0 | 12.0 | 10 | 16 | 0 | 0 | 0 | 0 | 0 | 14300 | 0.0 |

1. 1 mph = 1.6 km/hr
2. Slopes presented as horizontal run: 1 vertical rise
3. 1 ft = 0.3048 m
4. Intersections and driveways per mile include both directions of travel.

## Table 1 (con't) - Summary of All Analysis Sites for Median Crashes

resulted in some of the roadway segments being excluded from the study. For example, the site visit revealed that one route was a two lane, not a four lane roadway. In addition, there were ten crashes for which the crash reports could not be located, due to discrepancies in the report numbers provided by CARE. Since the crash characteristics could not be verified, these crashes were not included in the study. Since no construction or major maintenance contracts had been enacted at the crash sites, the physical characteristics of each site were assumed to be consistent for the entire five year time period.

**Two Way Left Turn Lane (TWLT)**

Twenty-six of the selected sites were five lane roadways with the center lane being a paved TWLT lane. Information on median width was not initially available resulting in the TWLT segments initially being characterized as divided arterials. The TWLT characteristic was discovered during the field visits. Rather than discard the data these sites were analyzed separately. Regression techniques including linear, quadratic, transformations, and multiple, failed to provide coefficient of determination values that exceeded 39.4%. It was determined, therefore, to conduct an analysis of the characteristics of data range. The data obtained for the TWLT sites are summarized in Table 2.

Table 2 indicates that 48 of the 72 head-on or sideswipe crashes occurred at TWLT sites. Analysis of the original crash reports established that driver action preceding the crash did not include intentionally crossing the median; such as attempting a left turn maneuver.

# Table 2 - Summary of TWLT Crashes

| Alabama Route | Milepoint Begin | Milepoint End | Speed (mph)[1] | Median Slope[2] | Median Width (ft)[3] | Per Mile[4] Inter. | Per Mile[4] Dwys | Median Crashes Freq. | Median Crashes Vehicles | Median Crashes PDO | Median Crashes Fatal | Median Crashes Injury | Average ADT | Crash Rate (100 MVM) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 212.8 | 213.8 | 45 | 0 | 12 | 5 | 17 | 1 | 2 | 0 | 0 | 1 | 22646 | 2.4 |
| 8 | 214.0 | 215.0 | 45 | 0 | 12 | 5 | 10 | 1 | 3 | 0 | 1 | 0 | 25832 | 2.1 |
| 16 | 15.0 | 16.0 | 45 | 0 | 12 | 4 | 40 | 2 | 4 | 1 | 0 | 1 | 28032 | 3.9 |
| 16 | 17.0 | 18.0 | 45 | 0 | 12 | 5 | 40 | 1 | 3 | 1 | 0 | 0 | 29830 | 1.8 |
| 16 | 18.0 | 19.0 | 45 | 0 | 12 | 5 | 50 | 0 | 0 | 0 | 0 | 0 | 32174 | 0.0 |
| 16 | 19.2 | 20.2 | 50 | 0 | 12 | 2 | 50 | 0 | 0 | 0 | 0 | 0 | 30468 | 0.0 |
| 38 | 1.9 | 2.9 | 55 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 71446 | 0.0 |
| 38 | 3.0 | 4.0 | 55 | 0 | 12 | 2 | 2 | 2 | 5 | 0 | 0 | 2 | 56690 | 1.9 |
| 38 | 4.2 | 5.2 | 55 | 0 | 12 | 2 | 0 | 1 | 2 | 1 | 0 | 0 | 68184 | 0.8 |
| 38 | 5.5 | 6.5 | 55 | 0 | 12 | 3 | 2 | 2 | 4 | 1 | 0 | 1 | 68184 | 1.6 |
| 38 | 6.8 | 7.8 | 55 | 0 | 12 | 4 | 5 | 2 | 4 | 1 | 0 | 1 | 45250 | 2.4 |
| 38 | 10.0 | 11.0 | 55 | 0 | 12 | 2 | 0 | 8 | 18 | 3 | 0 | 5 | 43998 | 10.0 |
| 42 | 10.9 | 11.9 | 50 | 0 | 12 | 1 | 6 | 3 | 6 | 2 | 0 | 1 | 17212 | 9.6 |
| 42 | 12.1 | 13.1 | 45 | 0 | 12 | 2 | 28 | 4 | 9 | 2 | 0 | 2 | 23726 | 9.2 |
| 42 | 13.1 | 14.1 | 45 | 0 | 12 | 0 | 17 | 1 | 2 | 0 | 0 | 1 | 23726 | 2.3 |
| 42 | 14.2 | 15.2 | 50 | 0 | 12 | 11 | 37 | 2 | 5 | 0 | 1 | 1 | 24758 | 4.4 |
| 42 | 15.3 | 16.3 | 50 | 0 | 12 | 5 | 30 | 2 | 4 | 0 | 0 | 2 | 24758 | 4.4 |
| 42 | 17.0 | 18.0 | 50 | 0 | 12 | 3 | 8 | 1 | 2 | 1 | 0 | 0 | 23186 | 2.4 |
| 53 | 57.1 | 58.1 | 55 | 0 | 12 | 1 | 5 | 6 | 13 | 1 | 1 | 4 | 12530 | 26.2 |
| 53 | 59.0 | 60.0 | 55 | 0 | 12 | 2 | 10 | 2 | 4 | 0 | 0 | 2 | 12530 | 8.7 |
| 53 | 60.0 | 61.0 | 55 | 0 | 12 | 3 | 9 | 2 | 4 | 2 | 0 | 0 | 13186 | 8.3 |
| 53 | 62.4 | 63.4 | 55 | 0 | 12 | 3 | 10 | 3 | 6 | 2 | 0 | 1 | 14816 | 11.1 |
| 53 | 63.4 | 64.4 | 55 | 0 | 12 | 0 | 0 | 1 | 2 | 0 | 1 | 0 | 14816 | 3.7 |
| 75 | 3.7 | 4.7 | 35 | 0 | 12 | 9 | 50 | 0 | 0 | 0 | 0 | 0 | 12868 | 0.0 |
| 75 | 5.0 | 6.0 | 45 | 0 | 12 | 7 | 7 | 1 | 2 | 0 | 0 | 1 | 15584 | 3.5 |
| 75 | 7.2 | 8.2 | 45 | 0 | 12 | 10 | 16 | 0 | 0 | 0 | 0 | 0 | 14300 | 0.0 |

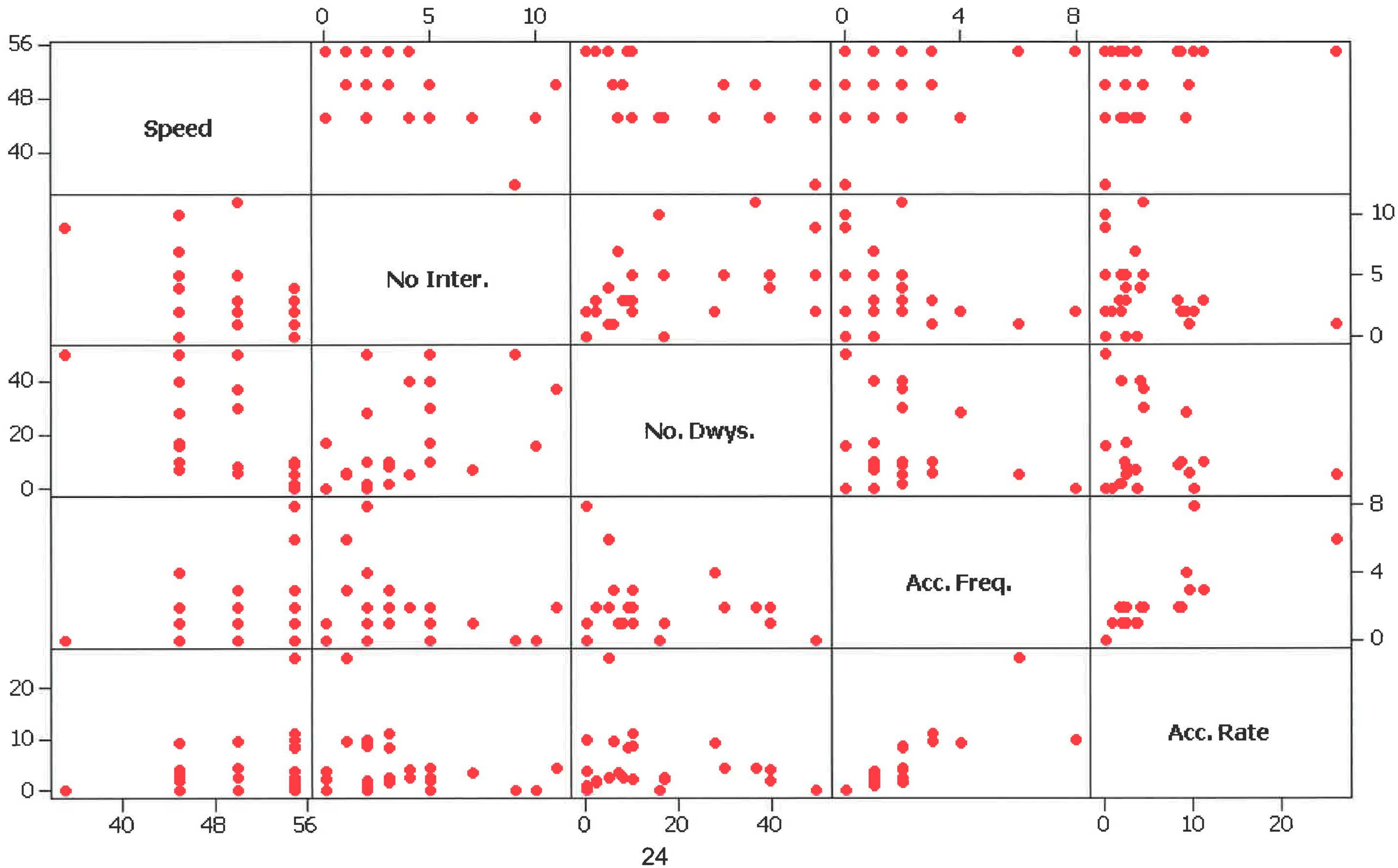
1. 1 mph = 1.6 km/hr
2. Slopes presented as horizontal run: 1 vertical rise
3. 1 ft = 0.3048 m
4. Intersections and driveways per mile include both directions of travel.

A matrix plot of the TWLT crash data, Figure 4 failed to reveal any correlation between crash frequency or crash rate and any independent variables. A matrix plot enables assessing the relationships among several pairs of variables at once by displaying an array of small scatter plots on a single graph. The axes for each matrix element are contained in the margins of each respective column and row. For example, Figure 4 indicates that the crash frequency varied from 0 to 8.

The interquartile (IQR) method was used to first identify data outliers for crash rate. The IQR is a measure of variability that is resistant to the effect of outliers. The median separates the data set into two equal parts so that 50% of the values exceed the median and 50% are smaller than the median. The lower and upper quartiles, along with the median, separate the data into four equal parts: 25% of all values are smaller than the lower quartile, 25% exceed the upper quartile, and 25% reside between each quartile and the median. The IQR is the difference between the upper and lower quartile. A data value more than 1.5 IQR from the nearest quartile is an outlier. Alabama route 53 from milepost (MP) 57.1 to 58.1 was removed from the data base prior to the IQR analysis. This roadway segment has a relatively low ADT of 12,530 but experienced 6 crashes; involving 13 vehicles, resulting in 1 fatality and 12 personal injuries. The subsequent rate of 43.7 crashes/100 MVM (160 MVKM) indicates that a crash investigation should be conducted on this segment to identify causation factors and to develop countermeasures.

The IQR analysis of the remaining 25 TWLT roadway segments is summarized in Table 3. A roadway segment that experiences crash rate values greater than 1.5 IQR from the upper quartile is considered as experiencing an abnormally high crash

# Figure 4 - Matrix Plot of TWLT Crash Rate and Frequency



experience. Analysis of both crash frequency and crash rate were conducted but the relatively small range of crash frequency did not result in meaningful IQR results. The IQR analysis of crash rate indicates that roadway segments with a crash rate exceeding 14.1 crashes/100 MVM (160 MVKM) should be investigated to determine causation factors and to develop remedial countermeasures.

Table 3 – IQR Analysis of TWLT Median Crashes

| Crash Variable | Number | Lower Quartile | Upper Quartile | IQR | Threshold Values | |
|---|---|---|---|---|---|---|
| | | | | | Analysis Period | Annual |
| Rate (100 MVM) | 25 | 1.20 | 6.35 | 5.15 | 14.08 | 14.08 |

When the IQR crash rate criteria is applied to the TWLT data of Table 2 no segment (other than Alabama route 53 from milepost (MP) 57.1 to 58.1) is sufficiently high to warrant a safety study. The IQR analysis of crash frequency provided trivial results because the range between the upper and lower quartile equaled one.

**Median Roadway Segments**

The remaining 26 analyzed sites, summarized in Table 4, were divided, four lane, partial control of access arterials with median widths varying from 23.5 ft (4.2 m) to 100.7 ft (30.7 m). A matrix plot of the median data is provided as Figure 5. This Figure does not indicate a discernable pattern between either crash frequency, or rate, with any of the independent variables.

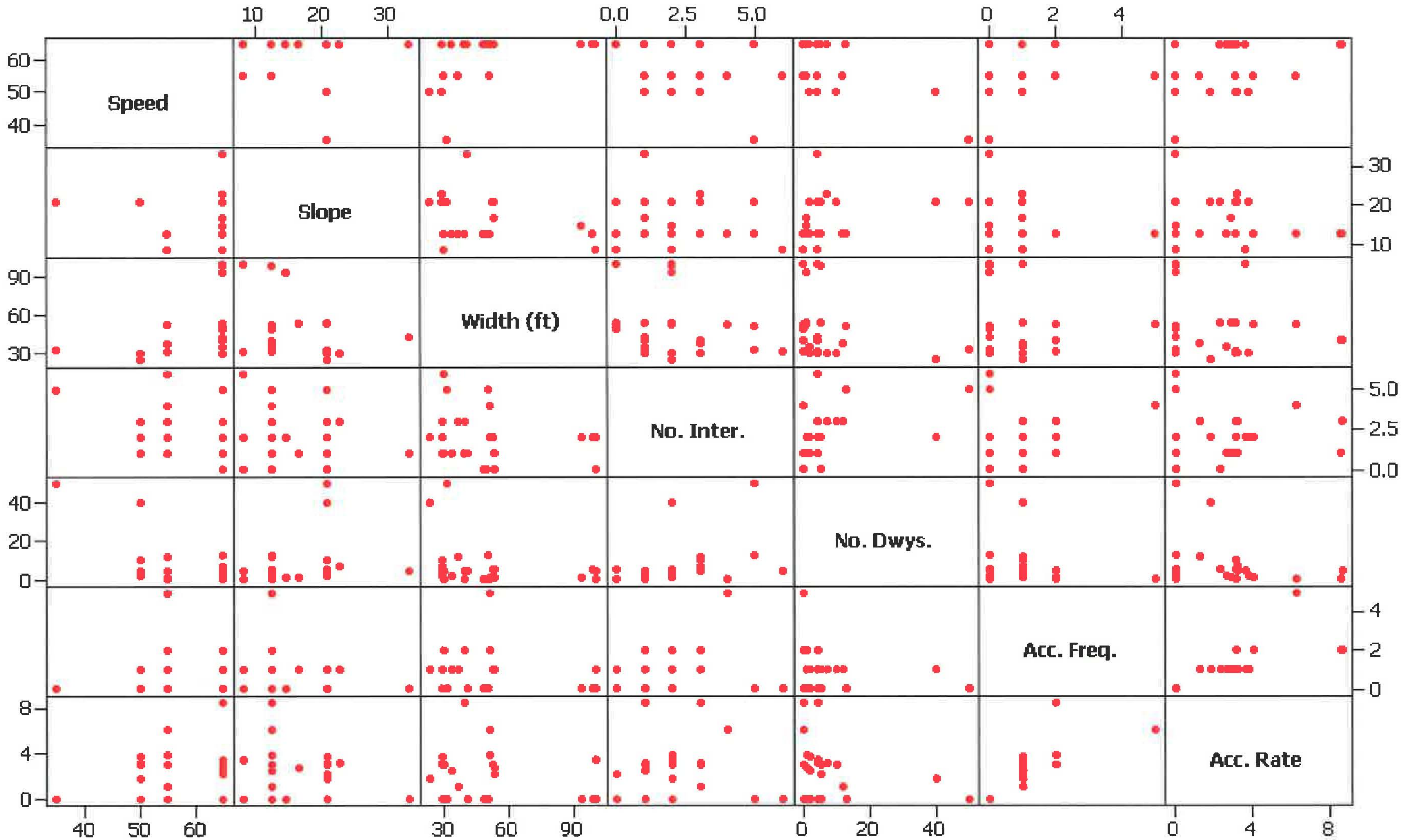
The Pearson correlation coefficients, summarized in Table 5, do not reveal any linear relationship. The Pearson product moment correlation coefficient measures the degree of linear relationship between two variables. The correlation coefficient assumes

## Table 4 - Summary of Median Crashes

| Alabama Route | Milepoint Begin | Milepoint End | Speed (mph)[1] | Median Slope[2] | Median Width (ft)[3] | Per Mile[4] Inter. | Per Mile[4] Dwys | Median Crashes Freq. | Median Crashes Vehicles | Median Crashes PDO | Median Crashes Fatal | Median Crashes Injury | Average ADT | Crash Rate (100 MVM) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 109 | 110 | 65 | 12.5 | 33.8 | 1 | 2 | 1 | 2 | 0 | 0 | 1 | 21244 | 2.6 |
| 1 | 118.74 | 119.74 | 65 | 16.7 | 53.4 | 1 | 1 | 1 | 2 | 1 | 0 | 0 | 18996 | 2.9 |
| 1 | 126.7 | 127.7 | 65 | 8.3 | 100.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15074 | 0.0 |
| 1 | 128.8 | 129.8 | 65 | 8.3 | 100.7 | 2 | 4 | 1 | 2 | 0 | 0 | 1 | 15074 | 3.6 |
| 1 | 132.6 | 133.6 | 65 | 14.6 | 94.2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 14572 | 0.0 |
| 8 | 122.9 | 123.9 | 65 | 33.3 | 41.2 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 13952 | 0.0 |
| 8 | 215 | 216 | 55 | 12.5 | 29.8 | 1 | 0 | 2 | 4 | 2 | 0 | 0 | 34854 | 3.1 |
| 13 | 13.4 | 14.4 | 50 | 20.8 | 28.9 | 3 | 10 | 1 | 2 | 1 | 0 | 0 | 17828 | 3.1 |
| 13 | 14.8 | 15.8 | 50 | 20.8 | 28.9 | 1 | 4 | 1 | 2 | 0 | 0 | 1 | 17302 | 3.2 |
| 13 | 17.5 | 18.5 | 50 | 20.8 | 28.9 | 2 | 2 | 1 | 2 | 0 | 0 | 1 | 14548 | 3.8 |
| 13 | 18.5 | 19.5 | 50 | 20.8 | 28.9 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 14548 | 0.0 |
| 13 | 23.2 | 24.2 | 65 | 12.5 | 50.8 | 5 | 13 | 0 | 0 | 0 | 0 | 0 | 12700 | 0.0 |
| 16 | 16 | 17 | 50 | 20.8 | 23.5 | 2 | 40 | 1 | 1 | 1 | 0 | 0 | 30970 | 1.8 |
| 38 | 8.4 | 9.4 | 55 | 12.5 | 36.7 | 3 | 12 | 1 | 2 | 0 | 0 | 1 | 43998 | 1.2 |
| 38 | 11.5 | 12.5 | 55 | 12.5 | 51.7 | 4 | 0 | 5 | 11 | 3 | 0 | 2 | 43998 | 6.2 |
| 38 | 12.5 | 13.5 | 55 | 12.5 | 51.7 | 2 | 1 | 2 | 4 | 1 | 0 | 1 | 27676 | 4.0 |
| 38 | 36.5 | 37.5 | 65 | 20.8 | 53.4 | 0 | 5 | 1 | 3 | 0 | 1 | 0 | 23346 | 2.3 |
| 38 | 39 | 40 | 65 | 22.9 | 29.2 | 3 | 7 | 1 | 2 | 0 | 0 | 1 | 17294 | 3.2 |
| 53 | 54.1 | 55.1 | 65 | 12.5 | 39.3 | 1 | 0 | 2 | 4 | 0 | 0 | 2 | 12824 | 8.5 |
| 53 | 55.7 | 56.7 | 65 | 12.5 | 39.3 | 3 | 4 | 2 | 4 | 0 | 1 | 1 | 12756 | 8.6 |
| 53 | 81.5 | 82.5 | 65 | 20.8 | 53.2 | 2 | 5 | 1 | 2 | 0 | 0 | 1 | 17778 | 3.1 |
| 53 | 90.8 | 91.8 | 65 | 12.5 | 48.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15150 | 0.0 |
| 53 | 97.5 | 98.5 | 65 | 12.5 | 49.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15800 | 0.0 |
| 53 | 103 | 104 | 65 | 12.5 | 99.2 | 2 | 5 | 0 | 0 | 0 | 0 | 0 | 16774 | 0.0 |
| 75 | 2.5 | 3.5 | 35 | 20.8 | 31.5 | 5 | 50 | 0 | 0 | 0 | 0 | 0 | 26744 | 0.0 |
| 75 | 8.3 | 9.3 | 55 | 8.3 | 29.9 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 11642 | 0.0 |

1. 1 mph = 1.6 km/hr
2. Slopes presented as horizontal run: 1 vertical rise
3. 1 ft = 0.3048 m
4. Intersections and driveways per mile include both directions of travel.

# Figure 5 - Matrix Plot of Median Crash Rate and Frequency.



a value between -1 and +1. If one variable tends to increase as the other decreases, the correlation coefficient is negative. Conversely, if the two variables tend to increase together the correlation coefficient is positive. The correlation coefficients do indicate that increases in all dependent variables, with the exception of speed with crash rate, results in a decrease in crash rate and frequency. The data did not, however, indicate any threshold values.

Table 5 - Pearson Correlation Coefficients for Median Arterials

| Variable | Speed | Slope | Width | Intersection Per Mile | Driveways Per Mile |
|---|---|---|---|---|---|
| Rate (100 MVM) | 0.8 | -.11 | -.20 | -.01 | -.22 |
| Frequency | -0.8 | -.15 | -.17 | -.43 | -.19 |

Regression techniques including linear, quadratic, transformations, and multiple failed to provide coefficient of determination values that exceeded 23.9%. It was decided, therefore, to conduct the analysis of median crashes in the same manner as used for the TWLT crashes.

The IQR analysis of the 26 median roadway segments is summarized in Table 6. Analysis of both crash frequency and crash rate were conducted but, as with the TWLT analysis, the relatively small range of crash frequency did not result in meaningful IQR results. The IQR analysis of crash rate indicates that roadway segments with a crash rate exceeding 8.3 crashes/100 MVM (160 MVKM) should be investigated to determine causation factors and to develop remedial countermeasures. This criteria results in two consecutive segments of Alabama route 53, from milepoint 54.1 through 56.7, which should have a safety analysis conducted. The IQR analysis of crash frequency provided trivial results because the range between the upper and lower quartile equaled one.

Table 6. – IQR Analysis of Median Crashes

| Crash Variable | Number | Lower Quartile | Upper Quartile | IQR | Threshold Values | |
|---|---|---|---|---|---|---|
| | | | | | Analysis Period | Annual |
| Rate (100 MVM) | 26 | 0.0 | 3.30 | 3.30 | 8.25 | 8.25 |

## 4. CONCLUSIONS AND RECOMMENDATIONS

A strong correlation could not be established between cross median crash frequency or crash rate with site data. Site specific crash experience was determined as being the best factor for identifying segments that should be investigated for remedial countermeasures. Determining the appropriate countermeasure(s) for divided arterials with partial access control differs from considerations employed for full control of access arterials; such as freeways.

TWLT arterials do not have the installation of a median barrier as a viable option. Countermeasures which may be appropriate for TWLT cross median crashes can include textured pavement marking or rumble strips along the left edge of the traveled way or the installation of a raised median to separate traffic and regulate left turn movements. Driveway frequency, placement, and design can also be analyzed to determine if relocating or consolidating driveways can reduce crash potential.

If median barriers are considered as a countermeasure, for divided arterials with partial access control, then the number of median openings will increase barrier cost, and effectiveness. For example each opening will add approximately $4000 for terminals, depending on barrier type, while simultaneously leaving a barrier gap for vehicle intrusion.

With these considerations in mind the analyses indicated that TWLT arterials should be investigated for cross median countermeasures when crash rate exceeds 14.1 median crashes per 100 MVM (160 MVKM) travel. Similar considerations should be applied on divided arterials with partial access control when the cross median crash rate exceeds 8.3 median crashes per 100 MVM (160 MVKM) travel.

It was not the intent of the study to perform analyses on TWLT sites. They were erroneously identified as divided arterials and not recognized as TWLT segments until the field investigation. By this time the crashes had been identified by CARE and requests for hard copies of the original crash reports submitted. Safety investigations, and the identification of potentially hazardous locations, would be enhanced if State wide files of geometric characteristics existed.

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12. Ryan, Barbara,.Joiner, Brian L., and Cryer, Jonathon, *MINITAB Handbook* – Fifth Edition, Thompson – Brooks/Cole, Belmont, CA, 2005.
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Appendix A - Southeastern State Survey

## Median Safety Barrier Guidelines Survey

Name: ______________________________ Phone:________________

State Agency:______________________________________________

Auburn University through its Highway Research Center is conducting a study for the Alabama Department of Transportation on cross-median crashes on high speed (>45 mph) bifurcated arterials; excluding the interstate system. We are soliciting information from your State related to any cross-median crash problems on your high speed, non-Interstate, bifurcated highways. Your knowledge and experience will assist in addressing the same problems in Alabama. Do not hesitate to contact me at 334-844-6245 or paulkrw@auburn.edu if you have any questions concerning this survey.

1. What guidelines are used in determining median safety barrier installations on high speed bifurcated arterials; excluding Interstate?

   ☐ Roadside Design Guide
   ☐ State guidelines different from Roadside Design Guide
   (please provide a copy or information on how to obtain one)
   ☐ ADT (Threshold: _______________)
   ☐ % Trucks (Threshold: _______________)

2. If State guidelines are used, was a study conducted to develop them?

   ☐ No (please provide any information on how they were developed)
   ☐ Yes (please provide a copy or information on how to obtain one)

3. Are there any median safety barrier installations in your state that were installed because of cross-median crash history and not the guidelines?

   ☐ Yes ☐ No

4. If Yes, please provide roadway route and mileposts identifying the installation(s) and, if available, information about operational and site characteristics (ADT, % trucks, median width and slopes) and type of barrier installed on the page provided.

## Appendix A - (continued)

| Route | Milepost | | Barrier Type | ADT | % Trucks | Median Width (ft) | Median Slope (V:H) |
|---|---|---|---|---|---|---|---|
| | Beginning | Ending | | | | | |
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# Appendix B.1 - Results of New Jersey Survey

**Alabama**

*We have installed concrete median barrier and double sided guardrail on the interstate in conjunction with lane additions in the median. We have used the concrete barrier when the entire median is being enclosed and recently installed a double sided W beam guardrail where we added lanes but did not completely enclose (pave) the median. After the lane additions, an approx. 40 foot median remained with 12 foot shoulders (10 ft paved) and 16 foot grassed ditch. We also installed a cable barrier on a section of I-10 that was known to have frequent cross median accidents. It has a 54 ft median.*

*Don Arkle*

**Arizona**

*Arizona began looking at the need for median barrier for medians wider than the AASHTO 30' warrant due to several median crossover accidents on the Phoenix urban freeway system in 1999. Our predominant median width is 46' which allows for the future median lanes with shoulders and a concrete median barrier when programming allows. We studied various alternatives and decided to utilize the 3-strand cable median barrier as the interim solution since it is a more forgiving barrier than the other alternates considered.*

*We developed a draft policy for urban freeways that considers the use of median barrier for medians 50' and less and also considers median barriers up to 75' when there are 3 or more lanes in each direction. We have installed 100+ miles of cable barrier in the Phoenix urban area and we average approximately 50 hits per month. We have a maintenance contract that costs about $1M per year.*

*Terry H. Otterness, PE*

**Florida**

*The Florida Department of Transportation presently installs Test Level-3 barriers per the requirements outlined in the attached table below.*

**2.2 Medians[1]**

**Table 2.2.1 Median Widths**

| **MEDIAN WIDTHS (FEET)** | |
|---|---|
| **TYPE FACILITY** | **WIDTH** |
| FREEWAYS | |
| Interstate, Without Barrier | 64 [1] |
| Other Freeways, Without Barrier--- | -- |
| Design Speed =60 mph | 60 |
| Design Speed < 60 mph | 40 |
| All, With Barrier, All Design Speeds 26 2 | 26 [2] |
| ARTERIAL AND COLLECTORS | |
| Design Speed > 45 mph | 40 [5] |
| Design Speed =45 mph | 22 [3] |
| Paved And Painted For Left Turns | 12 [4] |

Median width is the distance between the inside (median) edge of the travel lane of each roadway.

1. 88 ft. when future lanes planned.
2. Based on 2 ft. median barrier and 12 ft. shoulder.
3. On reconstruction projects where existing curb locations are fixed due to severe right of way constraints, the minimum width may be reduced to 19.5 ft. for design speeds = 45 mph, and to 15.5 ft. for design speeds = 40 mph.
4. Restricted to 5-lane sections with design speeds = 40 mph. On reconstruction projects where existing curb locations are fixed due to severe right of way constraints, the minimum width may be reduced to 10 ft. These flush medians are to include sections of raised or restrictive median for pedestrian refuge and to conform to ***Section 2.2.2*** of this volume and the Access Management Rules.
5. Curb sections with design speed of 50 mph which are posted at 45 mph or less may be 22 ft.

[1] Florida Department of Transportation, *Plans Preparation Manual,* Volume 1 - English, (January 2003), p. 2-44

*Recently, the Department reviewed 134 randomly selected median crashes and summarized the following:*

*Of the 134 crashes,*

- *2% of the crashes was the crossing vehicle a truck (any vehicle larger than a passenger car).*
- *19% either had alcohol involvement or was suspected of having alcohol involved.*
- *The speed differential data in showed that 78% of the crashes occurred when the crossing vehicle's estimated speed was within 5 mph of the posted speed.*
- *Good weather prevailed in 75% of all crashes with 83% of those being attributed to driver error and avoidance maneuvers.*
- *Of the 25% that occurred during adverse weather, 52% were attributed to driver error and avoidance maneuvers. The remaining were attributed to hydroplaning.*
- *The evaluation of the crash location showed that 62% of all the crashes occurred within a half-mile of ramp termini and 82% within one mile.*

*The Department is pursuing providing test level -3 barriers within 1 mile (each direction) of ramp termini.*

*Thomas R. Bane, PE*

**Georgia**

*In Georgia, typically our rural interstates have 64' grass medians from edge of travel lane to edge of travel lane. Typically these do not have any type of barrier.*

*When the medians are less than 44', we do require a positive barrier. Normally it is double faced guardrail.*

*For 44' to 64', a positive barier is not required, but there have been sections that we determined it would be appropriate to install positive barrier and we normally used double faced guardrail.*

*David Studstill*

**Hawaii**

Hawaii DOT's policy is to follow the Roadside Design Guide for evaluating the need for median barrier. We use concrete New Jersey - shape barrier for most of our freeways.

*Julius B. Fronda, PE*

# Appendix B - Results of New Jersey Survey

**Illinois**

*We had a major accident involving a Salvation Army bus that resulted in ten fatalities. This accident was in an area with a 40 foot median. We have been looking at our accidents history involving median crossover accidents. I believe California has a policy that if 3 or more median crossover accidents occur in a mile segment of Interstate in a five year period that a barrier system must be installed regardless of what the Roadside Design Guide warrants. We are considering a move in that same direction.*

*Mike L. Hine*

**Iowa**

*We use the warrants in the AASHTO Roadside Design Guide for some very general guidance but the decision is really made on a site-specific case-by-case basis.*

*In the past we have not used a lot of median barrier other than concrete barrier on some urban and suburban freeways. However, we have an interesting project that will be let in February to install 3.5 miles of Brifen Wire Rope Safety Barrier along Interstate 35 just north of Des Moines (our largest urban area). We feel this system shows promise as part of the solution to this problem.*

*Will Stein*

*From the standpoint of recommendations in the AASHTO Roadside Design Guide (RDG), the content regarding median barrier warrants is little changed between the 2002 and 1996 versions. We have added a bit on information regarding Florida and California practices. Other than those few additional comments, the Task Force has been awaiting the completion of NCHRP Project 17-14 before considering substantial changes to AASHTO guidance for median barrier placement.*

*Project 17-14 is unfortunately around a year from completion. This project has been delayed for a number of reasons, but is back on track for completion. One task recently added to 17-14 is a state-of-the-practice survey of the state DOTs in the next few months. One reason for undertaking this survey is that many states have struggled with this issue since 17-14 began back in the mid-1990's, and many have undertaken median barrier retrofit projects as a result. What actions the states have taken independently and the results of those actions hopefully will be valuable information we can use to establish future guidelines.*

*David L. Little, PE*

**Kansas**

*Kansas is fortunate that we have not experienced a high incidence of median crossover accidents, particularly those of 60 ft. width. Therefore, we do not have remedies to suggest.*

*For narrower medians, we follow the Roadside Design Guide for barrier warrants.*

*James O. Brewer*

**Kentucky**

*Kentucky typically does not protect in medians of 30' or more. Most of our interstate medians are 60'.*

*David Kratt*

**Louisiana**

*Louisiana has many miles of rural and suburban interstate with median widths near this value of 60 foot. The only time we are doing any retrofit of median barrier is when we add lanes in the median for capacity improvement. We have had several crossover crashes but never 4 in one day.*

*Kent Israel*

**Maryland**

*Maryland also has experienced some recent tragic fatal accidents caused by median cross-overs. Although we defer to the AASTHTO Roadside Design Guide's 30 ft clear zone to determine minimum median barrier warrants, we generally call for median barriers on medians less than or equal to 50 ft width on all high speed roadways (note: this is for new construction projects and does not necessarily apply to all existing systems). Because of recent incidents, we revisited this issue and implemented a new guideline for median barrier placement on fully controlled access highways only. The following recommendations for median barrier placement were developed for these guidelines:*

- *Medians less than or equal to 30 ft where ADT is greater than 0*
- *Medians less than or equal to 50 ft where ADT is greater than 40,000*
- *Medians less than or equal to 75 ft where ADT is greater than 80,000*

*Norie A. Calvert*

**Massachusetts**

*Massachusetts does not yet use this barrier and does not put barrier in wide medians, but is considering the cable guardrail solution for wide medians.*

*Stanley Wood*

**Minnesota**

*We are in the middle of a study of fatal median crossover crashes. Have examined police reports for all appropriate crashes, and found that we have had 86 fatal crashes (with 102 fatalities) in the ten year 1992 to 2001 time period. We are now gathering median width data, and expect to come up with a proposal to install this in appropriate areas.*

*Lauren Hill, PE*

**Mississippi**

*Mississippi follows the Roadside Design Guide barrier guidelines. Our normal median width is 64 feet which does not warrant barrier. We have had some experience with cross-over crashes. We have placed median barrier at specific sites due to the crash history. We placed the barrier 10 feet from the travelway or at the edge of the 10 foot shoulder. This shoulder has a 10:1 slope or flatter.*

*Steven W. Reeves*

# Appendix B.1 - Results of New Jersey Survey

**Montana**

*MDT's cross median accident experience where median widths of 60 ft or more exist has been quite limited. We have dealt with a couple situations on a case-by case basis where median widths were less than 60 ft. In one of those we had intermittent sections of 10ft flush median over a 30 mile section of Interstate that was originally constructed with no barrier. (Design decisions used guidelines of the old Barrier Guide/Yellow Book) This was a mountain pass area with lots of curves and we used 42 inch Concrete barrier. Now we're being asked to look at the effect this has on endangered species.*

*Carl S. Peil*

**Missouri**

*MoDOT has recently compiled data for a court case. The results of the study are found in the attachments below. The data represents approximately half the installation of three-strand guard cable in Missouri. It also represents the oldest sections. This safety device is fairly new to MoDOT and we do not have a lot of data available for a before/after study.*

*The study shows a reduction in cross-median crashes. It also shows a significant increase in total crashes. The median is used as a recovery zone. With the installation of the safety device, we have introduced a fixed object that will be hit. Vehicles that entered the median before had a better opportunity to recover and drive away. Now, those vehicles are hitting the cable and increasing the overall crash rate. Three-strand guard cable creates a situation much like a traffic signal. Total crashes will increase but the overall severity of the crashes should reduce. As a reminder, three-strand cable installations will not do much to improve the crash situation you are experiencing where heavy trucks are crossing the median.*

*John Schaefer*

## Franklin County
## 3-Strand Guard Cable Study

Traffic Operations was given the task to study 3-strand guard cable for IS 44 in Franklin County. Of 34 miles of Interstate in Franklin County, nearly 13 miles incorporate 3-strand guard cable as a median treatment. Portions of the remaining 21 miles utilize either concrete median barriers or median widths greater than 60 feet. A map of the 3-strand guard cable locations has been included. The study spanned 1997 through 2001. The data included two years before installation and two years after installation.

Data was reviewed for locations where the cable was installed as well as locations where the cable was not installed. Each crash was classified as either enter median only, enter median & struck cable, crossed-median only (locations without cable), or struck cable & crossed-median (the vehicle struck the median cable and continued across the median into the opposing lanes of travel).

**"After" Cable Installed**

At locations where the cable was installed, cross-median crashes reduced nearly 2/3 (33 before, 12 after). Fatal crossed-median crashes reduced by 2/3 as well (3 before, 1 after). A reduction of only two fatal crashes may not be statistically feasible to be considered significant. Injury cross-median crashes reduced 50% (13 before, 6 after) and Property Damage Only (PDO) cross-median crashes reduced 70% (17 before, 5 after).

The Enter Median Only crashes reduced in the "after" time period. This is expected since there is less recovery area before the car will strike the median cable installations. In general, there was a 45% reduction in the Enter Median Only crashes. There were 129 instances were a crash involved a vehicle striking the cable, preventing the vehicle from crossing the median. For comparison, there were only 54 crashes reported in the "before" years for Enter Median Only crashes, less than half. Combining Enter Median Only crashes with Struck Cable Only crashes for the "after" installation condition, the totals increased from 54 to 159 crashes. The influence of cable barriers nearly triple the number of reported median only (enter median only & struck cable) crashes. The number of median only (enter median only & struck cable) injury crashes increased over 150% and the number of median only (enter median only & struck cable) PDO crashes increased nearly 400%.

**"After" No Cable Installed**
Overall, median crashes reduced where the cables were not installed (82 before, 58 after). The total number of cross-median crashes reduced as well (33 before, 25 after). Cross-median fatal crashes increased (2 before, 4 after) but the total number of combined crossed-median fatal and injury crashes were nearly the same (21 before, 16 after). According to the data, there were fewer reported cases of median crashes where there was no cable installed.

**Conclusions**
The AADT for IS 44 through Franklin County has generally stayed the same for both the before and after studies with a difference of only 300 vehicles a day. Although the crash rates remain below the statewide average for similar facilities, the rates have increased since the installation of cable. The installation of median guard cable was one of the factors for the increased crash rates.

In conclusion, where the cable was installed, the cross-median crashes reduced 66%, but the total number of median crashes doubled. The total number of cross-median injury crashes reduced 50%, but the total number of median injury crashes increased. Cable barriers decrease the chance for cross-median crashes; however, cross-median crashes will still occur. Based on this study, when cross-median crashes occur, there is a 50% chance the crash will have an injury or fatality.

## Nebraska

*Nebraska is in the process of designing for the reconstruction and expansion of Interstate 80 between Lincoln and Omaha. This probably doesn't apply to your situation if you are trying to retrofit an existing system, but you may find it useful. The existing median width is 40' for 11.5 miles, 64' for 30.5 miles and varies from 64' to over 300' for 1.5 miles. The crossover accident rate for the 40' wide median has been about twice as high as the rate for the 64' median.*

*We studied median widths of 40', 52', 64' and 76' without any type of median barrier, 40' and 52' medians with a flexible barrier system in the middle of the median and a 28' wide paved median with a concrete median barrier. AASHTO's Roadside program was used to estimate the crash costs to society for each option. Other issues considered included: traffic phasing during construction, right-of- way impacts, maintenance, overall construction cost and several other miscellaneous issues.*

*The 76' depressed median was selected for most of the corridor. The 28' wide paved median with median barrier will be used for a 5 mile urban stretch due to high right-of-way costs and a sensitive environmental area.*

*Eric Dixon, PE*

**Nevada**

*Due to a number of cross-median fatalities in the last 4 years, we are now developing a new policy. The following has been proposed to our Front Office:*

*Adopt the California warrants high volume freeways, which are:*

*The traffic volume/median width warrant, i.e. areas under 20,000 ADT or with medians over 75 feet will not fall within this warrant, and would therefore not be considered for cross-median protection. A crash warrant of 0.50 cross-median crashes per mile per year of any crash severity, or 0.12 fatal cross-median crashes per mile per year would warrant protection. The rate calculation requires a minimum of three accidents occurring within a five-year period.*

*In the past 4 years we have provided cross-median protection on two high volume freeway facilities in response to fatal accidents. In one case we used a combination of concrete barrier and cable barrier. In the other, we used thrie beam guardrail on each shoulder of the median because of high mast lighting in the median.*

*Wayne Kinder*

**New Hampshire**

NHDOT can understand the gravity of your issue. We customarily consider that installation of median barrier for medians of less than 50 feet.

*A number of years back (1991), we did a internal study utilizing ROADSIDE program out of the 1989 RDG. This study analyzed collisions frequencies for median widths of 26 ft., 40 ft., 50 ft., 60 ft. and 70 ft. (with and without median barrier) for 40,000 ADT. The purpose of the study was to support our EIS study for median width on the NH Rte 101 facility (an important State east–west highway). The study concluded (given the limited study variables) that a 50 foot median is where the trade-off becomes apparent for barrier versus no barrier based upon the cost-benefit analysis. Outside of this limited evaluation, we customarily utilized the "RDG" for consideration of barrier needs on selected median widths. In new installations, we will used a 350 median barrier and give consideration for concrete barrier if traffic conditions (% trucks, cross-over history, etc.) warrants additional protection.*

*Keith Cota*

**New Mexico**

*Generally, we follow guidance provided in the Roadside Design Guide (RDS), specifically Figure 6.1, on page 6-2. However, where there is documented evidence of more than usual occurrence of cross-over crashes, we have installed continuous concrete wall barrier even though the RDS indicates it is optional or not normally considered.*

*Bob Bracher*

**New York**

*New York State has averaged around one fatal accident per year from median crossovers.*

*We have been considering increasing our width warrant to 75 feet. New York State DOT owns and maintains 265 miles of high-speed highways that have both ADTs of 20,000 or greater and median widths of 37 feet or greater. Only about a fourth (around sixty miles) of the highways would need to have barrier added under the California warrant. On these wider, traversable medians, it would be our preference to install cable barrier in the middle of wide medians since it is effective* *at engaging vehicles, forgiving for high angle impacts, and more economical and less visually obtrusive than other barriers. Its susceptibility to damage is outweighed by the fact that a central location in a median would keep it well-removed from brush hits and snowplows.*

*At present, we are at an impasse as NYSDOT has parties wishing to expand the width warrant and parties arguing that our fatality rates do not justify making a change. Unless our accident cross-median rate increases, it is unlikely that we will increase our width warrant.*

*Rick Wilder, PE*

**North Carolina**

*North Carolina provides positive median protection on all new and reconstructed freeways with median widths of 70 feet or less. We are in the 4th year of a 5 year program to install guardrail protection on all existing freeways with median widths of 70 feet or less.*

*Len Hill*

*In order to improve safety by preventing cross median accidents, North Carolina incorporates median guardrail on all freeway projects with median widths of 70 feet or less. This includes all new construction, reconstruction, or resurfacing projects.*

*In 1999 North Carolina started a initiative to install median guardrail on the existing interstates and freeways throughout the state. The program includes 991.9 miles of interstate and freeway facilities. 800 miles have been complete or let to contract.*

*Two types of guardrail are predominately used: cable guiderail or strong post steel beam guardrail.*

*Typical Placement in Various Median Widths:*

*36 feet:* *typically use two rows of strong post steel beam guardrail. (Assuming median slopes are steeper than 6:1), guardrail is placed on the shoulder where slopes are 10:1 or flatter,*

*46 feet:* *one line of cable guiderail (approximately 4 feet from the centerline of the ditch) if median slopes are 6:1 or flatter, two lines of strong post steel beam guardrail if median slopes are steeper than 6:1, guardrail is placed on the shoulder where slopes are 10:1 or flatter,*

*60 feet and above:* *one line of cable guiderail placed approximately 4 feet from the center of the ditch.*

*Concrete median barrier is used for narrow shoulders where the entire median is paved.*

*Jay A. Bennett, PE*

**Ohio**

*Ohio DOT has a very similar experience to that of Wisconsin. We had a rash of crossover crashes on I-75 north of Cincinnati and have relented to use the Brifen Cable in a 12 mile stretch. That project is under construction and is scheduled for completion in March.*

*The accidents caused 12 fatalities in 10 months ending earlier this year. The section of interstate is a high volume 6 lane freeway with a 60 ft. median and otherwise very good geometrics. When the accident reports were reviewed, we could find no commonality in the accidents. I've been told the highway had no previous fatals in this stretch for its 40 year life.*

*This project has sparked interest in other ODOT districts, but as of yet we have not had any other formal requests to install cable.*

*ODOT continues to use the AASHTO median barrier warrants and currently have no plans* *to change. However, we are staying abreast of the latest research.*

*Dean Focke*

**Oklahoma**

*We have in the last 5 or 6 years experienced what appears to be a dramatic increase in median crossover accidents. I have not noted that trucks were contributing to a substantial number of these types of accidents in Oklahoma. We had one new facility that was built as a parkway along the shoreline of a lake in Oklahoma City, it was six lanes divided and designed to be an aesthetic facility. The median was I think 46' in width, no center bridge piers, no overhead sign structures, a really award winning design. We began to experience problems with crossover accidents and ended up with I think 9 fatalities during a 3 year period and the pressure was intense to do something. The contributing factors in the accidents were speed and aggressive driving and efforts at increased enforcement had minimal success. We ran cost figures for installing concrete median barrier the length of the parkway which was about 5.5 miles and that number was $11.3 million based on completely filling and surfacing the center median. We became aware of a cable restraint system called the Brifen Wire Rope Safety Fence which was being used in Europe. It was manufactured in England and was not being distributed in the U.S. We ended up getting FHWA approval to do this system as an experimental project and installed it for about $1.3 million on the entire 5.5 miles. Since being installed this system has reportedly been hit more than 100 times and no vehicles have crossed the median. It is a four cable system similar to cable guardrail except the cables are pre-stretched and in tension. It is mounted on light weight metal posts that yield on impact and the cable stays operational due to the tension. It has been very effective however it has not been hit by a truck to my knowledge. Their video tapes of crash testing show truck impacts but the trucks are different than those seen on U.S. highways. I have been very impressed with this system and I understand it is being marketed in the U.S. now. The system itself is compliant with NCHRP 350 but I don't know if the anchor system has been approved. We protected ours with sand barrels. I don't have any ideas about the effectiveness with trucks and the roadway we have it installed on probably has less than 1 % truck traffic.*

*Bruce E. Taylor*

**Oregon**

*Currently our minimum width for a separated highway is 75 feet fog to fog. We have, in the past placed longitudinal berms in that median area, but now that practice is stopped. Any median with less than 75 feet fog to fog receives a positive barrier. After investigation of each unique site, the barrier could range from 3-cable rail to our Tall "F" shape precast concrete barrier. If there is no room for deflection we would also consider a cast-in-place "F" shape.*

*Daniel MacDonald*

**Pennsylvania**

*In PA, our Design Manual is modeled after the AASHTO criteria for barrier warrants. Anything else is made on a site specific case-by-case basis (not much proactive stuff done in the past).*

*We recently completed an Interstate/Expressway Median Safety Study in PA and the only statistically significant finding was that cross median crashes were more likely to occur within 800 feet downstream of an interchange on-ramp (measured from the end of the acceleration lane or taper); I have heard other states express similar findings (i.e higher probability within an interchange area).*

*As you know, we have a similar recent accident experience on I-95 (60 foot grass median) in Bucks County north of Phila. We will be looking at this for potential countermeasures.*

*James P. Tenaglia, PE*

**Puerto Rico**

*Puerto Rico follows the Roadside Design Guide for median treatment.*

*Javier Ramos*

**Rhode Island**

*Rhode Island has had a few of these types of accidents but , mostly on narrow median arterials with speeds around 50 MPH (or greater). Our informal policy is to provide positive barrier protection according to the Roadside Design Guide on all medians less than 30 Ft. wide. On roads with medians over 30 Ft. we usually don't use any kind of barrier unless there is an obvious geometric, operational or accident history problem.*

*Mike Bennett*

**South Dakota**

*South Dakota is like Wyoming for treatment.*

*Joel W. Gengler*

**Utah**

*Utah has installed concrete barrier in those areas which have exhibited an accident history with median crossovers. Most of these areas had cable initially in the median and was then upgraded to the concrete barrier.*

*Jason Davis, PE*

**Vermont**

*Vermont has not experienced any real problems with median cross over accidents. Perhaps this is because many of our divided highways have separate vertical and horizontal alignments for each barrel, thereby creating a variable and often wide, wooded median. On one two mile section we did install concrete barrier where the median was only about 20 feet wide, but this was to replace the original steel beam guardrail, installed when the interstate was first constructed.*

*Bob Shattuck, PE*

**Virginia**

*VDOT addressed this in Greensville County on I-95 where we had median widths less than 40' several years ago (FHWA is now looking at 60' as the desirable, safer median width) by installing strong post guardrails along the highest shoulder and added a rail element on the back side of the guardrail run to eliminate a vehicle from impacting or snagging on the posts from the backside in the opposing direction. The Road Design Guide shows where to install guardrails on median shoulders having varying heights.*

*Steve D. Edwards*

*I am not aware of any recent accidents involving trucks crossing a wide median on our Interstate highways. However if there is such a case we will deal with it on a case by case basis and make necessary modifications to prevent it from happening again. VDOT guardrail/median barrier selection parallels the suggested guidelines published in AASHTO,s Roadside Design Guide (Figure 6-1, Page 6-2).*

*Mohammad Mirshahi, PE*

**Washington**

*I will refer to a couple of studies, the Washington State Department of Transportation (WSDOT) has participated in. WSDOT participated in a study titled "Evaluating Median Crossover Likelihoods with Clustered Accident Counts" (Shankar, Albin, Milton, Mannering). This study was published as Transportation Research Record 1635 and focused on modeling processes and factors affecting median crossover frequencies. A second study conducted by WSDOT titled "Median Treatment Study of Washington State Highways" (Glad, Albin, MacIntosh, Olson) evaluated accident history and benefit cost thresholds for barrier treatments. This study is available on-line at http://www.wsdot.wa.gov/eesc/design/policy/pdf/MedianTreatmentStudy.pdf As a result of this study, policy was implemented stating, "Provide median barrier on full access control, multilane highways with median widths of 50' or less and posted speeds of 45 mph or more. Consider median barrier on highway with wider medians or lower posted speeds when there is a history of cross median accidents." Additional guidance is offered in our Design Manual regarding shoulder widths and barrier selection. Let me know if you want more information on this.*

*We are also reviewing the accident data used in our study to determine if truck involvement is readily available.*

*Dave Olson*

**West Virginia**

*West Virginia Division of Highways uses the Roadside Design Guide for determining whether a barrier is necessary. Recently we have placed a cable guardrail system on a 40' median at a location on I-81 and at a location on I-64. These were locations where the public raised safety issues. Neither location had serious accident rates related to mediancrossover accidents.*

*Randy Epperly*

**Wisconsin**

*Wisconsin has experienced recent median cross-over crashes with resulting deaths which have increased our interest in median barrier treatments. One drunk driver, cross-over crash which killed two young children on I-43 north of Milwaukee generated media and political reaction and lead to installation of 20,600' of three strand cable guard in the center of a 64' wide median. However, our standard median barrier policy has been to follow the Roadway Design Guide. We are trying to defend the case for some sort of positive barrier for any median width on new construction of less than 60'. We have noted with interest more restrictive guidance being implemented by some states and have decided to join the states contributing to NCHRP project 17-14 in the hope of gaining a national review and then updated guidance for median width and barrier treatments.*

*John Haverberg*

**Wyoming**

*Wyoming basically follows the roadside design guidelines unless a steep grade is involved or accident experience justifies otherwise.*

*Paul Bercich*

Appendix C - Alabama Department of Transportation Division Survey

## ALDOT Division Median Safety Barrier Survey

Name: __________________ Division: _______ Phone:____________

Auburn University through its Highway Research Center is conducting a study for ALDOT on cross-median crashes on high speed (>45 mph) bifurcated arterials; excluding the Interstate system. Information provided by your Division on the location and possible crash prone segments of these arterials is necessary for the success of this project. Do not hesitate to contact me at 334-844-6245 or paulkrw@auburn.edu if you have any questions concerning this survey.

1. Are there any high speed (>50 mph) bifurcated arterial segments in your Division that have cross-median crashes?

   ☐ Yes ☐ No

   If Yes, please provide roadway route and mileposts identifying the segments and, if available, information about operational and site characteristics (ADT, % trucks, median width and slopes) on the page provided.

2. Are there any median safety barrier installations on high speed bifurcated arterials in your Division that were installed because of cross-median crash history?

   ☐ Yes ☐ No

   If Yes, please provide roadway route and mileposts identifying the installation(s) and, if available, information about operational and site characteristics (ADT, % trucks, median width and slopes) and type of barrier installed on the page provided.

3. Have any studies concerning median safety barriers been conducted by your Division?

   ☐ Yes ☐ No

   Please provide a copy or information on how to obtain one.

# Appendix C - Alabama Department of Transportation Division Survey

| Route | Milepost | | Barrier Type | ADT | % Trucks | Median Width (ft) | Median Slope (V:H) |
|---|---|---|---|---|---|---|---|
| | Beginning | Ending | | | | | |
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# DATA COLLECTION SHEET

DATE: September , 2003

TIME: :

WEATHER: ______________

EDGE OF TRAVELED WAY

TRAVEL DIRECTION

N S E W

EDGE OF TRAVELED WAY

TRAVEL DIRECTION

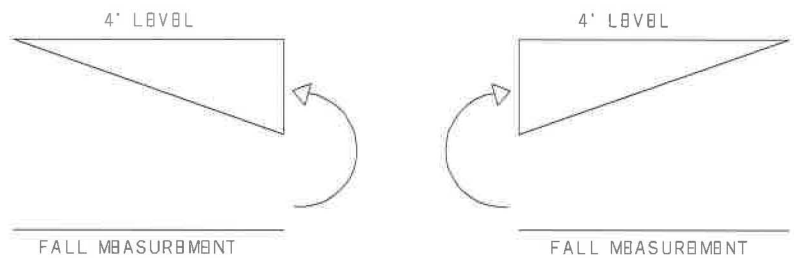
N S E W

______________
ROUTE NUMBER

______________ ______________
BEGIN END
MILEPOST

______________
NUMBER OF DRIVEWAYS
WITHIN SEGMENT

______________
MINOR INTERSECTIONS
WITHIN SEGMENT

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D-1

Appendix D - Data Collection Sheet

# Appendix E - ALDOT AADT Data

| Route | Milepost | | AADT 1998 | AADT 1999 | AADT 2000 | AADT 2001 | AADT 2002 |
|---|---|---|---|---|---|---|---|
| | Begin | End | | | | | |
| 1 | 109.00 | 110.00 | 19720 | 20840 | 21230 | 21530 | 22900 |
| 1 | 118.74 | 119.74 | 18000 | 18690 | 18730 | 19470 | 20090 |
| 1 | 126.70 | 127.70 | 13880 | 15090 | 14920 | 15520 | 15960 |
| 1 | 128.80 | 129.80 | 13880 | 15090 | 14920 | 15520 | 15960 |
| 1 | 132.60 | 133.60 | 13450 | 14070 | 14950 | 15040 | 15350 |
| 4 | 130.10 | 131.10 | 7400 | 7520 | 6780 | 6750 | 6210 |
| 4 | 137.00 | 138.00 | 4410 | 4390 | 3810 | 3730 | 3920 |
| 4 | 138.00 | 139.00 | 4410 | 4390 | 3810 | 3730 | 3920 |
| 4 | 139.50 | 140.50 | 4410 | 4390 | 3810 | 3730 | 3920 |
| 4 | 147.20 | 148.20 | 3610 | 3850 | 3660 | 3470 | 3570 |
| 8 | 122.90 | 123.90 | 13170 | 13930 | 14400 | 14310 | 13950 |
| 8 | 212.80 | 213.80 | 22570 | 22010 | 22430 | 22500 | 23720 |
| 8 | 214.00 | 215.00 | 25650 | 25150 | 25630 | 25710 | 27020 |
| 8 | 215.00 | 216.00 | 34410 | 34280 | 33580 | 38170 | 33830 |
| 13 | 13.40 | 14.40 | 17670 | 19020 | 18670 | 17240 | 16540 |
| 13 | 14.80 | 15.80 | 16620 | 18420 | 18320 | 17180 | 15970 |
| 13 | 17.50 | 18.50 | 13150 | 15950 | 15870 | 15020 | 12750 |
| 13 | 18.50 | 19.50 | 13150 | 15950 | 15870 | 15020 | 12750 |
| 13 | 23.20 | 24.20 | 12620 | 13040 | 12980 | 12430 | 12430 |
| 16 | 15.00 | 16.00 | 28960 | 29250 | 29170 | 28120 | 24660 |
| 16 | 16.00 | 17.00 | 33190 | 31360 | 31390 | 30300 | 28610 |
| 16 | 17.00 | 18.00 | 29600 | 28770 | 29010 | 30470 | 31300 |
| 16 | 18.00 | 19.00 | 32790 | 32400 | 32050 | 29940 | 33690 |
| 16 | 19.20 | 20.20 | 32910 | 31200 | 30260 | 29770 | 28200 |
| 38 | 1.90 | 2.90 | 69790 | 72460 | 70100 | 72490 | 72390 |
| 38 | 3.00 | 4.00 | 52880 | 58130 | 56000 | 58150 | 58290 |
| 38 | 4.20 | 5.20 | 69890 | 64020 | 67220 | 67320 | 72470 |
| 38 | 5.50 | 6.50 | 69890 | 64020 | 67220 | 67320 | 72470 |
| 38 | 6.80 | 7.80 | 45030 | 39760 | 42400 | 48020 | 51040 |
| 38 | 8.40 | 9.40 | 40960 | 40970 | 43700 | 45900 | 48460 |
| 38 | 10.00 | 11.00 | 40960 | 40970 | 43700 | 45900 | 48460 |
| 38 | 11.50 | 12.50 | 40960 | 40970 | 43700 | 45900 | 48460 |
| 38 | 12.50 | 13.50 | 24180 | 26260 | 28280 | 29450 | 30210 |
| 38 | 36.50 | 37.50 | 23810 | 22770 | 23200 | 23660 | 23290 |
| 38 | 39.00 | 40.00 | 18070 | 16440 | 17180 | 17220 | 17560 |

# Appendix E - ALDOT AADT Data

| Route | Milepost | | AADT 1998 | AADT 1999 | AADT 2000 | AADT 2001 | AADT 2002 |
|---|---|---|---|---|---|---|---|
| | Begin | End | | | | | |
| 42 | 10.90 | 11.90 | 16590 | 17920 | 17050 | 16810 | 17690 |
| 42 | 12.10 | 13.10 | 23110 | 24420 | 23870 | 23540 | 23690 |
| 42 | 13.10 | 14.10 | 23110 | 24420 | 23870 | 23540 | 23690 |
| 42 | 14.20 | 15.20 | 24770 | 25370 | 24920 | 24730 | 24000 |
| 42 | 15.30 | 16.30 | 24770 | 25370 | 24920 | 24730 | 24000 |
| 42 | 17.00 | 18.00 | 22070 | 23800 | 23330 | 23420 | 23310 |
| 53 | 54.10 | 55.10 | 12240 | 13150 | 12910 | 12520 | 13300 |
| 53 | 55.70 | 56.70 | 12170 | 13190 | 12990 | 12600 | 12830 |
| 53 | 57.10 | 58.10 | 12170 | 13190 | 12820 | 12120 | 12350 |
| 53 | 59.00 | 60.00 | 12170 | 13190 | 12820 | 12120 | 12350 |
| 53 | 60.00 | 61.00 | 12550 | 13800 | 13360 | 12630 | 13590 |
| 53 | 62.40 | 63.40 | 14400 | 15610 | 15080 | 14250 | 14740 |
| 53 | 63.40 | 64.40 | 14400 | 15610 | 15080 | 14250 | 14740 |
| 53 | 81.50 | 82.50 | 16380 | 18220 | 18690 | 17570 | 18030 |
| 53 | 90.80 | 91.80 | 14720 | 15440 | 15670 | 14720 | 15200 |
| 53 | 97.50 | 98.50 | 15230 | 16160 | 16320 | 15390 | 15900 |
| 53 | 103.00 | 104.00 | 15990 | 16900 | 16970 | 17490 | 16520 |
| 53 | 177.10 | 178.10 | | | | | |
| 75 | 2.50 | 3.50 | 27960 | 26890 | 26660 | 26140 | 26070 |
| 75 | 3.70 | 4.70 | 14540 | 14270 | 12160 | 11780 | 11590 |
| 75 | 5.00 | 6.00 | 15600 | 15620 | 15650 | 15390 | 15660 |
| 75 | 7.20 | 8.20 | 13730 | 14000 | 14570 | 14440 | 14760 |
| 75 | 8.30 | 9.30 | 10990 | 11210 | 11960 | 11840 | 12210 |

Appendix F - Site Data

| Route | Milepost | | Median Width | Number of | | Speed Limit |
|---|---|---|---|---|---|---|
| | Begin | End | | Intxs | Driveways | |
| 1 | 109.00 | 110.00 | 33.81 | 1 | 2 | 65 |
| 1 | 118.74 | 119.74 | 53.43 | 1 | 1 | 65 |
| 1 | 126.70 | 127.70 | 100.66 | 0 | 0 | 65 |
| 1 | 128.80 | 129.80 | 100.66 | 2 | 4 | 65 |
| 1 | 132.60 | 133.60 | 94.25 | 2 | 1 | 65 |
| 4 | 130.10 | 131.10 | 0.00 | 0 | 10 | 45 |
| 4 | 137.00 | 138.00 | 0.00 | 2 | 10 | 45 |
| 4 | 138.00 | 139.00 | 0.00 | 2 | 5 | 45 |
| 4 | 139.50 | 140.50 | 0.00 | 3 | 7 | 55 |
| 4 | 147.20 | 148.20 | 0.00 | 2 | 19 | 55 |
| 8 | 122.90 | 123.90 | 41.18 | 1 | 4 | 65 |
| 8 | 212.80 | 213.80 | 12.00 | 5 | 17 | 45 |
| 8 | 214.00 | 215.00 | 12.00 | 5 | 10 | 45 |
| 8 | 215.00 | 216.00 | 29.76 | 1 | 0 | 55 |
| 13 | 13.40 | 14.40 | 28.85 | 3 | 10 | 50 |
| 13 | 14.80 | 15.80 | 28.85 | 1 | 4 | 50 |
| 13 | 17.50 | 18.50 | 28.85 | 2 | 2 | 50 |
| 13 | 18.50 | 19.50 | 28.85 | 2 | 2 | 50 |
| 13 | 23.20 | 24.20 | 50.75 | 5 | 13 | 65 |
| 16 | 15.00 | 16.00 | 12.00 | 4 | 50 | 45 |
| 16 | 16.00 | 17.00 | 23.47 | 2 | 50 | 50 |
| 16 | 17.00 | 18.00 | 12.00 | 5 | 50 | 45 |
| 16 | 18.00 | 19.00 | 12.00 | 5 | 50 | 45 |
| 16 | 19.20 | 20.20 | 12.00 | 2 | 50 | 50 |
| 38 | 1.90 | 2.90 | 12.00 | 0 | 0 | 55 |
| 38 | 3.00 | 4.00 | 12.00 | 2 | 2 | 55 |
| 38 | 4.20 | 5.20 | 12.00 | 2 | 0 | 55 |
| 38 | 5.50 | 6.50 | 12.00 | 3 | 2 | 55 |
| 38 | 6.80 | 7.80 | 12.00 | 4 | 5 | 55 |
| 38 | 8.40 | 9.40 | 36.74 | 3 | 12 | 55 |
| 38 | 10.00 | 11.00 | 12.00 | 2 | 0 | 55 |
| 38 | 11.50 | 12.50 | 51.65 | 4 | 0 | 55 |
| 38 | 12.50 | 13.50 | 51.65 | 2 | 1 | 55 |
| 38 | 36.50 | 37.50 | 53.35 | 0 | 5 | 65 |
| 38 | 39.00 | 40.00 | 29.20 | 3 | 7 | 65 |

Appendix F - (continued)

| Route | Milepost | | Median Width | Number of | | Speed Limit |
|---|---|---|---|---|---|---|
| | Begin | End | | Intxs | Driveways | |
| 42 | 10.90 | 11.90 | 12.00 | 1 | 6 | 50 |
| 42 | 12.10 | 13.10 | 12.00 | 2 | 28 | 45 |
| 42 | 13.10 | 14.10 | 12.00 | 0 | 17 | 45 |
| 42 | 14.20 | 15.20 | 12.00 | 11 | 37 | 50 |
| 42 | 15.30 | 16.30 | 12.00 | 5 | 30 | 50 |
| 42 | 17.00 | 18.00 | 12.00 | 3 | 8 | 50 |
| 53 | 54.10 | 55.10 | 39.29 | 1 | 0 | 65 |
| 53 | 55.70 | 56.70 | 39.29 | 3 | 4 | 65 |
| 53 | 57.10 | 58.10 | 12.00 | 1 | 5 | 55 |
| 53 | 59.00 | 60.00 | 12.00 | 2 | 10 | 55 |
| 53 | 60.00 | 61.00 | 12.00 | 3 | 9 | 55 |
| 53 | 62.40 | 63.40 | 12.00 | 3 | 10 | 55 |
| 53 | 63.40 | 64.40 | 12.00 | 0 | 0 | 55 |
| 53 | 81.50 | 82.50 | 53.20 | 2 | 5 | 65 |
| 53 | 90.80 | 91.80 | 48.62 | 0 | 0 | 65 |
| 53 | 97.50 | 98.50 | 49.61 | 0 | 0 | 65 |
| 53 | 103.00 | 104.00 | 99.22 | 2 | 5 | 65 |
| 53 | 177.10 | 178.10 | 0.00 | 2 | 22 | 55 |
| 75 | 2.50 | 3.50 | 31.52 | 5 | 50 | 35 |
| 75 | 3.70 | 4.70 | 12.00 | 9 | 50 | 35 |
| 75 | 5.00 | 6.00 | 12.00 | 7 | 7 | 45 |
| 75 | 7.20 | 8.20 | 12.00 | 10 | 16 | 45 |
| 75 | 8.30 | 9.30 | 29.90 | 6 | 4 | 55 |