OKLAHOMA TRANSPORTATION CENTER

ECONOMIC ENHANCEMENT THROUGH INFRASTRUCTURE STEWARDSHIP

OPTIMUM CABLE BARRIER DESIGN AND PLACEMENT FOR THE STATE OF OKLAHOMA

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16. ABSTRACT

This research evaluated the effectiveness of ODOT's cable barrier program. Site inspections of all known cable barrier systems were conducted. Locations of most cable sites were found to be within guidelines for effective use. Comparison to sites with steeper slopes than 1 to 6 were located in the literature and discussed.

The SAFE-T traffic data system was used to analyze cross over median collisions and F.O. cable barrier collisions. Cable barrier system decrease fatalities significantly. The societal cost savings for the saved lives is estimated to be $48 million dollars per year. The analysis also identified that cable barrier system increase the number of reported events with property damage.

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SI (METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units				
Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	25.40	millimeters	mm
ft	feet	0.3048	meters	m
yd	yards	0.9144	meters	m
mi	miles	1.609	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm
ft^2	square feet	0.0929	square meters	m^2
yd^2	square yards	0.8361	square meters	m^2
ac	acres	0.4047	hectares	ha
mi^2	square miles	2.590	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0283	cubic meters	m^3
yd^3	cubic yards	0.7645	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.4536	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	degrees Fahrenheit	(°F-32)/1.8	degrees Celsius	°C
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.448	Newtons	N
lbf/in^2	poundforce per square inch	6.895	kilopascals	kPa

Approximate Conversions from SI Units				
Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.0394	inches	in
m	meters	3.281	feet	ft
m	meters	1.094	yards	yd
km	kilometers	0.6214	miles	mi
		AREA		
mm^2	square millimeters	0.00155	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.196	square yards	yd^2
ha	hectares	2.471	acres	ac
km^2	square kilometers	0.3861	square miles	mi^2
		VOLUME		
mL	milliliters	0.0338	fluid ounces	fl oz
L	liters	0.2642	gallons	gal
m^3	cubic meters	35.315	cubic feet	ft^3
m^3	cubic meters	1.308	cubic yards	yd^3
		MASS		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.1023	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	degrees Celsius	9/5+32	degrees Fahrenheit	°F
		FORCE and PRESSURE or STRESS		
N	Newtons	0.2248	poundforce	lbf
kPa	kilopascals	0.1450	poundforce per square inch	lbf/in^2

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Optimum Cable Barrier Design and Placement for the State of Oklahoma

FINAL REPORT

January 10, 2013

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EXECUTIVE SUMMARY

Over the past decade, cross median crashes have grown to be a serious problem for a variety of reasons. These include traffic growth, higher driving speeds, more variation in the mix of traffic, and driver issues such as aggressive & distracted driving. Increased traffic volume alone increases the probability that a vehicle might leave the roadway and if it traverses the median that the possible exposure to on-coming traffic is higher.

DOTs have recognized the problem and have attempted to mitigate the problem in various ways. A recent mitigation approach has been to deploy cable barriers in the medians to redirect or capture vehicles before a cross median crash can occur. Cable median barriers are considered attractive to DOT's because of low costs, short implementation time, ease of installation, adaptability for sloped conditions and low visual impact. The general consensus is that cable median barriers are highly effective but cases of slipping under the cable "underride" or passing over the cable "override" have been noted to occur with catastrophic results (Sposito and Johnston, 1998, Rob 2005 and Nauman et al 2008).

Several research teams are trying to understand the causes for barrier interface problems and improve the guidance to DOT's to help get the maximum effectiveness possible. Present research has shown that cable barrier effectiveness is related to barrier design, configuration of the median, and position relative to the terrain.

As more median cable barrier systems are installed in the state of Oklahoma, there is a need to study their effectiveness in reducing crossover accidents and the cost-effectiveness of the

various cable barrier systems. This study would include all crashes related to the systems being hit, types of systems, and an analysis of prevented accidents since the installation.

An additional objective of this effort was be to evaluate vehicle-to-barrier interface for cable placement and side slopes. Oklahoma has chosen to limit cable barriers to maximum 1:4 slope. This slope limit is somewhat arbitrary and expensive to build at all locations. Texas has been placing cable barriers on slopes up to 1:6. This study will provide accident data to compare with the Texas experience and will allow ODOT to make informed decisions as to the effective installation of cable barriers on our highways.

1. EXPERIMENTAL PROGRAM TASKS

This report is presented in the same order in which the experimental program was broken down into tasks. These include:

- Perform literature search – Chapter 2
- Inspection of the cable barrier projects – Chapter 3
- Evaluate the performance of all types of cable barriers used by ODOT – Chapter 4
- Perform an analysis of the initial and repair cost as related to manufacture type – Chapter 5
- Perform an analysis of the landscape maintenance cost as related to manufacture type – Chapter 5
- Perform an analysis of preventable accidents since the installation – Chapter 6
- Investigate and compare historic crossover crash data to the present deflective crashes – Chapter 6
- Use multi-variant regression analysis to prove effectiveness of the cable barriers – Chapter 7

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2. LITERATURE SEARCH

The American Association of State Highway and Transportation Officials (AASHTO) define median barriers as “longitudinal barriers that are most commonly used to separate opposing traffic on a divided highway” (AASHTO, 2006). A median barrier is designed to contain and redirect an out of control vehicle without exceeding a given deceleration rate and impact angle to minimize injury (Miaou et al., 2005). In 1968, Jehu stated there are six objectives of crash barriers:

1. Preventing any vehicle from injuring innocent persons outside of that vehicle
2. Preventing passenger cars, and as far as economically possible also heavy vehicles, from entering an area hazardous to travel
3. Redirecting the vehicle nearly parallel to the direction of the barrier
4. Containing within tolerable limits the forces experienced by the vehicle occupants
5. Minimizing property damage costs
6. Withstanding impact from a colliding vehicle without danger of either the vehicle or the barrier becoming a hazard to traffic.

Median barriers are recommended anywhere there is the potential for high-severity crashes. The major function of these median barriers is reducing cross median crashes (CMCs). A CMC occurs when a vehicle leaves the roadway, crosses the median and then heads into opposing traffic striking one or more other vehicles. Another effect is a vehicle crossing over can force a driver of the opposing lane to wreck without actually coming into contact with the cross over vehicle. A visual representation of a CMC as well as other crash types can be seen in Figure 1.

Since highways have high speeds associated with them and the nature of the accidents are typically head on, these CMCs often result in severe injury if not a fatality (Miaou et al., 2005).

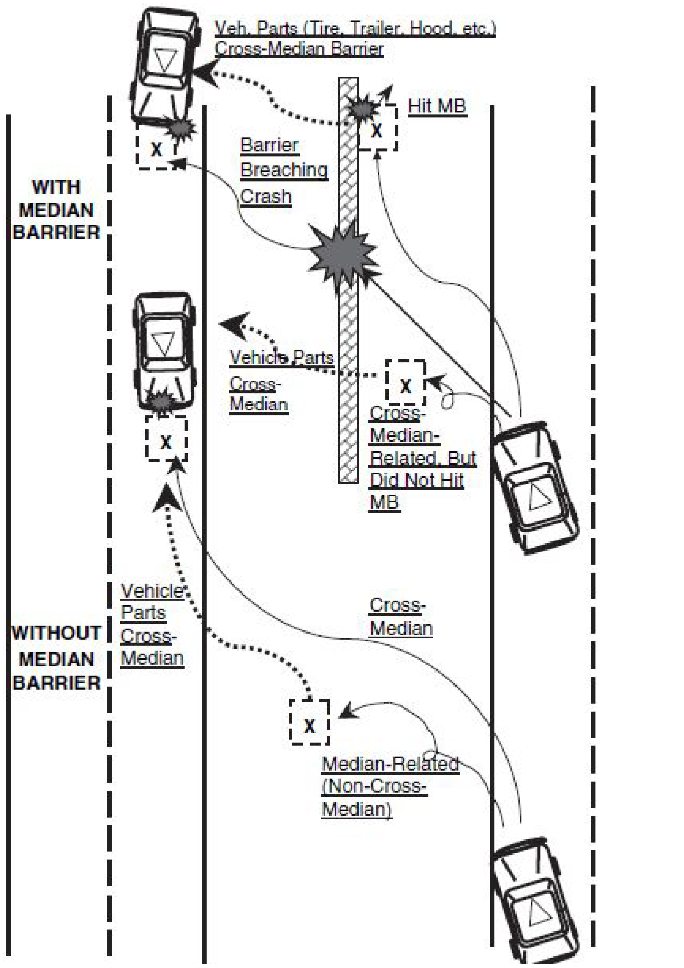

Figure 1 Types of Crashes (Miaou et al., 2005)

Crash safety systems were first researched on a large scale by the California Department of Transportation (Caltrans) starting in the 1950's. This research looked mainly into the crash history of different median geometry features. These median features were things such as flat medians versus those with barriers, ditches and berms. This research led to Caltrans research studying the effectiveness of median barriers such as concrete barriers and metal guard rails. The results of that research was used to develop a set of guidelines to determine when a median barrier is needed using median width and annual average daily traffic (AADT) limits. Eventually those guidelines were adopted as the first set of guidelines to warrant median barriers on a national level. Forms of those guidelines were used from the 1970's until the 2000's. Through the 1970's and 1980's, no major changes were made to the warranting guideline due to the fact that the traffic levels remained low to today's standards as well as the passing of the law which imposed a national speed limit. Finally, in 1996 the national speed limit law was repealed and speed limits were allowed to increase nationwide. With an increased traffic load since the 1970's coupled with the newly increased speed limit, it was unsure what effect these things would have on CMCs as well as other types of crashes. Caltrans, along with multiple other state departments of transportation, started conducting research over crash barrier systems to bring the systems up to date with their current needs and concerns (Sicking et al., 2009).

The first research that focused on cable barrier systems was done by the New York Department of Transportation (NYDOT) in the 1960's (Albin et al., 2001). NYDOT studied a three strand barrier set on steel posts. The results from this research showed that cable barriers subjected the passengers of the vehicle to lower forces than the tradition concrete and guardrail systems that were being used as median barriers at the time. In 1988, AASHTO began including cable median barrier info in its *Roadside Design Guide*. These first systems used cables at low-tensions. Any state was capable of designing their own standards as long as they passed the proper safety testing. Eventually companies came along with proprietary high tension systems. These systems could reduce the impact deflection by larger amounts.

a. Design Considerations for Cable Barriers

The process of designing a median has several stages. The first step is doing a warrant analysis to see if installing a median barrier is justified. Next, if the barrier is warranted, the proper barrier must be selected. There are many factors that are used when trying to warrant a cable barrier. It has been shown that CMCs are more likely to occur on horizontal curves. This frequently happens when the driver becomes distracted and fails to recognize that a curve in the road is approaching. This distraction typically causes the drivers to crash towards the outside of the horizontal curvature. Another factor is the frequency of interchanges. Due to human error and the increased congestion that occurs at intersections, many accidents occur on the roadway around these regions. Weather is also believed to have an effect on CMCs. In winter weather, research found that the frequency of CMCs increased. Although there was an increase in the number of accidents, the severity of these crashes were much lower than usual. This was thought to be due to slower speeds drivers travel at in the winter conditions (Sicking et al., 2009).

The most common design consideration is median geometry. This includes median slope and width. The guidelines state that if a median barrier is to be placed, a median slope of 1V:10H or flatter is preferred although a slope of 1V: 6H can also be used (AASHTO, 2006). A recent study tested these slope recommendations using cable barriers and found that the success of slopes of 1V:6H or flatter was 93.9% and for steeper slopes than 1V:6H was 98.1% (Yue, 2010). This counters the idea that steeper slopes leads to more failures, and actually states that the steeper slopes have an increased success rate. This increased success rate may have to do with the underlying assumptions used in the development of the AASHTO guidelines. These assumptions relate to the stiffness of the vehicle suspension and the soil characteristics. The computer prediction models reviewed at Fears Lab assumed an infinitely stiff soil and a moderately stiff suspension. Changing either of these characteristics would change the success rate of cable barrier system. A vehicle leaving the roadway and crossing the median on a steeper slope than 1V:6H that strikes the median before the cable barrier is likely to plow into the ground reducing the energy of impact with the cable barrier.

The other part of median geometry is the median width. Extensive research has been done into median width by looking into CMCs and determining the median width where they occurred. In a survey done by the Federal Highway Administration (FHWA) in 2004, it was found that two-thirds of all CMCs occur where the median is less than 50 feet wide (AASHTO, 2006). Using a combination of the median widths and AADT, AASHTO created a chart detailing when a median barrier should be used. This chart can be seen in Figure 2.

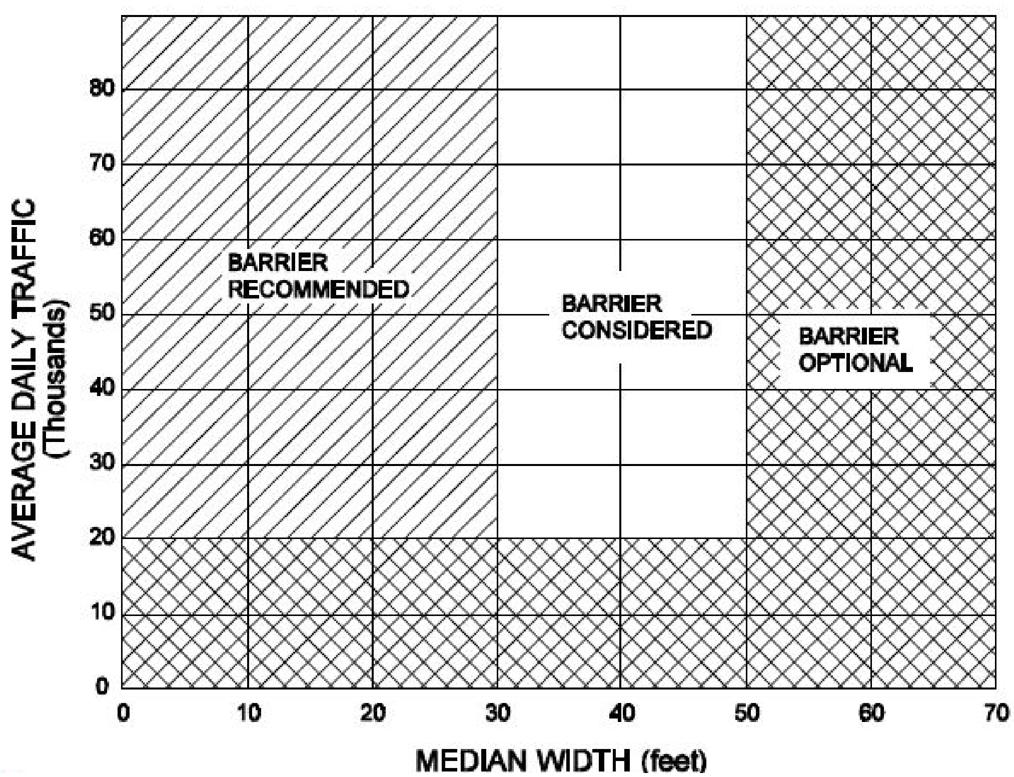

Figure 2 AASHTO Median Barrier Recommendations (AASHTO, 2006)

Many states have chosen their own standards to determine when to employ median barriers. For instance, Caltrans says a median barrier can be warranted for medians up to 75 feet wide with an AADT exceeding 62,000 vehicles. The North Carolina stated that any median less than 70 feet wide should have a barrier regardless of the traffic volume. A study was conducted in North Carolina starting in 1998. The findings found that 95% of all CMCs could be eliminated if barrier protection is provided for medians less than 70 feet wide (Bennett and Murphy, 2006). A visual representation of the research findings can be seen in Figure 3. Many states in the Midwest have the advantage of having larger open spaces with a relatively low population density. This allows for roadways to have large flat medians that can ultimately negate the need for having median barriers (Sicking et al., 2009).

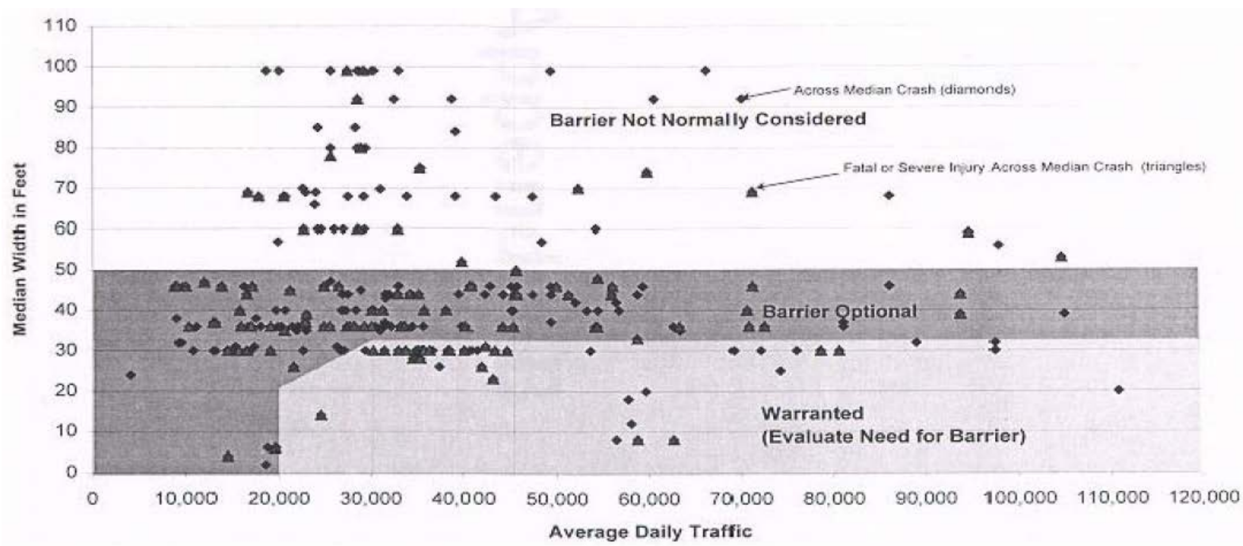

Figure 3 Effects of Median Width and AADT on CMCs (Bennett and Murphy, 2006)

After the considerations for warranting a barrier have been covered, choosing the appropriate barrier is next. There are several instances in which a cable barrier is not the preferred system. For example, if the median is very narrow, it may be best to go with a concrete barrier. This is due to the fact that a cable barrier will deflect approximately 12 feet under design impact conditions (Alberson et al., 2003). Due to that fact, a median width of 24 feet is needed for a cable system installed in the center of the median (AASHTO, 2006). Washington State Department of Transportation (WSDOT) didn't consider cable barriers until the median exceeded 32 feet in width during the 1990's (Albin et al., 2001). Other factors that could favor the use of concrete over cable barriers are roads with high speeds or high traffic loads (Alberson et al., 2003). Another consideration to take into account when using cable barriers is maintaining the designed tension. As the temperature varies, the cable will become slack and potentially move out of position allowing a potential vehicle penetration (Alberson et al., 2005). In one study, it was found that 77% of the cable tension was lost after one year of installation (Sheikh et al., 2008).

A cable barrier is a good choice if you have wider medians where the impact deflection is not an issue. It is also preferable in areas that receive large amounts of snow and have troubles with other barriers accumulating snow drifts. Cable barriers also do not impede drainage the way a concrete barrier would. An extremely beneficial property of cable systems is also the low initial installation cost, although the maintenance costs are increased. A study by the Oregon Department of Transportation looked into all the costs associated with both cable and concrete barriers. Their findings stated that the initial cost of cable barriers was 70% less than concrete barriers. The yearly cost to maintain the cable barrier was $2,014/km ($3,241/mile) versus only $35/km ($56/mile) for the concrete barriers, but it was stated that the maintenance cost of the cable barrier could be increased to $3,857/km ($6,207/mile) and it would still be as economical over a 30 year service life. Another benefit of the cable barrier system is that on average only four to six posts are in need of repair after a crash, and that the repairs typically take less than two hours to finish (Sheikh et al., 2008).

If a cable barrier system is going to be used, it first must be pass the Test Level 3 performance requirements as laid out by the NCHRP Report 350. To pass the test, the cable barrier must be tested in two scenarios. The first scenario requires an 820kg (1810 lb) car travelling at 100km/h (62 mph) striking the cable barrier at a 20 degree angle. The second scenario requires a 2000kg (4410 lb) truck traveling at 100km/h (62 mph) striking the cable barrier at 25 degrees (Ross et al., 1993). An example of a cable barrier being tested can be seen in Figure 4.

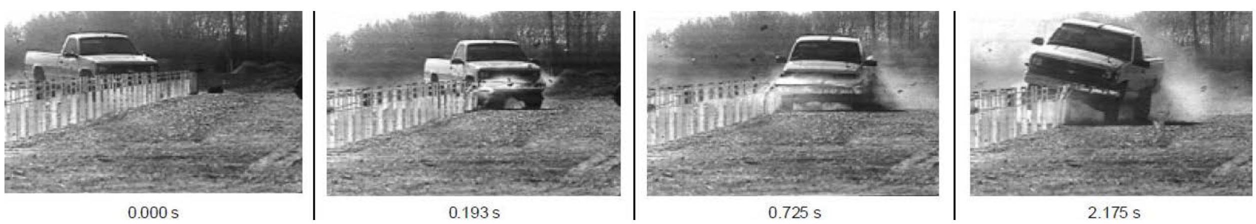

Figure 4 NCHRP 350 Compliance Test (Griffith, 2003)

There are two types of cable barriers as stated by AASHTO, the three-strand cable and the high-tension cable (AASHTO, 2006). The low-tension barriers are not patented so any state is capable of designing their own system. In the AASHTO *Roadside Design Guide*, a cable barrier is described that meets the NCHRP Report 350 testing requirements. It states that the cables should be placed at 21in, 25.5in and 30in off the ground to accommodate large and small vehicles (AASHTO, 2006). Several states departments of transportation have designed low-tension cable barrier systems that have passed the NCHRP Report 350 requirements. The Washington State Department of Transportation's (WSDOT) design calls for three 19mm cables on S75x8.5 posts 1.6m high spaced 5m center-to-center, and with the top and bottom wire are at 770mm and 530mm, respectively (Albin et al., 2001). The middle wire is spaced halfway between the other wires.

The high-tension cable systems are proprietary to the companies who have designed them. These high-tension cable barriers must also meet the NCHRP Report 350 testing requirements. A detailed report of the cable barrier layout and the Test Level 3 results are available on the FHWA's website. There is another level of testing called Test Level 4 which some of the high-tension cable barriers have been able to withstand. According to AASHTO's 2006 version of the *Roadway Design Guide*, there were five accepted high-tension barrier systems that have passed the Test Level 3 and are sufficiently designed to be installed. A breakdown of the market share these high-tension cable systems have can be seen in Figure 5. The five different high-tension cable barrier systems are listed with their market share:

- Brifen Wire Rope Safety Fence by Brifen USA, Inc. (37%)
- The Cable Safety System (CASS) by Trinity Industries, Inc. (38%)
- U.S. High-Tension Cable System by Nucor Steel Marion Inc. (10%)
- Blue Systems (Safence) (5%)
- Gibraltar Cable Barrier System (10%)

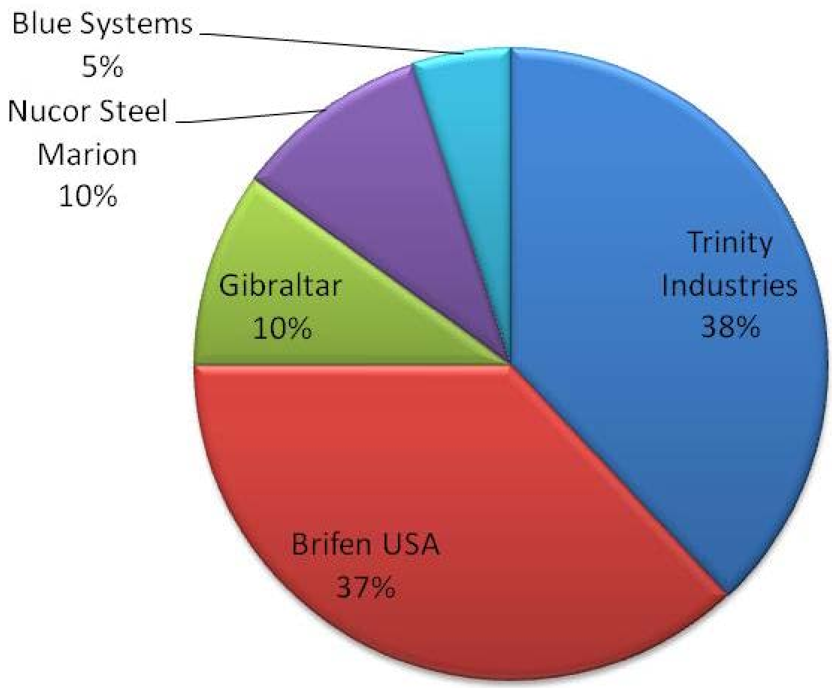

Figure 5 High-Tension Cable Barrier Market Share (Alberson, 2006)

b. Performance of Cable Barriers

The performance of median barriers has been looked into extensively. The results show several distinct patterns. The first pattern is that as median barriers are increasingly used, the number of total crashes also increases. This may be due to the fact that if the barrier weren't present, the driver may have been able to correct the vehicle before crashing (Miaou et al., 2005). Or, from a pure statistics point of view, all cross over events where the vehicle crosses over into the oncoming lanes of traffic do not always result in physical damage, injury or fatality. And as such are not reported by the highway patrol and never enter the traffic event data base (SAFE-T). Another pattern is that the number of CMCs is drastically reduced. The last major pattern is the number of injuries and fatalities are reduced to a fraction as opposed to before the barrier was put in place.

There are several studies that provide convincing statistics as to the success of cable barrier systems throughout the United States. For instance, a low-tension installation in Oregon prevented 21 potential crossovers in just 16 months, which accounted for 40% of all impacts over that period. A study by WSDOT found that the number of fatal accidents per year fell from 3.00 to just 0.33 and that disabling accidents went from 3.6 to 1.76. WSDOT also found that the societal costs dropped to $3.32 million per year where it had previously been $13.58 million per year. The Missouri Department of Transportation found that even on slopes, only 67 of 1,402 cable barrier collisions couldn't be prevented. That brings its successful crossover prevention rate to 95.2%. The Ohio Department of Transportation evaluated its Brifen high-tension cable barrier. It found that only four vehicles weren't successfully stopped from penetrating the barrier. The barrier was even struck by a semi-truck that was well beyond its design. The Ohio DOT also found that over a three year period, no CMC fatalities were recorded as opposed to nine CMC related fatalities the three years prior to the barriers use (Sheikh et al., 2008). A comparison was done using data obtained in North Carolina that shows the level of severity of different median barriers. It was found that the cable barriers led to the lowest severities (Bennett and Murphy, 2006). The results of those findings can be seen in Table 1. These values are determined by ranking the injuries of the crash on a scale of one to five. A value of one represents only property damage where a value of five represents a fatality (Bennett and Murphy, 2006).

Table 1 Median Barrier Average Crash Severity (Bennett and Murphy, 2006)

Barrier Type	# of Hits	Avg. Severity
Cable	1,592	1.31
Weak Post	567	1.44
W-Beam	1,266	1.63
Concrete Barrier	67	1.64
Total	3,486	1.45

c. Cost Analysis by other states

Many studies concerning cable barriers include research on the life-cycle costs of cable barriers in comparison with other types of barriers. Life-cycle costs include installation costs and maintenance/repair fees. Figure 6 shows a cable barrier being installed along I-40. A barrier system could have a very low installation cost but if it needs to be repaired often and for a high cost, the system may not be as economical as other options. Therefore, since cable barriers are a relatively new median barrier system, many states want to determine if the system is economically better than older barriers.

Texas DOT did an in depth study of the costs of their own cable barrier systems, including part-by-part cost analyses and an investigation on repair costs (Cooner etal.). Although many studies simply use an average installation cost for a basic cable barrier system, Texas DOT compared several different manufacturers in Table 2, where the costs are broken down into cost per linear foot and cost per mile. High, low, and weighted average costs are also included, since prices may change from state to state.

Figure 6 Cable Barrier Installation on I-40

Table 2 Cable Barrier System Costs – Texas ISPE Sites (Cooner, et al.)

Barrier Manufacturer	Cost per Linear Foot			Cost Per Mile		
	High	**Low**	**Weighted Average**	**High**	**Low**	**Weighted Average**
Brifen (26.5 mi.)	$17.70	$13.28	$14.67	$93,456	$70,118	$77,458
Gibraltar (91.6 mi.)	$12.00	$8.75	$9.88	$63,360	$46,200	$52,166
Nucor (150.5 mi.)	$13.60	$8.48	$8.66	$71,808	$44,744	$45,725
Trinity (162.7 mi.)	$13.75	$8.85	$9.86	$72,600	$46,728	$52,061
All Combined (431.3 mi.)	$17.70	$8.48	$9.74	$93,456	$44,744	$51,427

When calculating the life-cycle costs of a system, estimating the repair and maintenance costs is usually the most difficult. Figure 7 shows an example of a damaged cable barrier after an impact on I-35. First, the average repair cost per impact must be calculated. For cable barriers, this can be done by calculating the repair costs for one damaged post, which mostly involves replacement of the post. Table 3, from a study by Monsere *et al.* on cable barriers in Oregon, shows some states' repair costs per accident and per post. Costs can vary between states and manufacturers, so it is important to investigate the cost of repairs and installation for specific situations before calculating life-cycle cost.

Figure 7 Damaged Cable Barrier on I-35

Table 3 Crash Comparisons with Other States (Monsere, et al.)

	Oregon	North Carolina	Iowa	New York
Study Period in Years	4.1	1.8	2.0	3.0
Mk Cable Median Barrier (mi)	35.2 (21.9)	13.7 (8.5)	NA	NA
Repairs/Year	44	71	29	NA
Repair Cost/Accident ($)	$1,419	NA	$543	$328
Repair Cost/Post ($)	$320	$86	$90	NA

NA: Not available   Costs adjusted to 2001 assuming 4% inflation

Calculating the repair costs does not end with determining the repair cost per post or accidents. The frequency of repairs must also be estimated in order to obtain a clear picture of the system's cost over a long period of time. Texas DOT evaluated total repair costs by first determining the average number of posts damaged from one impact. It is important to realize that not all impacts cause the same amount of damage but since collisions are impossible to predict, it is easiest to use average post damage. Figure 8 shows that the average number of damaged posts per impact is 7.3, which is similar to the averages in other states (Cooner, et al.).

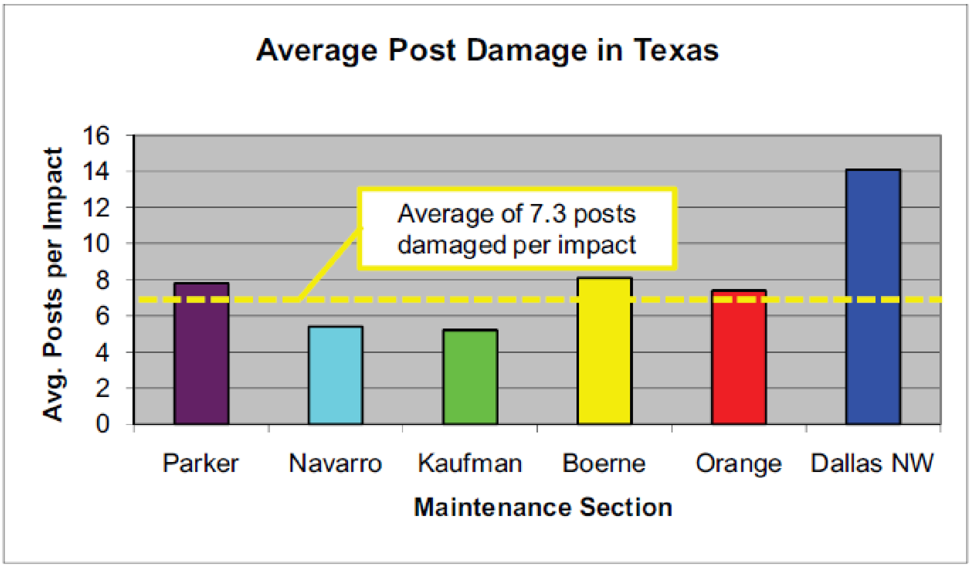

Figure 8 Average Post Damage from Cable Barrier Impacts in Texas (Cooner et al.)

After calculating the average posts per impact, Texas DOT evaluated the average number of impacts per mile per year, as seen in Figure 9. Then, the average number of posts damaged per year could be calculated. Last, a total repair cost per year could be determined by simply multiplying the posts damaged per year by the repair cost per post. If it is needed, the total repair cost over several years could be calculated. Figure 10 shows some averages of impacts per mile per year from other states.

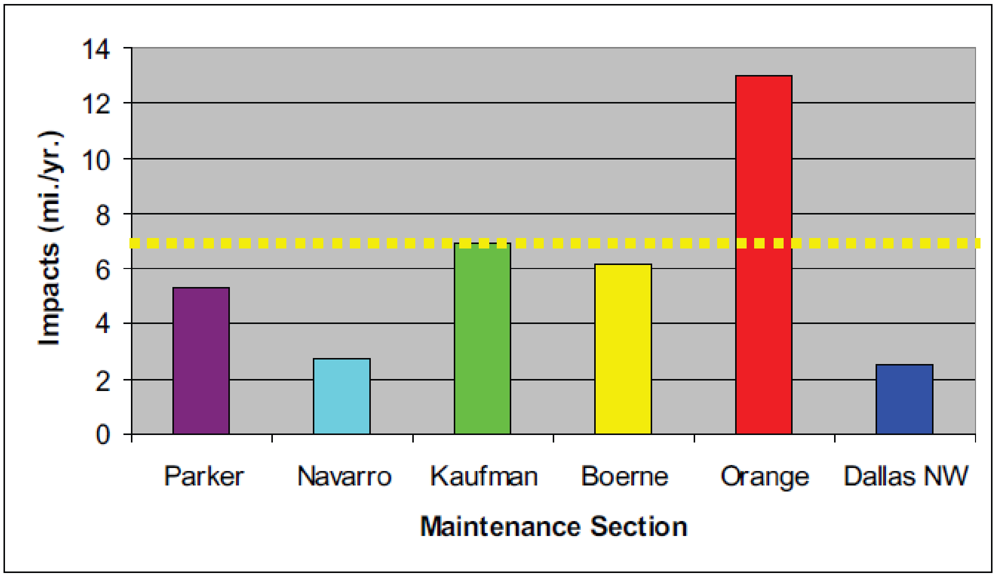

Figure 9 Average Cable Barrier Impact Frequency Per Mile in Texas (Cooner, et al.)

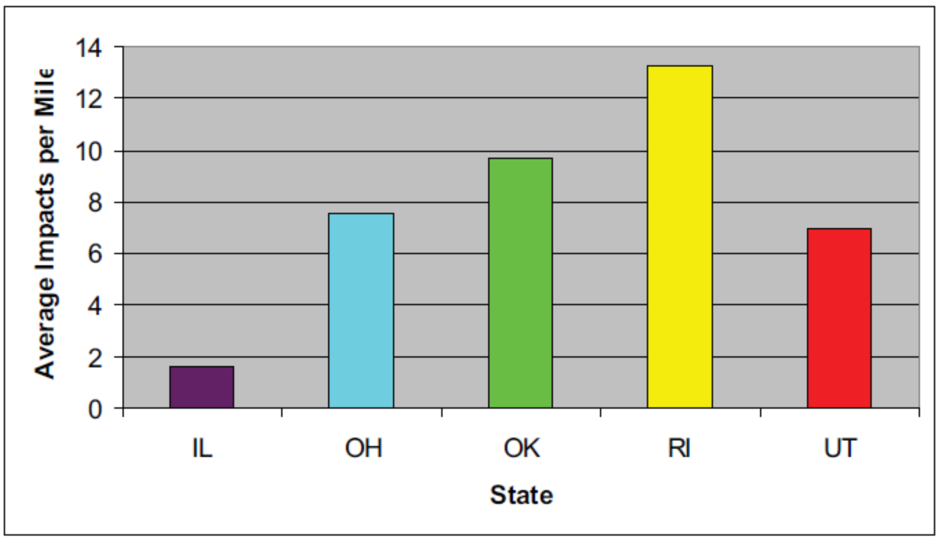

Figure 10 Cable Barrier Impact Frequency Per Mile in Other States (Cooner et al.7)

Once installation costs and repair costs are calculated, the life-cycle cost can also be calculated. For example, a state DOT wants to install a length of cable barrier along a highway and needs to know the estimated costs for the system to be used for 30 years. Unless the DOT takes inflation or something similar into account, the life-cycle cost for 30 years can be determined by summating the installation cost and the repair cost per year times 30 years. Texas DOT calculated and compared the life-cycle cost of a cable barrier system to three different types of concrete barriers. Shown in Table 4 are Texas DOT's estimations of installation cost, recurring costs (repair and maintenance costs), discount rate, and life-cycle cost. Instead of 30 years, Texas DOT calculated the costs for 15 years.

Table 4 Life-Cycle Costs of Cable vs. Concrete Barrier Installation for a 5-mile Project (Cooner et al.)

Barrier	Installation Cost	Recurring Cost	Discount Rate	Time (years)	Life-Cycle Cost
High-Tension Cable	$550,000	$21,250	5%	15	$8,250,000
Concrete: Pre-cast Portable	$600,000	$1,250	5%	15	$8,600,000
Concrete: Pre-cast Single Slope	$1,050,000	$1,250	5%	15	$15,000,000
Concrete: Cast-in-Place	$1,250,000	$1,250	5%	15	$17,900,000

The results from Texas DOT's study show that a high-tension cable barrier would be more economical than all three concrete barrier types for a 15 year period. Similar results have been found by other states, such as in a study by Sposito and Johnston for Oregon where it was calculated that a cable barrier in Oregon would be more economical than a concrete barrier for over 30 years (Sposito, et al.). In conclusion, in most cases a cable barrier is more economical to use over a long period of time than a concrete barrier.

3. INSPECTION OF THE CABLE BARRIER PROJECTS

Cable Barrier systems throughout the state of Oklahoma were visited to evaluate the effectiveness of the barriers location with respect to the median, drainage system, and slope characteristics. This investigation occurred starting in March 2010 and ended in September 2012. Figure 11 shows a typical installation in Oklahoma with shallow median slopes, acceptable median width, and reasonable drainage. Figure 12 shows a typical center of median installation while Figure 13 shows a typical edge of median installation in which the cable barrier is 8 feet from the high speed lane, note the yellow lane line. At design speeds, vehicles crossing the median (in Figure 13 – from the right) and impacting the cable barrier can cause the cable to deflect up to 8 feet At speeds above the design speed the cable deflection will exceed the 8 feet between the cable barrier system and the high speed lane. This deflection could potentially cause a vehicle to vehicle collision with high speed traffic on the left in figure 13. Though this would require two events to occur at the same time, these are 1) a vehicle in the high speed lane bearing to the left in the high speed lane and 2) a speeding vehicle impacting the system at a speed and/or weight above the design limits. This makes this event extremely unlikely. This is one of the few instances of a potential problem in the Oklahoma inventory of cable barriers. Figure 14 shows a cable barrier system after a collision event.

A more complete collection of the photographic documentation may be found in Appendix I. No major construction staging issues were noted. In general access to Oklahoma Highways by construction crews are not hindered by limited staging areas. The one area of the state in which this may be an issue would be on the eastern portion of I-40 at a few discrete hilly regions. In general these areas have wide medians and are not strong candidates for safety cables.

Figure 11 Cable Barrier on I-40

Figure 12 Cable Barrier installed in center of median


Figure 13 Cable Barrier installed at median edge


Figure 14 Typical Damage to Cable Barrier after Vehicle Impact

During the process of developing the inventory, it was discovered that there are seven different types of cable barriers used in Oklahoma, manufactured by five different companies, which are described briefly in the following sections. Pictures of the cable barrier sections can be found in Appendix I, where they are organized by interstate.

Brifen Wire Rope Safety Fence (WRSF)

This cable barrier system is a high tension, four cable system designed by Brifen, a British company (Figure 15). The cable heights are 20in, 26.5in (two interweaving cables in the middle), and 28.5in. This cable barrier system is present only on a 2 mile stretch of I-35 between mileposts 108 and 110.

Brifen TL-4

Brifen TL-4 is also a high tension, four cable system manufactured by Brifen (Figure 16). However, all four cables weave between the posts. The weaving of the cables is believed to be effective in capturing cars impacting from either side of the cable barrier. The cables are 18.9in, 24.8in, 30.7in, and 36.6in from the ground. Thus,the TL-4 has a wider range of cable heights than the WRSF. Brifen TL-4 is used on a total of 81 miles along I-35, I-40, and I-44.

Figure 15 Brifen Wire Rope Safety Fence (WRSF)

Figure 16 Brifen TL-4

BLUE SYSTEMS SAFENCE

Blue Systems is a European company that designed the high tension, four strand cable barrier known as Safence (Figure 17). The cables are 18.9in, 22in, 25.1in, and 28.3in off the ground. The system is recognizable by the blue caps at the top of each

Figure 17 Blue Systems Safence

post. Instead of being attached to the outside of the post like in other systems, Safence's cables are fixed in a slot in each post. There are 142 miles of Safence beingused in Oklahoma, making it the most used system in the state.

Gibraltar TL-4

Gibraltar TL-4 is another high tension, four strand cable barrier (Figure 18). This system consist of metal posts with hooks along one side where the cables are fixed at heights of 20in, 25in, 30in, and 35in. Gibraltar creates a weaving effect similar to Brifen by alternating the directions of the hooks for every post. This system is only used on I-35 from milepost 0 to 12 for a total of 8.5 miles.

Figure 18 Gibraltar TL-4

TRINITY CASS 3

Trinity is a relatively new cable barrier manufacturer and is based in the United States (Figure 19). CASS, or Cable Safety System, is a high tension, three cable system. The main feature of this system is the C-shaped posts with a "wave" slot for the cable. The company claims that the C-shape of the post allows for it to be more easily bent during impact. The wave slot is used to create friction and slow the cables' departures from the post during impact, which is meant to help prevent overriding the cables during the initial stages of the impact. Trinity can only be found on 1 mile of I-35 (milepost 98.5 to 99.5) where its performance is being evaluated.

Figure 19 CASS 3 cable system on C-Shaped posts

TRINITY CASS 4 CABLE SYSTEM

This is an unusual cable system (Figure 20). This CASS, or Cable Safety System, is a high tension, four cable system. And it features an I-shaped post instead of Trinity's typical C-shaped posts with a "wave" slot for the cable. This system has four cables running through slots in the posts, similar to Blue System Safence and Trinity CASS. However, this system is taller than both Safence and Trinity's three cable system. This system was also only found on I-40, from milepost 82 to 101 and 310 to 322, for a total of 25.5 miles.

Figure 20 Trinity CASS 4 Barrier with 4 cables

U.S. HIGH-TENSION CABLE SYSTEM BY NUCOR STEEL MARION INC

This cable barrier system is one of two that could not be identified (Figure 21). The actual heights of the cables could not be recorded during the drive-by visit. However, some basic observations can be made of the system. First, it is a four cable system with the cable fixed by hooks on the side of the posts. Second, two cable are placed on either side of the posts and there is no weaving of the cables. Third, the cables seem to be of similar height range as the Gibraltar TL-4 and Brifen TL-4 systems. This system was found only on I-40 in varying locations for a total of 35.5 miles.

Figure 21 U.S. High-Tension Cable System by Nucor Steel Marion Inc.

4. EVALUATE THE PERFORMANCE OF ALL TYPES OF CABLE BARRIERS USED BY ODOT

The experimental Program Tasks lists the sub-components of this section as the creation of a matrix of the various elements used per location. The matrix will include location and height in median. This “matrix” was created as an excel spreadsheet discussed below.

In order to determine the locations and conditions of the cable barriers in Oklahoma, an inventory was taken by locating cable barriers by recorded construction jobs and visiting the cable barrier sites over the months of June and July 2011. During the drive-by, the following data was recorded:

- Start and end of the cable barrier by milepost number
- Median width
- Manufacturer
- Location within the median
- Notes concerning damages or other interesting observations

Extensive picture taking was also performed in case of any discrepancies in the data. The data taken during the drive-by visits were then organized in an Excel sheet with additional data, such as job number and cable heights as provided by manufacturer specifications. Though all of the inventory data can be found in Appendix II, an example of the data spreadsheet used to organize the inventory data is shown in Table 5:

Table 5 Example of Inventory Data Spreadsheet

Section	Mile Start	Mile End	Length (miles)	Median Width (ft)	Distance from Median Center (ft)	Manufacturer	Cable Heights (in)	Job Number	Let Date
35.1.1	0	1.5	1.5	20	2 East	Gibraltar	20, 25, 30, 39	2414104	Nov-07
35.1.2	2.5	6	3.5	30	0	Gibraltar	20, 25, 30, 39	2414104	Nov-07
35.1.3	7.5	10	2.5	20	0	Gibraltar	20, 25, 30, 39	2414104	Nov-07
35.1.4	11	12	1	20	0	Gibraltar	20, 25, 30, 39	2414104	Nov-07
35.2	32	36	4	70	35 East	Blue Systems	18.9, 22, 25.1, 28.3	2407704	Sep-08
35.3.1	36	38	2	70	35 West	Blue Systems	18.9, 22, 25.1, 28.3	2407604	Sep-08
35.3.2	38	41	3	70	35 East	Blue Systems	18.9, 22, 25.1, 28.3	2407604	Sep-08

Blue System's Safence is the most used cable barrier in Oklahoma by mileage, making up almost 50% of all the cable barriers in the state. See Figure 22 for the percentages of cable barriers by type in Oklahoma.

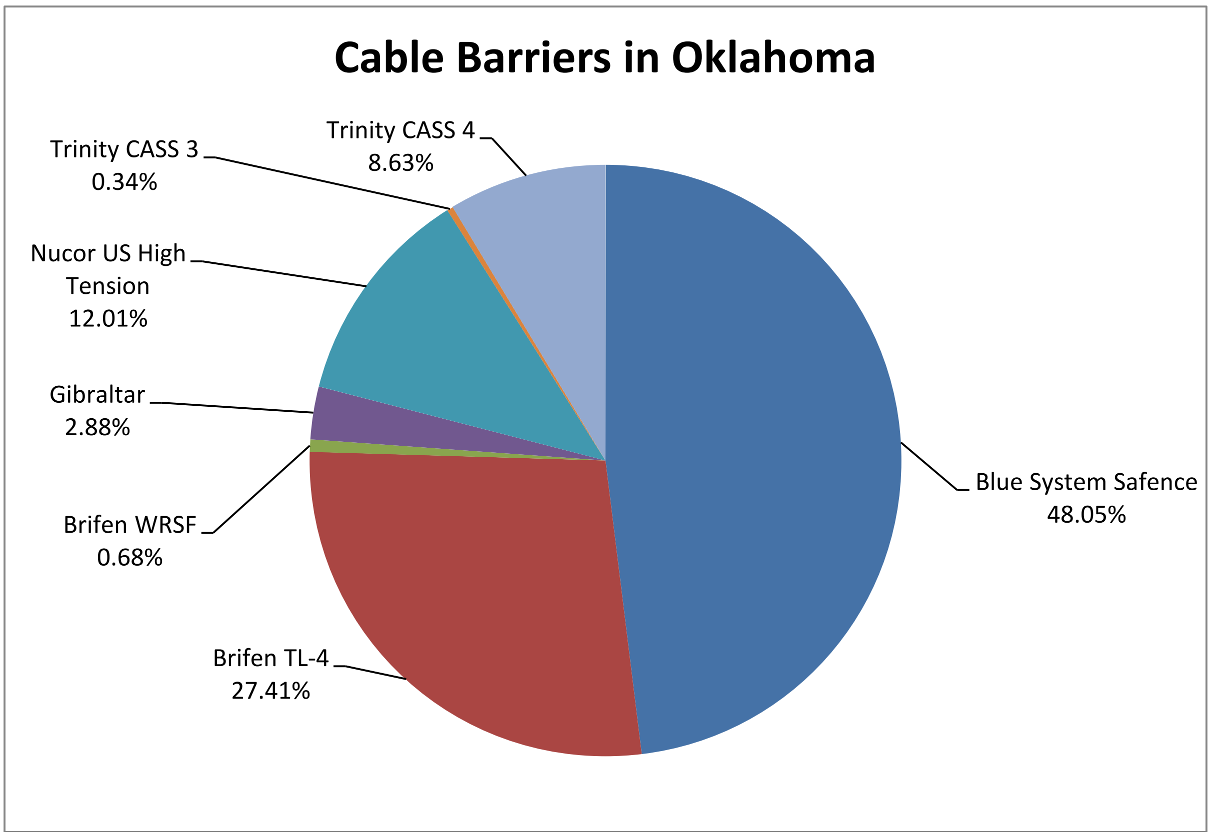

Figure 22 Cable Barrier Types Used in Oklahoma

It is important to note the placement of the cable barriers in Oklahoma, as well, since it may be used in future studies. Out of 302.5 total miles of cable barrier in January 2011, only 85 miles of cable barrier were placed in the center of the median. A majority of the center-oriented cable barriers (40.5 miles) are along I-35. Approximately 28% of the cable barriers are placed in the center of the median in Oklahoma. Many studies have concluded that the center median location decreases the frequency of cable collisions, decreasing the maintenance costs for the cable system, though it increases the median maintenance cost and negatively impacts the drainage.

A large part of the process for determining the need for cable barriers is the width of the median. Through this investigation, it was determined that 55.87% of the cable barriers in Oklahoma are placed in medians of 30ft width. The second most common median width for cable barriers is 40ft (15.54%). Refer to Figure 23 for the percentages of median widths found at cable barrier sites.

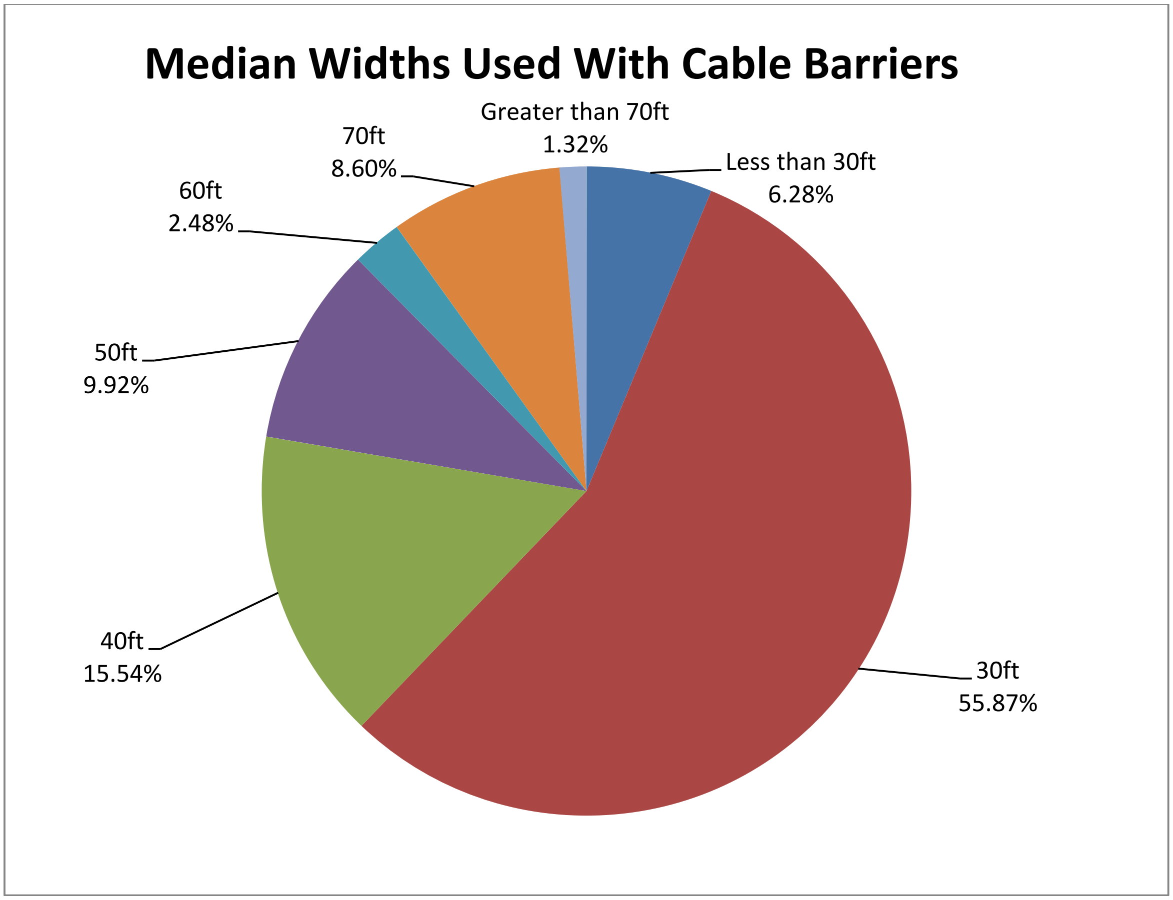

Figure 23 Median Widths Used with Cable Barriers in Oklahoma

The inventory taken of Oklahoma's cable barriers along Interstates 35, 40, and 44 shows where, what, and how cable barriers are placed in the state of Oklahoma.

a. Location in Median

By installing a cable barrier, or any barrier, the median is essentially separated into two sections. This decreases the available recovery zone on either side of the barrier. In most cases, placing the cable barrier directly in the center of the median maximizes the recovery area on both sides of the barrier (Figure 24). However, this is not always possible due to issues such as median geometry and drainage.

Figure 24 Cable Barrier in Center of Median

Another option is to place the barrier directly along one side of the median, usually at the edge of one interior shoulder (Figure 25). This allows the most possible recovery area for

Figure 25 Cable Barrier Along Interior Shoulder

vehicles on one side but does not provide any recovery area for the vehicles in the travelled way closest to the barrier. This type of placement is mostly used along highways where the majority of median crossover crashes originate from only one direction. For example, on a highway with lanes going north and south, the northbound lanes might be the source of most of the median crossover crashes. Therefore, a cable barrier might be placed along the northbound interior shoulder. One problem with this placement is that impacts from the other side, the southbound side in this example, may cause a deflection into the northbound traffic lanes. This possibility is minimized in Oklahoma due to the maximum lateral design deflection of eight feet. It is important to consider the probability of crashes from either travelled way before placing a cable barrier directly next to an interior shoulder. In Oklahoma the placement of cable barriers follow the following guidelines, per Faria Emamian, ODOT Traffic Division:

1. Placing barrier on higher side of median to decrease the possibility of vehicle penetration
2. Changing the placement side to allow median cross over for emergency vehicles
3. Changing the side for existing roadway structures such as bridge piers
4. Changing the side for location of existing rivers or bridge overpass
5. Facilitating median maintenance

A third option for cable barrier location is anywhere between the center of the median and the interior shoulder (Figure 26). This solves any possible drainage problems and provides some recovery area on either side.

Figure 26 Cable Barrier Located Between Center and Edge of Median

b. Cable Heights

Cable heights vary among different cable barrier systems. As discussed all of the seven different types of cable barriers found in Oklahoma have different cable heights, as well as different numbers and placements of cables. When considering low-tension cable barrier systems, there is a much larger variety of different designs. This is because state DOTs can develop their own systems in addition to the cable barrier systems developed by private companies. Since high-tension cable barriers are relatively new, states cannot develop their own systems yet and must rely on private manufacturers, resulting in a smaller variety of systems than low-tension cable barriers. Oklahoma uses only high-tension cable barriers and, thus, has not developed its own cable barrier system.

Among the cable barriers found in Oklahoma, there are three main types of cable placement on the metal posts. Trinity, Blue Systems, and Nucor, US High Tension cable barriers have the cables running through the metal posts, specifically in a vertical slot. Brifen WRSF, Brifen TL-4, and Gibraltar have the cables "woven" between the posts, meaning that one or more of the cable alternate between the sides of the posts. Brifen WRSF and Trinity, CASS 4 place two cables on both sides of each post. All of these placement methods allow equal performance of the cable barrier during impacts from either side. If all of the cable remained on one side of the posts, then the barrier would be most effective during impacts from the side where the cables are fixed. This is because the cable would impact the post, where friction would hold it in place for a longer period of time during the impact.

The cable heights are very important when designing a cable barrier. If the cables are too high, then a smaller vehicle may be able to under ride the barrier. If the cables are too low, they may be overridden by a larger vehicle. If funds were not restricted, a cable barrier could be designed with several cables at a wide range of heights. If there are more cables, the force between the cables and the vehicle would be more evenly distributed and the barrier would be able to take larger impacts. Also, including more cables with a wide range of heights would allow the system to accommodate for larger vehicles, such as tractor trailers. However, as funds are limited and it is not economical, adding more cables to the barrier is not possible. Instead, designers compromise by designing the cable barrier to accommodate the most common impacting vehicles, cars and small trucks. There are no set heights for cables as many companies and organizations are still studying and testing to find the most economical cable barrier designs.

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5. REPAIR AND LANDSCAPING MAINTENANCE COSTS IN THE STATE OF OKLAHOMA

In Oklahoma maintenance costs for the cable barrier systems and the landscaping, or mowing maintenance costs are very difficult to obtain. In general the divisions do not track this specific information, and if they do it is often mixed with other cost items. For instance, Division 1 tracked the cable barrier system materials costs for 10 miles of I-40 in Sequoyah county. They spent approximately $3,000 per year in parts but did not track the cost of labor. Generally labor is at least equal to the material costs but a report generated by Division 5 states their labor cost for cable system maintenance is 13.48%. So, the cost for Division 1 may be between $346.75/mi/year and $600/mi/year.

Data from Urban contractors via Jay Milroy, in July 2009 suggests a maintenance cost of $24,500 for 44.5 miles of cable in Oklahoma County. This would be $6,607/mi/year. Yet this same contractor says that 13.5 miles of cable in Canadian County in a rural area has a maintenance cost of $1,900. This would be $1,689/mi/year. This contractor says that 10.75 miles of cable also in Canadian County but in an area with less traffic has a maintenance cost of $6,150. This would be $6,875/mi/year. Division 5 spent $5,409.25 for 52 miles cable maintenance in June 2009. This would be $1,248/mi/year for a rural area.

In summary the costs that Oklahoma spends on cable barrier maintenance is sensitive to traffic volume, which can crudely be divided into two categories: rural and urban environments. In Oklahoma the cost of cable barrier maintenance in a rural environment ranges from $346/mi/year to $1,248/mi/year, with an average cost of $800/mi/year. While the cost of cable barrier maintenance in an urban environment ranges from $1,689/mi/year to $6,865/mi/year, with an average cost of $5,000/mi/year. If you break the cost down to individual posts the cost differences between the seven systems are minor.

6. ANALYSIS OF ACCIDENTS USING SAFE-T DATA BASE

The Statewide Analysis For Engineering & Technology (SAFE-T) is a traffic event data base that uses Highway Patrol traffic reports and citations as the data source. This system was used to analyze the effectiveness of cable barrier systems in the state of Oklahoma. This analysis covers the period from January 1998 till December 2012. Two types of query's were run. All of the query's used a median width between 1 and 99 feet to limit the search to collision events that occurred on divided highways. For example, a median width of zero would be an undivided highway.

The first type of query was for cross over median collisions where all cable barrier collisions are excluded. A statewide map of the cross median collision events can be seen in Figure 27. Please note that this search was limited to counties that have a cable barrier system installed by December 2012 and had a traffic report due to a collision. The second type of query was for all F.O. cable barrier collisions. A statewide map of the cable barrier collision events can be seen in Figure 28. Please note that red indicates a fatality, blue indicates an injury and green is property damage. Figure 27 represents 1,963 collision events involving fatality or injuries to 2,883 people in 15 years while Figure 28 represents 3,655 collision events involving fatality or injuries to 1,063 people in a period of 9 years. These simple statistics and the maps illustrate that cable barrier systems reduce fatality and injury but increase the number of reported events. Raw data for Oklahoma can be seen in Tables 6 -13.

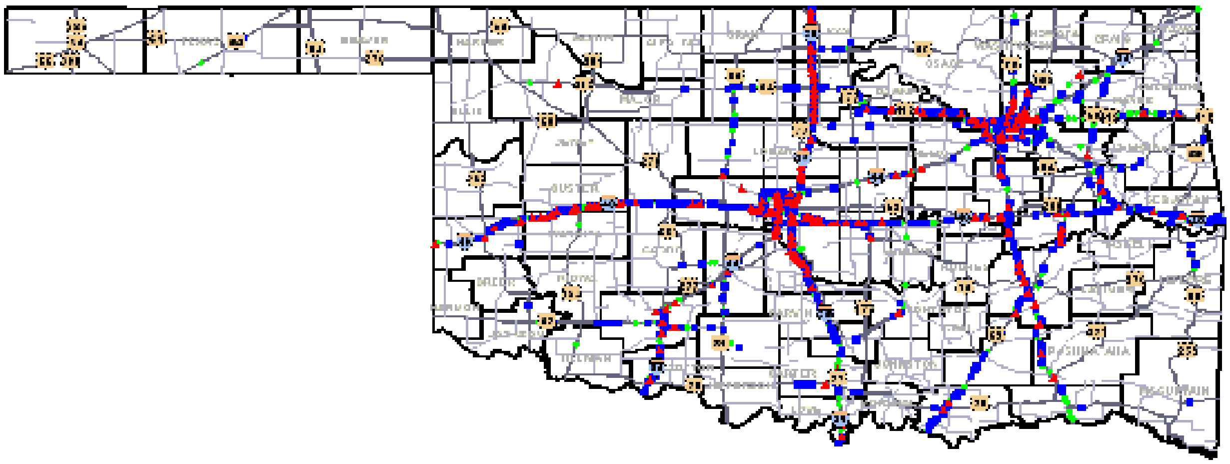

Figure 27 Cross Over Median Collisions 1995 – 2012

Red = Fatality Blue = Injury Light Green = Property Damage

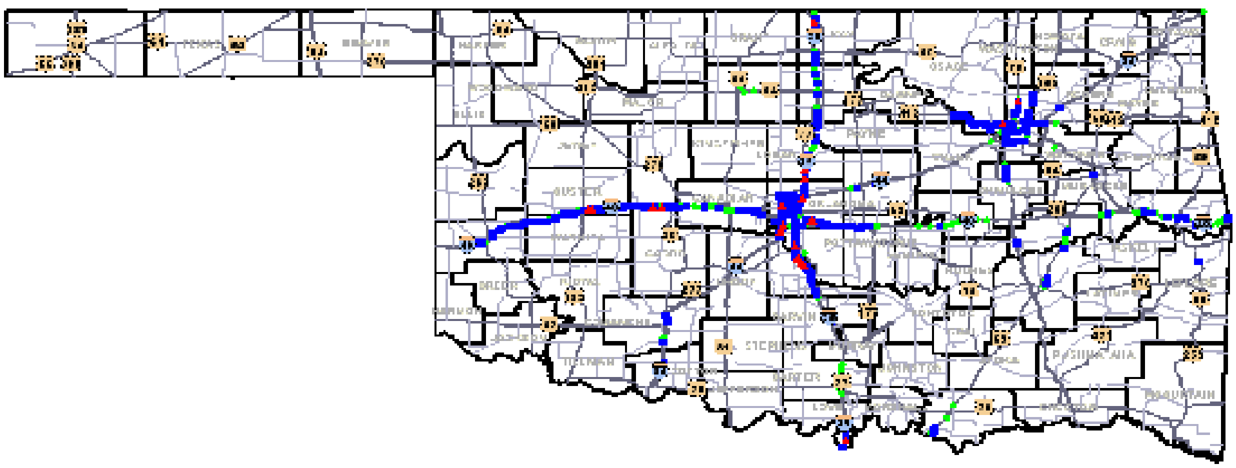

Figure 28 F.O. Cable Barrier Collisions 1995 - 2012

Red = Fatality Blue = Injury Light Green = Property Damage

Table 6 SAFE-T data for Cross Over Median Collisions 1998 - 2005

County			1998			1999			2000			2001			2002			2003			2004			2005		
			Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage
5	Beckham	Collisions		1		2				1		1	2	3		2	1	1	4	2	1		1	1	3	1
		Persons		1		2	3			2		1	4			3		2	5		3	1		1	8	
7	Bryan	Collisions						1	1				4	3		1	1			1		1	2		3	
		Persons							1	1			5			1						1			4	
8	Caddo	Collisions						1		1	1		2	1	1	2	1		2				1		3	1
		Persons								4			3		1	5			2						6	
9	Canadian	Collisions		5	2		3			4	2		1	2	1	2	3		4	5	1	3	3		3	4
		Persons		9			4			8			3		1	3			9		1	10			3	
10	Carter	Collisions			2					2	1		1					1			1	1	1		2	
		Persons								2			2					1	2		1	10			4	
14	Cleveland	Collisions	2	1	5	1	8	6	1	7	1	2	4	2	1	7	4	1	7	4	3	5	4		1	1
		Persons	3	3		1	26		1	31		2	9		1	17		1	12		4	18			2	
20	Custer	Collisions	2	5	1		2	1	1	3	1	1		4		2	4	2	4	3	2	3	4		2	3
		Persons	4	12			4		1	6		1				6		2	12		4	9			3	
24	Garfield	Collisions											2			3						1	1			1
		Persons											2			3						1				
36	Kay	Collisions	1	2					2				2	1	2	1	1		6	1		5			4	2
		Persons	1	5					4	2			3		4	1			16			9			8	
41	Lincoln	Collisions									1						1				1			1		
		Persons																			2	3		1		
42	Logan	Collisions	2			1	4	1					4	1		3	5	1	1	1	1	4	2	1		1
		Persons	6	2		1	7						8			5		1	2		2	13		1	5	
43	Love	Collisions						1	1	1		1	1				1	1	1	2		1				
		Persons							1	2		1	5					1	5			1				
44	McClain	Collisions	2	2		3	1	1	2	5	2	1	4	4	3	6	4	1	7	4	3	5	4	2	6	4
		Persons	2	10		4	9		3	21		1	15		4	24		1	22		5	11		3	13	
46	McIntosh	Collisions	2	3		1	2			1	3	1	3		2	2	1		1	1		1				
		Persons	3	9		2	3			1		1	10		2	2			2			1				
51	Muskogee	Collisions		2			1			2			1		1				6			1				
		Persons		2			2			4			4		3	1			9			1				

Table 7 SAFE-T data for Cross Over Median Collisions 1998 – 2005 (Continued)

County			1998			1999			2000			2001			2002			2003			2004			2005		
			Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage
52	Noble	Collisions		1		1		1		4	2		5		1	3	4	1	5	3		2		1	2	2
		Persons		5		2				12			10		1	4		1	7			3		1	4	
55	Oklahoma	Collisions	6	18	4	6	25	7	2	25	12	2	31	10	9	27	14	3	18	7	6	20	14	1	7	10
		Persons	9	56		8	77		2	68		3	66		11	79		5	51		8	49		1	17	
56	Okmulgee	Collisions	1							1					1		1		1		1	2	1		1	
		Persons	1	1						3					3	3			1		1	9			3	
57	Osage	Collisions																								
		Persons																								
58	Ottawa	Collisions						1						1												
		Persons																								
59	Pawnee	Collisions	1	2				1	1				2	1		5	3			2	1	1			1	
		Persons	1	10					2	1			9			6					1	1			3	
60	Payne	Collisions	1	1					2				2			2	3	1	1			2			1	
		Persons	1	2					4	6			3			2		1	5			4			2	
61	Pittsburg	Collisions		1			1					1	1			4	2	1	1	2	3	2	1	1	2	1
		Persons		2			2					1	6			6		1	3		4	14		1	2	
63	Pottawatomie	Collisions	1			1	1	1				2	1			3					1	2	1		4	
		Persons	1	2		2	3					2	5			10					1	13			9	
66	Rogers	Collisions		2		1	1	1							1	4	2	1	1	1			2	1	4	
		Persons		5		2	4								1	9		1	9					1	6	
68	Sequoyah	Collisions		1			1	1	1	1	3		2	1		2	1	1	2			1	2		2	
		Persons		1			2		1	2			5			3		1	4			2			4	
72	Tulsa	Collisions	2	11	7	2	14	4	2	16	9	4	23	9	6	16	5	2	12	2	5	20	6	4	12	7
		Persons	2	34		4	34		2	39		4	51		6	35		2	28		6	47		4	21	
73	Wagoner	Collisions											1			1						1	1			1
		Persons											2			1						2				
75	Washita	Collisions			1	1	2			1				2		3	2			1	1	2	1		1	
		Persons				3	13			3						7					1	7			1	
		Collisions	23	58	22	20	66	29	16	75	38	16	99	45	29	101	64	18	84	42	31	86	52	13	64	39
		Persons	34	171	0	31	193	0	22	218	0	17	230	0	38	236	0	21	206	0	44	240	0	14	128	0
		Total	57	229	22	51	259	29	38	293	38	33	329	45	67	337	64	39	290	42	75	326	52	27	192	39

Table 8 SAFE-T data for Cross Over Median Collisions 2006 - 2012

County			2006			2007			2008			2009			2010			2011			2012						
			Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Total
5	Beckham	Collisions		3	1		2			2	2		2	2			1					2		6	24	14	49
		Persons		7			3			2			4									4		9	47	0	56
7	Bryan	Collisions			3	1	3	1		2	3		3	1		4	3			1		3	1	2	24	21	54
		Persons				1	5			2			3			9						5		2	36	0	38
8	Caddo	Collisions		2	3		4			1	1		2	4			1		1			1		1	21	15	45
		Persons		3			6			4			2						7			1		1	43	0	44
9	Canadian	Collisions	1	4	2	1	4	4	2	4	2		7	3		2	1		5	4	2	2	2	8	53	39	109
		Persons	1	9		1	5		2	8			13			4			8		2	4		8	100	0	108
10	Carter	Collisions			2			2					4	1		2				1		1		2	13	10	35
		Persons											5			2						2		2	29	0	31
14	Cleveland	Collisions		2		1	1	1	1	2	1	1		2		1	3					1	1	14	47	35	110
		Persons		3		4	1		1	5		1	1			3						2		19	133	0	152
20	Custer	Collisions	3	7	3	1	5	4		6	1		3									1		12	43	29	104
		Persons	9	15		2	7			7			3									1		23	85	0	108
24	Garfield	Collisions								2							2		1				1	0	9	5	38
		Persons								3									3					0	12	0	12
36	Kay	Collisions	1	2		2	3	2		3	4		2	1					1			1		8	32	12	88
		Persons	1	5		3	7			4			4						1			1		13	66	0	79
41	Lincoln	Collisions				1				1						1								3	2	2	48
		Persons				1				6						1								4	10	0	14
42	Logan	Collisions	1	3	2	1	5	3		1		1	3	2			1	1			1	2	1	11	30	20	103
		Persons	1	11		3	9			2		1	6					1	1		1	2		18	73	0	91
43	Love	Collisions		1	2			1					1	1		1						1	3	3	8	11	65
		Persons		3									1			1						1		3	19	0	22
44	McClain	Collisions	2	6	8	1	3	4	1	3				2		3								21	51	37	153
		Persons	2	17		1	4		1	6						4								27	156	0	183
46	McIntosh	Collisions		2	1		1		1	3	1		4		1	4	5	1	1			1		9	29	12	96
		Persons		4			2		1	4			8		1	5		7	3			2		17	56	0	73
51	Muskogee	Collisions		1						4	1		3	3	1	2	2		1	1	1	2	2	3	26	9	89
		Persons		1						6			4		1	3			2		1	4		5	43	0	48

Table 9 SAFE-T data for Cross Over Median Collisions 2006 - 2012(Continued)

County			2006			2007			2008			2009			2010			2011			2012						
			Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Total
52	Noble	Collisions		2	4	2		3		1	5	2	9	8	1	2	2		5	1	1	2	2	10	43	37	142
		Persons		5		2	1			7		4	24		1	5			11		1	3		13	101	0	114
55	Oklahoma	Collisions	4	19	12	5	22	9	4	9	9	1	7	6		9	4			1	3	2	5	52	239	124	470
		Persons	4	54		6	45		6	30		1	11			13					3	9		67	625	0	692
56	Okmulgee	Collisions		1	1	1				3	2	1	5	1		2			2	1		1		5	19	7	87
		Persons		2		1				4		1	9			4			7			2		7	48	0	55
57	Osage	Collisions																						0	0	0	57
		Persons																						0	0	0	0
58	Ottawa	Collisions																						0	0	2	60
		Persons																						0	0	0	0
59	Pawnee	Collisions			2	1	2	1		1	2		3	6	1	3	5	2	3	1	1	1		8	24	24	115
		Persons				1	5			1			8		1	5		2	7		1	3		9	59	0	68
60	Payne	Collisions		1						1	2		3	1		1	1		5			2		4	22	7	93
		Persons		1						2			5			1			7			2		6	42	0	48
61	Pittsburg	Collisions		1		1		2	2	1			1	3		3	2		3	2		4		9	25	15	110
		Persons		2		1	1		2	6			1			5			4			14		10	68	0	78
63	Pottawatomie	Collisions	1	4		1	4			5	1					1	1					1		7	26	4	100
		Persons	2	7		1	9			9						1						1		9	69	0	78
66	Rogers	Collisions		3	1	1	1	1		2	3		3	1		3	2	1	2	1		1		6	27	15	114
		Persons		6		1	7			2			6			7		1	7			2		7	70	0	77
68	Sequoyah	Collisions	1	5		1	2	2		2	3		1	5		1	1		2	2		1	1	4	26	22	120
		Persons	3	7		1	4			6			1			3			3			1		6	48	0	54
72	Tulsa	Collisions	1	19	3	2	8	3	3	15	7	2	6	8	2	2	1		10	4		4	6	37	188	81	378
		Persons	6	45		2	23		4	31		2	8		2	5			16			11		46	428	0	474
73	Wagoner	Collisions		1	1		2			2	1		4	1		2	1	1				1	4	1	15	10	99
		Persons		1			2			3			5			2		1	1			3		1	22	0	23
75	Washita	Collisions				1	4		1	2	1		2		1	1							1	5	18	9	107
		Persons				7	9		1	5			3		1	2								13	50	0	63
		Collisions	15	89	51	25	76	43	15	78	52	8	78	62	7	50	39	6	42	20	9	38	30	251	1084	628	1963
		Persons	29	208	0	39	155	0	18	165	0	10	135	0	7	85	0	12	88	0	9	80	0	345	2538	0	2883
		Total	44	297	51	64	231	43	33	243	52	18	213	62	14	135	39	18	130	20	18	118	30	596	3622	628	

Table 10 SAFE-T data for F.O. Cable Barrier Collisions 1998 - 2005

County			1998			1999			2000			2001			2002			2003			2004			2005		
			Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage
5	Beckham	Collisions																								
		Persons																								
7	Bryan	Collisions																								
		Persons																								
8	Caddo	Collisions																								
		Persons																								
9	Canadian	Collisions																								
		Persons																								
10	Carter	Collisions																								
		Persons																								
14	Cleveland	Collisions																					1	6		6	21
		Persons																					1			6	
20	Custer	Collisions																								
		Persons																								
24	Garfield	Collisions																								
		Persons																								
36	Kay	Collisions																								
		Persons																								
41	Lincoln	Collisions																								
		Persons																								
42	Logan	Collisions																								
		Persons																								
43	Love	Collisions																								
		Persons																								
44	McClain	Collisions																						2			1
		Persons																								
46	McIntosh	Collisions																								
		Persons																								
51	Muskogee	Collisions																								
		Persons																								

Table 11 SAFE-T data for F.O. Cable Barrier Collision 1998 – 2005 (Continued)

	County		1998			1999			2000			2001			2002			2003			2004			2005		
			Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage
52	Noble	Collisions																								
		Persons																								
55	Oklahoma	Collisions											5	9		4	24		3	21		11	32		10	33
		Persons											6			5			4			11			11	
56	Okmulgee	Collisions																								
		Persons																								
57	Osage	Collisions																								
		Persons																								
58	Ottawa	Collisions																								
		Persons																								
59	Pawnee	Collisions																								
		Persons																								
60	Payne	Collisions																								
		Persons																								
61	Pittsburg	Collisions																								
		Persons																								
63	Pottawatomie	Collisions																								
		Persons																								
66	Rogers	Collisions																								
		Persons																								
68	Sequoyah	Collisions																								
		Persons																								
72	Tulsa	Collisions																								
		Persons																								
73	Wagoner	Collisions																								
		Persons																								
75	Washita	Collisions																								
		Persons																								
		Collisions	0	0	0	0	0	0	0	0	0	0	5	9	0	4	24	0	3	21	0	12	40	0	16	55
		Persons	0	0	0	0	0	0	0	0	0	0	6	0	0	5	0	0	4	0	0	12	0	0	17	0
		Total	0	0	0	0	0	0	0	0	0	0	11	9	0	9	24	0	7	21	0	24	40	0	33	55

Table 12 SAFE-T data for F.O. Cable Barrier Collision 2006- 2012

County			2006			2007			2008			2009			2010			2011			2012						
			Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Total
5	Beckham	Collisions											4	8		3	17		7	11		6	7	0	20	43	63
		Persons											8			5			10			8		0	31	0	31
7	Bryan	Collisions									6		1	6		1	4		3	9		1	6	0	6	31	37
		Persons											1			2			3			1		0	7	0	7
8	Caddo	Collisions								1	6		7	21	1	7	22	1	2	23		6	26	2	23	98	123
		Persons								1			10		1	11		1	3			9		2	34	0	36
9	Canadian	Collisions								3	3		3	15		2	4			12		9	39	0	17	73	90
		Persons								6			3			5						12		0	26	0	26
10	Carter	Collisions												7		1	8		2	9			27	0	3	51	54
		Persons														1			3					0	4	0	4
14	Cleveland	Collisions		2	29		13	57	1	9	39	1	16	38		5	23		9	23		5	24	2	66	260	328
		Persons		2			21		1	13		1	18			5			10			8		2	84	0	86
20	Custer	Collisions									15		7	27		5	34	2	7	40		11	45	2	30	161	193
		Persons											7			8		2	8			12		2	35	0	37
24	Garfield	Collisions						2												1				0	0	3	3
		Persons																						0	0	0	0
36	Kay	Collisions								1	2	1	3	11		4	8		3	8		3	13	1	14	42	57
		Persons								1		1	3			7			3			8		1	22	0	23
41	Lincoln	Collisions								2	1													0	2	1	3
		Persons								3														0	3	0	3
42	Logan	Collisions								2	19		4	17		4	22	1	6	23	2	2	31	3	18	112	133
		Persons								3			4			4		1	8		2	2		3	21	0	24
43	Love	Collisions									10		5	17	1	1	16		2	14		1	14	1	9	71	81
		Persons											5		1	1			2			1		1	9	0	10
44	McClain	Collisions			10	1	6	25		13	50		9	50		6	44	1	7	55	1	17	24	3	58	261	322
		Persons				1	12			17			12			8		1	18		1	21		3	88	0	91
46	McIntosh	Collisions											1	4			7		2	2		1	5	0	4	18	22
		Persons											1						4			2		0	7	0	7
51	Muskogee	Collisions															2		1	5		1	3	0	2	10	12
		Persons																	1			1		0	2	0	2

Table 13 SAFE-T data for F.O. Cable Barrier Collision 2006 – 2012 (Continued)

	County		2006			2007			2008			2009			2010			2011			2012						
			Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Fatality	Injury	Physical Damage	Total
52	Noble	Collisions														1	10		3	13		1	9	0	5	32	37
		Persons														1			3			1		0	5	0	5
55	Oklahoma	Collisions		2	25		7	42	1	26	91	1	56	194		49	154		35	174	4	54	161	6	262	960	1228
		Persons		3			10		1	37		1	72			69			50		4	76		6	354	0	360
56	Okmulgee	Collisions											1	7		1	3		1	9		4	10	0	7	29	36
		Persons											2			2			1			7		0	12	0	12
57	Osage	Collisions											1	1			1		1				2	0	2	4	6
		Persons											2						1					0	3	0	3
58	Ottawa	Collisions												1										0	0	1	1
		Persons																						0	0	0	0
59	Pawnee	Collisions											2	11		2	2			3		1	4	0	5	20	25
		Persons											3			2						1		0	6	0	6
60	Payne	Collisions						1								1			2	13		3	4	0	6	18	24
		Persons														1			2			5		0	8	0	8
61	Pittsburg	Collisions								1	2			6		3	3		1	5		2	4	0	7	20	27
		Persons								6						3			1			3		0	13	0	13
63	Pottawatomie	Collisions								1	6		6	24		8	32		5	29		6	18	0	26	109	135
		Persons								1			7			14			5			9		0	36	0	36
66	Rogers	Collisions								2	2		2	9		5	7		1	6		5	6	0	15	30	45
		Persons								3			3			9			1			11		0	27	0	27
68	Sequoyah	Collisions						1		2	7		1	14		2	24		7	23		4	28	0	16	97	113
		Persons								2			1			2			10			4		0	19	0	19
72	Tulsa	Collisions					2			8	25	1	30	80		28	56	1	27	70	1	26	56	3	121	287	411
		Persons					2			10		1	44			34		1	39		1	36		3	165	0	168
73	Wagoner	Collisions									1													0	0	1	1
		Persons																						0	0	0	0
75	Washita	Collisions											1	1		1	9		8	9		5	11	0	15	30	45
		Persons											1			1			11			6		0	19	0	19
		Collisions	0	4	64	1	28	128	2	71	285	4	160	569	2	140	512	6	142	589	8	174	577	23	759	2873	3655
		Persons	0	5	0	1	45	0	2	103	0	4	207	0	2	195	0	6	197	0	8	244	0	23	1040	0	1063
		Total	0	9	64	2	73	128	4	174	285	8	367	569	4	335	512	12	339	589	16	418	577	46	1799	2873	

Figures 29 through 34 evaluate different aspects of the SAFE-T data set for Oklahoma counties that have cable barrier systems in place with at least one traffic report incident by December 2012. Please note that the State of Oklahoma installed the first cable barrier on the Hefner Parkway in Oklahoma in 2001. ODOT evaluated this system for several years before installing the next cable barrier system in 2004.

Figures 29 through 34 are presented in pairs. The graph at the top of the page will always be the cross over median collision data with an exponential trend line to help identify trends. The graph at the bottom of the page will always be the cable barrier collision data with a moving average trend line.

Figures 29 and 30 present the number of fatalities due to cross over median collisions or from cable barrier collisions. From 1998 till 2007 the state of Oklahoma was averaging around 29 fatalities a year due to these events, in 2010 that number has dropped to 9, in 2011 it was 18 and in 2012 it was 17.

Figures 31 and 32 present the number of injuries due to cross over median collisions or from cable barrier collisions. From 1998 till 2007 the state of Oklahoma was averaging around 200 injuries a year due to these events. But between 2009 - 2012 this number has increased to around 300. This illustrates that while cable barriers are significantly reducing the number of fatalities they are increasing the number of reported injuries.

Figures 33 and 44 illustrate the number of collision events that resulted in property damage. From 1998 till 2007 the state of Oklahoma was averaging around 50 events a year that resulted in property damage. But between 2009 and 2012 this number has increased tenfold to around 580.

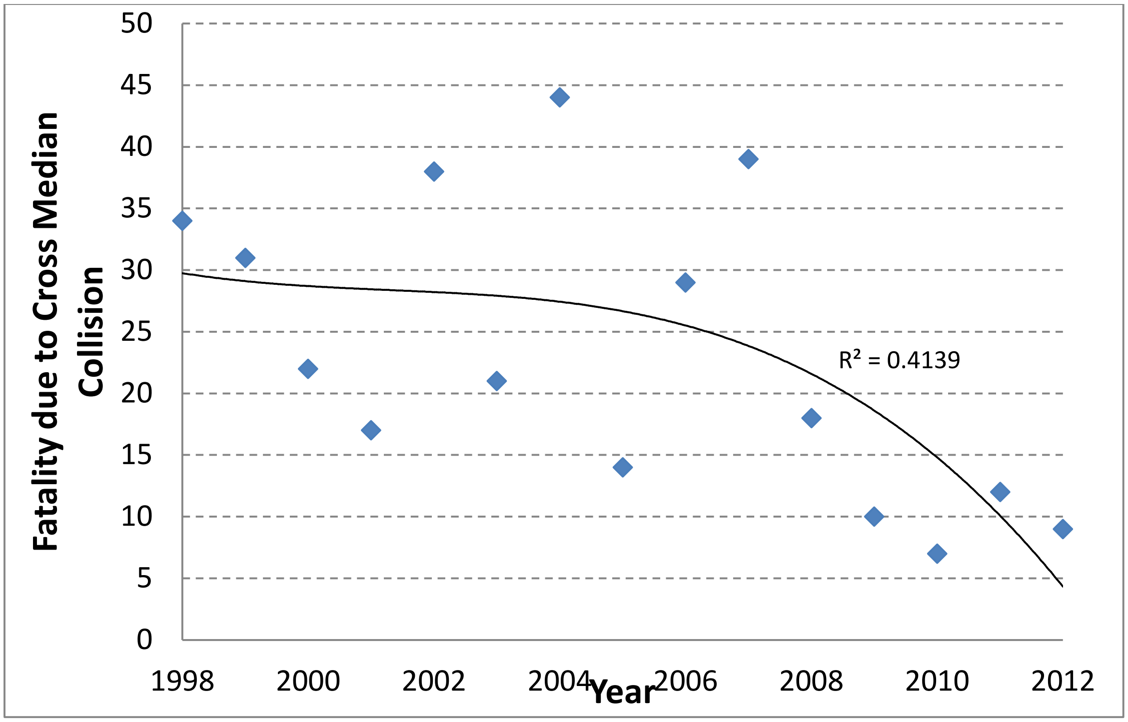

Figure 29 Fatality due to Across Median Collision Event

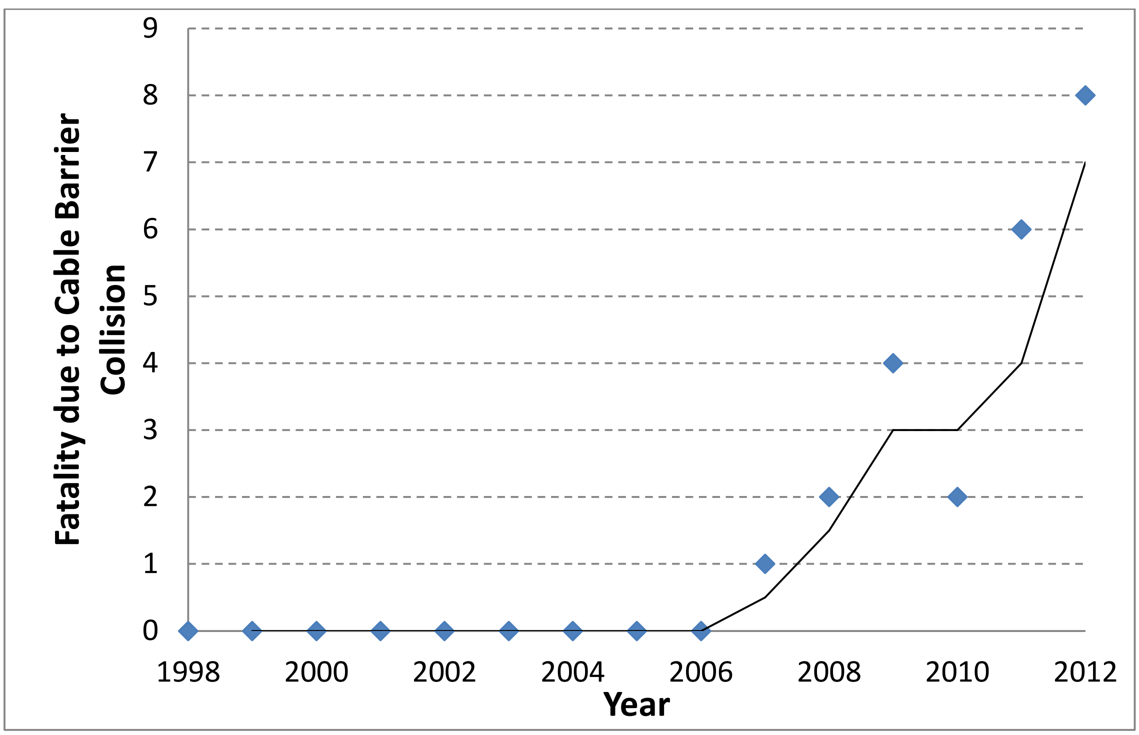

Figure 30 Fatality due to Cable Barrier Collision

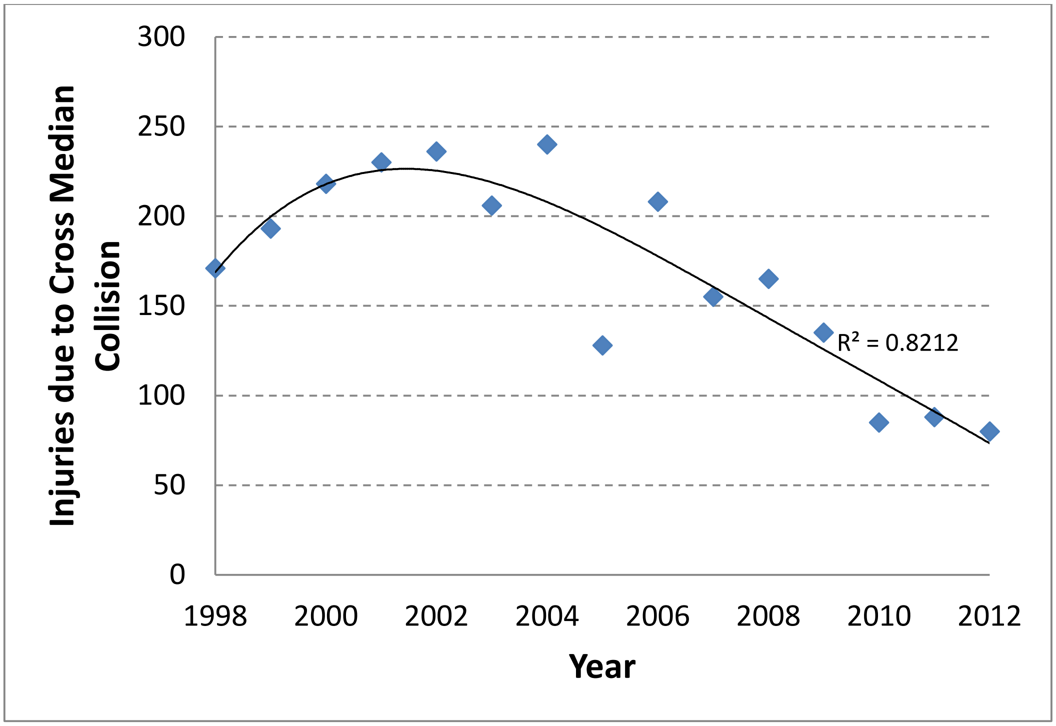

Figure 31 Injuries due to Across Median Collision

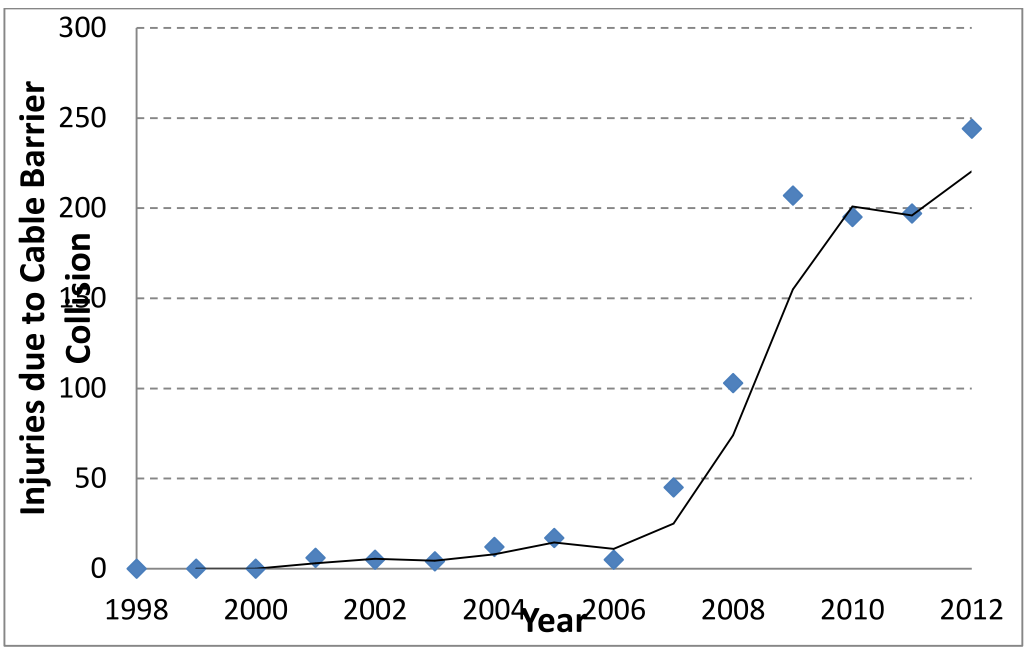

Figure 32 Injuries due to Cable Barrier Collision

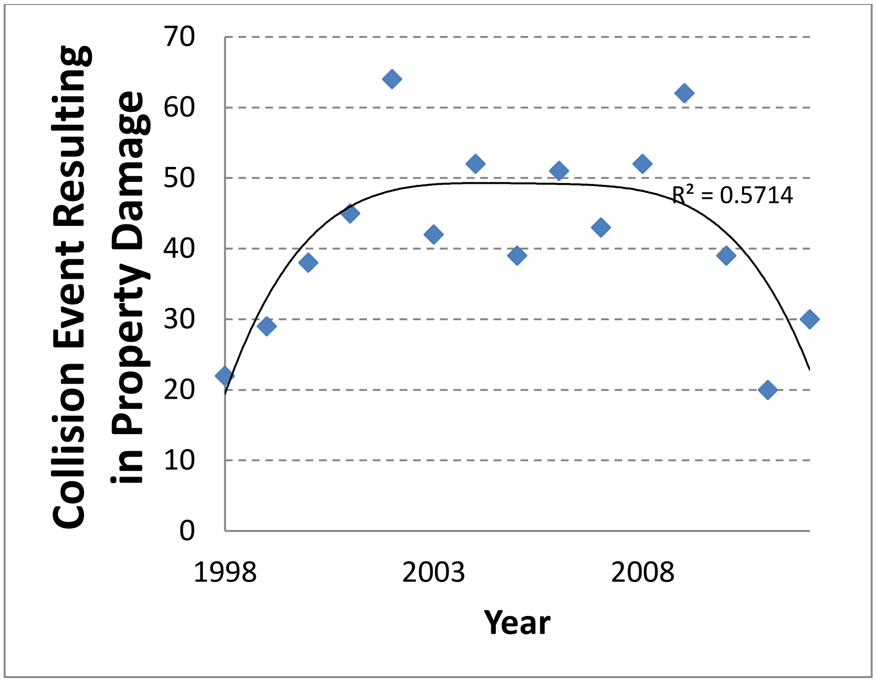

Figure 33 Across Median Collision Events Resulting in Property Damage

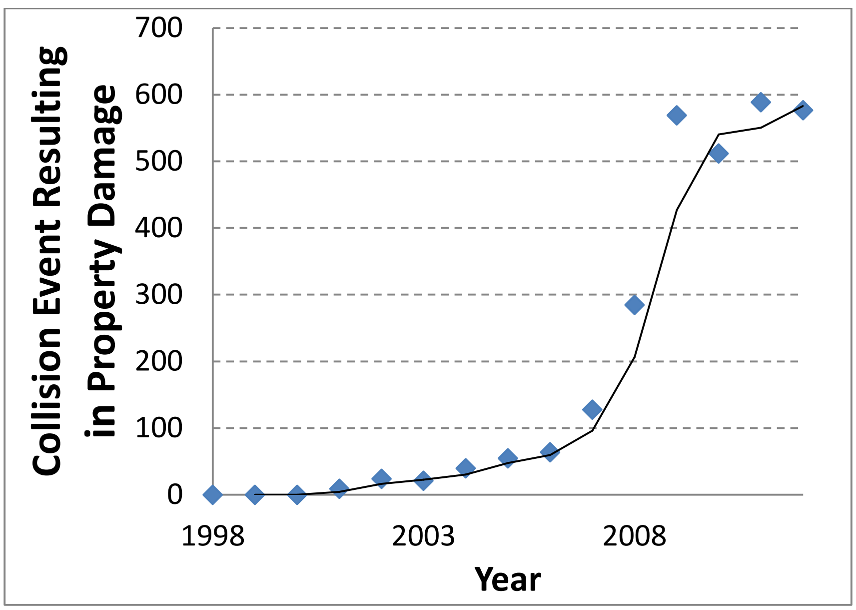

Figure 34 F.O. Cable Barrier Collision Events Resulting in Property Damage

7. MULTI-VARIANT REGRESSION ANALYSIS OF ACCIDENTS

A multi-variant regression analysis of the cross median and cable collision data set. This analysis was performed in SPSS using 143,784 discrete data points among the following variables:

1. County
2. City
3. Control #
4. Milepoint
5. Highway name
6. Highway class
7. Special features
8. Number injured
9. Number killed
10. Type of collision
11. Severity
12. Date
13. Alcohol related
14. Drug related
15. Control Section number
16. Day of the week
17. Light conditions
18. Manner of Collision
19. Weather Conditions
20. Median Type, and
21. Median Width

There have been a total of 23 (0.6%) people killed in collisions classified as cable barrier collisions between 1995 and 2012. These collisions are classified as:

- 8 involve a rollover
- 3 are Head-on collisions
- 2 occurred in construction zones
- 4 are classified as F-O Barrier Cable
- 4 are classified as Rear - End
- 2 are classified as Angle (other or right)
- 1 is classified as sideswipe - opposite

Cable barriers are not designed to stop a vehicle that is in the act of a rollover. The two fatalities in a construction zone should also be removed from the cable barrier collisions. Four of the events have the median classified as a #1 “open type with shoulders” and not as a #8 “cable barrier”. This makes some of the fatality data for the cable barrier collisions suspect. Three of the fatalities involved alcohol and none involved drugs. 11 occurred in the daylight, 6 in “not lighted dark” and 3 in a “lighted dark” and two at dawn or dusk. In only one case was it raining. In general the number of fatalities is so small that a good correlation between variables could not be determined. In 300+ miles of cable barrier, over a period of roughly 6 years, an average of 2 fatality per year due to collisions with cable barriers. This suggests that the data presented in Figure 30 incorrectly overstates fatalities.

2,917 (78.6%) cable barrier collisions between 1995 and 2012 resulted in no injuries. 375 (10.1%) resulted in “possible injuries” while 296 (8%) resulted in “non-incapacitating injury”. Only 97 (2.6%) resulted in an “incapacitating injury”.

If a vehicle is involved in a cross median collision and a cable barrier is not present, the likelihood of a fatality rises from 0.6% to 12.2%. 277 (12.2%) cross median collisions between 1995 and 2012 resulted in a fatality. 755 (33.2%) cross median collisions resulted in no injury.

355 (15.6%) resulted in “possible injuries” while 567 (24.9%) resulted in “non-incapacitating injury”. And 320 (14.1%) resulted in an “incapacitating injury”.

Table 14 Collision Severity vs. Type of Collision

	Cross Over Median Collision	Cable Barrier Collision
Fatality	12.2%	0.6%
Incapacitating Injury	14.1%	2.6%
Non-Incapacitating Injury	24.9%	8%
Possible Injuries	15.6%	10.1%
No Injury	33.2%	78.6%

8. Conclusion

There are many different guidelines that are used when trying to warrant the use of median barriers including the cable barrier systems. Regardless of what guideline is used, the fact remains that cable barriers save lives and reduce serious injury. In Oklahoma approximately 20 people per year will not become a fatality statistic due to cable barriers. On March 18, 2009 the Office of the Secretary of Transportation published a guidance memorandum on the “Treatment of the Economic Value of a Statistical Life”. This memorandum stated that the “…value of preventing a human fatality is $5.8 million.” Using this value of a statistical life the cable barrier system saves 20 lives a year with a societal cost savings of approximately $116 million dollars per year.

Cable barriers also offer a low initial cost alternative to concrete or metal guard rail systems. It is true that as the number of median barriers increase, so do the number of collisions. But these collisions are low severity events with minimal loss of life or injury. This is a small price to pay when the alternative is the possibly a fatality or much more sever injury. The total cost over an extended service life still favors the cable barrier system. Cable barriers provide an effective system for saving lives and will only continue to be improved.

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9. References

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1. Appendix – Photographic Documentation

Interstate 35:

Section 35.1.1

Section 35.1.2

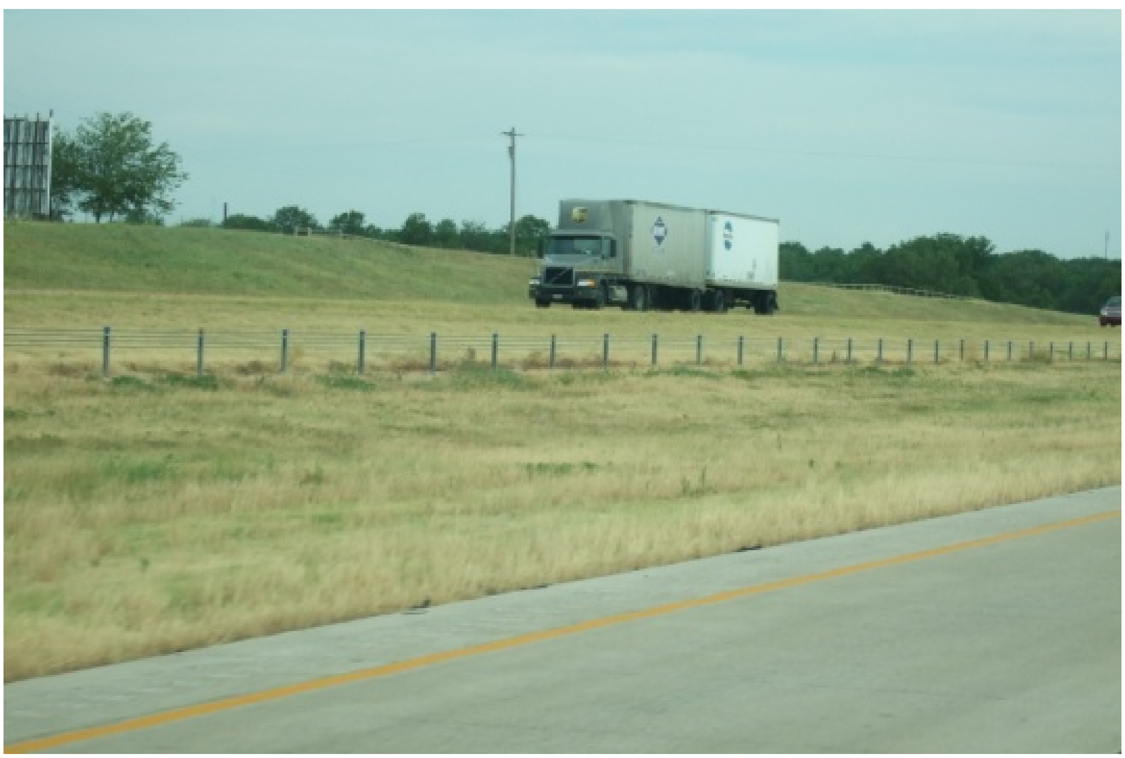

Section 35.1.3


Section 35.1.4

Section 35.2

Section 35.3.1

Section 35.3.2



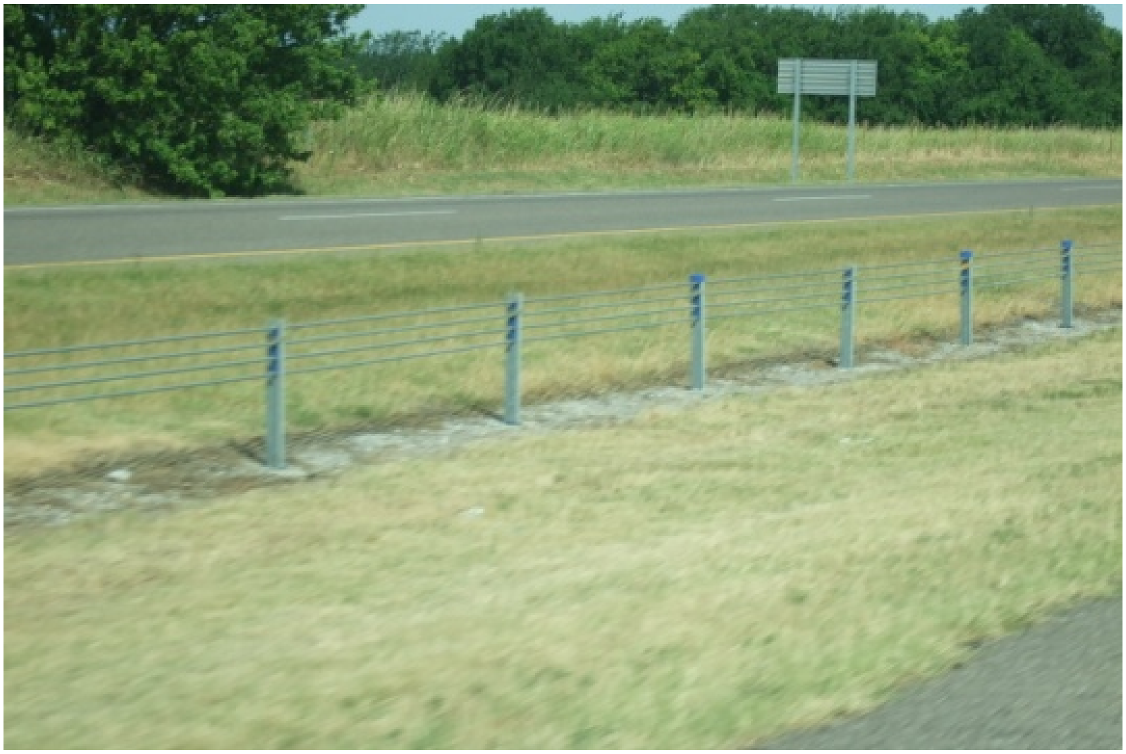
Section 35.4

Section 35.5

Section 35.6.1

Section 35.6.2

Section 35.7


Section 35.6.3


Section 35.8


Section 35.9


Section 35.10.1

Section 35.10.2

Section 35.10.3

Section 35.11

Section 35.12.1

Section 35.12.2

Section 35.12.5


Section 35.12.6


Section 35.13.1

Section 35.13.2

Section 35.13.3


Section 35.13.4


Section 35.14.1


Section 35.14.2


Section 35.15.1

Section 35.15.2

Section 35.16.1


Section 35.16.2


Section 35.16.3


Section 35.7


Section 35.8

Section 35.19.1

Section 35.19.2

I-40 Cable Barriers:

Section 40.1

Section 40.2


Section 40.3.1


Section 40.3.2

Section 40.3.3

Section 40.4.1


Section 40.4.2


Section 40.4.3


Section 40.5


Section 40.6.1

Section 40.6.2

Section 40.6.3


Section 40.7


Section 40.8


Section 40.9.1


Section 40.9.2


Section 40.10


Section 40.11


Section 40.12


Section 40.13


Section 40.14


Section 40.15

Section 40.16.1

Section 40.16.2

Section 40.17.1

Section 40.17.2


Section 40.17.3


Section 40.17.4


Section 40.17.5


Section 40.18.1


Section 40.18.2


Section 40.19.1


Section 40.19.2


Section 40.19.3

Section 40.20

Section 40.21.1

Section 40.22.1

Section 40.22.2

Section 40.22.3

Section 40.22.4

Section 40.23.2

Section 40.23.3


Section 40.24.1


Section 40.24.2

Section 40.25.1

Section 40.25.2

Section 40.25.3

Interstate 44:

Section 44.1

Section 44.2

Section 44.3.1

Section 44.3.2

Section 44.4.1

Section 44.4.2

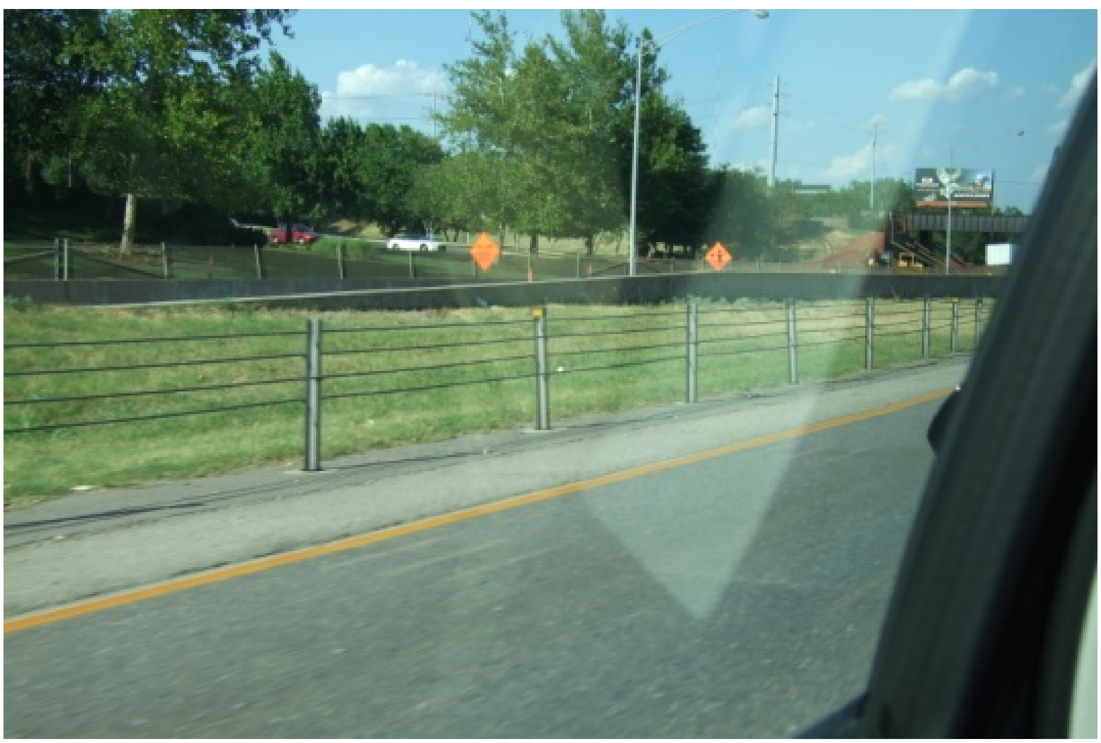

Section 44.5.1


Section 44.5.2


Section 44.5.3


Section 44.5.4

Section 44.5.5



Section 44.5.6

Section 44.6.2

Section 44.6.3

Section 44.6.4

Section 44.6.5

Section 44.7

2. APPENDIX – INVENTORY DATA

Interstate 35

Section	Mile Start	Mile End	Length (miles)	Median Width (ft)	Distance from Median Center (ft)	Manufacturer	Cable Heights (in)	Job Number	Let Date
35.1.1	0	1.5	1.5	20	2 East	Gibraltar	20, 25, 30, 39	2414104	Nov-07
35.1.2	2.5	6	3.5	30	0	Gibraltar	20, 25, 30, 39	2414104	Nov-07
35.1.3	7.5	10	2.5	20	0	Gibraltar	20, 25, 30, 39	2414104	Nov-07
35.1.4	11	12	1	20	0	Gibraltar	20, 25, 30, 39	2414104	Nov-07
35.2	32	36	4	70	35 East	Blue Systems	18.9, 22, 25.1, 28.3	2407704	Sep-08
35.3.1	36	38	2	70	35 West	Blue Systems	18.9, 22, 25.1, 28.3	2407604	Sep-08
35.3.2	38	41	3	70	35 East	Blue Systems	18.9, 22, 25.1, 28.3	2407604	Sep-08
35.4	66	73	7	70	5 West	Blue Systems	18.9, 22, 25.1, 28.3	2418204	2008*
35.5	81	85.5	4.5	60	0	Blue Systems	18.9, 22, 25.1, 28.3	2626604	Oct-10
35.6.1	89.5	94.5	5	30	0	Blue Systems	18.9, 22, 25.1, 28.3	2307204	2006*
35.6.2	96	98.5	2.5	30	0	Blue Systems	18.9, 22, 25.1, 28.3	2307204	2006*
35.7	98.5	99.5	1	30	7 East	Trinity	20.75, 25.25, 29.5		Aug-05
35.6.3	99.5	107	7.5	30	0	Blue Systems	18.9, 22, 25.1, 28.3	2307204	2006*
35.8	108	110	2	25	0	Brifen WRSF	20, 26.5(x2), 28.5	2066804	Sep-03
35.9	133.5	138	4.5	20	10 East	Blue Systems	18.9, 22, 25.1, 28.3	2414804	Jan-08
35.10.1	141.5	148	6.5	30	10 East	Brifen TL-4	18.9, 24.8, 30.7, 36.6		
35.10.2	148	149.5	1.5	30	10 West	Brifen TL-4	18.9, 24.8, 30.7, 36.6		
35.10.3	151.5	153	1.5	30	0	Brifen TL-4	18.9, 24.8, 30.7, 36.6		
35.11	153.5	157.5	4	30	0	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2408504	Jun-07
35.12.1	157.5	161	3.5	30	10 East	Blue Systems	18.9, 22, 25.1, 28.3	2623704	Jan-10
35.12.2	161	162.5	3	30	10 West	Blue Systems	18.9, 22, 25.1, 28.3	2623704	Jan-10
35.12.3	162.5	163	0.5	60	25 West	Blue Systems	18.9, 22, 25.1, 28.3	2623704	Jan-10
35.12.4	163	164	1	30	10 West	Blue Systems	18.9, 22, 25.1, 28.3	2623704	Jan-10
35.12.5	164	169.5	5.5	30	10 East	Blue Systems	18.9, 22, 25.1, 28.3	2623704	Jan-10
35.12.6	169.5	170.5	1	100+	50+ West	Blue Systems	18.9, 22, 25.1, 28.3	2623704	Jan-10
35.13.1	174.5	175.5	1	70	30 West	Blue Systems	18.9, 22, 25.1, 28.3	2626404	May-10
35.13.2	175.5	178	2.5	40	15 East	Blue Systems	18.9, 22, 25.1, 28.3	2626404	May-10
35.13.3	178	179	1	40	15 West	Blue Systems	18.9, 22, 25.1, 28.3	2626404	May-10
35.13.4	179	180.5	1.5	30	10 East	Blue Systems	18.9, 22, 25.1, 28.3	2626404	May-10
35.14.1	182.5	184	1.5	30	10 East	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2423204	Mar-10
35.14.2	184	186.5	2.5	30	10 West	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2423204	Mar-10
35.15.1	198	201	3	30	10 East	Brifen TL-4	18.9, 24.8, 30.7, 36.6		
35.15.2	201	204	3	30	10 West	Brifen TL-4	18.9, 24.8, 30.7, 36.6		
35.16.1	204	206	2	40	15 West	Blue Systems	18.9, 22, 25.1, 28.3		
35.16.2	206	207	1	20	5 East/West	Blue Systems	18.9, 22, 25.1, 28.3		
35.16.3	207	207.5	0.5	30	10 West	Blue Systems	18.9, 22, 25.1, 28.3		
35.17	208.5	215	6.5	40	15 East	Blue Systems	18.9, 22, 25.1, 28.3	2414004	Apr-08
35.18	221	227	6	30	0	Blue Systems	18.9, 22, 25.1, 28.3	2408404	May-07
35.19.1	227	235.5	8.5	30	10 East	Blue Systems	18.9, 22, 25.1, 28.3	2413904	Jan-08
35.19.2	235.5	236	0.5	20	0	Blue Systems	18.9, 22, 25.1, 28.3	2413904	Jan-08

Interstate 40

Section	Mile Start	Mile End	Length (miles)	Median Width (ft)	Distance from Median Center (ft)	Manufacturer	Cable Heights (in)	Job Number	Let Date
40.1	16	21	5	40	15 South	Blue Systems	18.9, 22, 25.1, 28.3	2414404	Mar-09
40.2	25	29.5	4.5	30	10 South	Trinity, CASS 4		2412604	Sep-08
40.3.1	29.5	30.5	1	30	10 North	Trinity, CASS 4		2412504	Sep-08
40.3.2	30.5	31	0.5	30	10 South	Trinity, CASS 4		2412504	Sep-08
40.3.3	31	32.5	1.5	30	10 North	Trinity, CASS 4		2412504	Sep-08
40.4.1	33	36	3	30	10 North	Blue Systems	18.9, 22, 25.1, 28.3	2627604	Aug-09
40.4.2	36	39	3	30	10 South	Blue Systems	18.9, 22, 25.1, 28.3	2627604	Aug-09
40.4.3	39	41	2	30	10 North	Blue Systems	18.9, 22, 25.1, 28.3	2627604	Aug-09
40.5	42	50	8	30	10 South	Trinity, CASS 4		2412605	Feb-09
40.6.1	50	51	1	30	10 South	Blue Systems	18.9, 22, 25.1, 28.3	2703604	Jul-10
40.6.2	51	55	4	30	10 North	Blue Systems	18.9, 22, 25.1, 28.3	2703604	Jul-10
40.6.3	55	59	4	30	10 South	Blue Systems	18.9, 22, 25.1, 28.3	2703604	Jul-10
40.7	59	61	2	30	10 North	Construction		2704204	
40.8	61	65	4	30	0	Blue Systems	18.9, 22, 25.1, 28.3		
40.9.1	65	68.5	3.5	30	10 South	Trinity, CASS 4			
40.9.2	68.5	69	0.5	30	10 North	Trinity, CASS 4			
40.10.	69	82	13	30	0	Trinity, CASS 4		2407904	Aug-07
40.11	82	91.5	9.5	30	10 North	Nucor		2412804	Feb-08
40.12	92	96	4	30	15 North	Nucor		2412904	Feb-08
40.13	97	98.5	1.5	30	10 South	Nucor		2413004	Jan-09
40.14	99	101	2	30	10 South	Nucor		2413504	Jan-09
40.15	101	106.5	5.5	30	10 North	Blue Systems	18.9, 22, 25.1, 28.3	2413604	Apr-08
40.16.1	126	127	1	30	10 South	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2607604	Mar-09
40.16.2	127	128	1	60	25 South	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2607604	Mar-09
40.17.1	128	131	3	40	20 North	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2407404	Oct-07
40.17.2	131	132	1	40	20 North/South	Blue Systems/ Brifen TL-4	18.9, 22, 25.1, 28.3 / 18.9, 24.8, 30.7, 36.6	2407404 /?	
40.17.3	132	133.5	1.5	40	20 North	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2407404	Oct-07
40.17.4	133.5	135	1.5	40	20 North/South	Blue Systems/ Brifen TL-4	18.9, 22, 25.1, 28.3 / 18.9, 24.8, 30.7, 36.6	2407404 /?	
40.17.5	135	136	1	50	5 North	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2407404	Oct-07
40.18.1	159	167	8	40	0	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2408104	Jun-07
40.18.2	168	170.5	2.5	40	0	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2408104	Jun-07
40.19.1	171.5	175	3.5	40	0	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2409104	Jun-07
40.19.2	176	177	1	40	0	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2409104	Jun-07
40.19.3	178	184	6	30	5 South	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2409104	Jun-07
40.20.	215	230	15	50	15 North	Construction		2676804	
40.21.1	276	281.5	5.5	50	20 North	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2423104	Nov-08
40.21.2	281.5	282	0.5	50	20 South	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2423104	Nov-08
40.22.1	293	294	1	50	20 South	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2410606	Jul-09
40.22.2	294	295	1	50	20 North	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2410606	Jul-09
40.22.3	295.5	296	0.5	70	35 South	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2410606	Jul-09
40.22.4	297	299	2	70	35 South	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2410606	Jul-09
40.23.1	299	299.5	0.5	70	35 South	Blue Systems	18.9, 22, 25.1, 28.3	2627004	Oct-10
40.23.2	299.5	301	1.5	60	30 North	Blue Systems	18.9, 22, 25.1, 28.3	2627004	Oct-10
40.23.3	301	308	7	60	30 South	Blue Systems	18.9, 22, 25.1, 28.3	2627004	Oct-10
40.24.1	310	312	2	20	0	Nucor		2410604	Jun-07

Section	Mile Start	Mile End	Length (miles)	Median Width (ft)	Distance from Median Center (ft)	Manufacturer	Cable Heights (in)	Job Number	Let Date
40.24.2	312	313	1	20	10 North	Nucor		2410604	Jun-07
40.25.1	316.5	317	0.5	40	0	Nucor		2410605	Jun-07
40.25.2	317	319	2	40	20 North	Nucor		2410605	Jun-07
40.25.3	319	322	3	40	0	Nucor		2410605	Jun-07

Interstate 44

Section	Mile Start	Mile End	Length (miles)	Median Width (ft)	Distance from Median Center (ft)	Manufacturer	Cable Heights (in)	Job Number	Let Date
44.1	33.5	36	2.5	30	10 East	Blue Systems	18.9, 22, 25.1, 28.3	2716404	2010*
44.2	39.5	41	1.5	20	5 West	Blue Systems	18.9, 22, 25.1, 28.3	2705204	Oct-10
44.3.1	43	45.5	2.5	50	20 East	Blue Systems	18.9, 22, 25.1, 28.3	2705604	Oct-10
44.3.2	45.5	46.5	1	50	20 West	Blue Systems	18.9, 22, 25.1, 28.3	2705604	Oct-10
44.4.1	107.5	108.5	1	30	0	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2407804	Aug-07
44.4.2	109	115	6	30	0	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2407804	Aug-07
44.5.1	115.5	117	1.5	40	20 West	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2408304	Aug-07
44.5.2	117.5	118	0.5	40	20 East	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2408304	Aug-07
44.5.3	118	119	1	50	15 West	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2408304	Aug-07
44.5.4	119	119.5	0.5	50	15 East	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2408304	Aug-07
44.5.5	119.5	120	0.5	70	25 West	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2408304	Aug-07
44.5.6	120	121.5	1.5	60	30 East	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2408304	Aug-07
44.6.1	126	127	1	50	25 East	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2408204	Jun-07
44.6.2	128	128.5	0.5	40	20 West	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2408204	Jun-07
44.6.3	128.5	129	0.5	30	15 East	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2408204	Jun-07
44.6.4	129	130	1	30	15 West	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2408204	Jun-07
44.6.5	130	130.5	0.5	30	15 East	Brifen TL-4	18.9, 24.8, 30.7, 36.6	2408204	Jun-07
44.7	237	238.5	1.5	25	5 West	Nucor		2415604	Jun-08

3. APPENDIX – SAFE-T INPUT PARAMETERS

QUERY CRITERIA RAN
01-01-1998 Thru 12-31-2011
CROSS-OVER MEDIAN COLLISION EXCLUDING CABLE BARRIER

Program Provided by:
Traffic Engineering Division
Collision Analysis and Safety Branch
(405) 522-0985
Created: 03/27/2011 by Chris Ramseyer

Query Number	Query on	Query By	Mileage Range	Date range
1	Entire County: 55-OKLAHOMA	-	-	01-01-1998 to 12-31-2011

FILTER DATA BY :	
Severity	All Selected
Special Feature	75
Unsafe Unlawful	All Selected
Type of Collision	All Selected
Harmful Event for Collision	0, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 30, 31, 32, 33, 34, 35, 36, 37, 38, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 99
Roadway Departure	All Selected
ROADWAY CRITERIA :	
Average Daily Traffic	All Selected
National Functional Class	All Selected
Number of Lanes	All Selected
Access Control	All Selected
Median Type	All Selected
Median Width	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99
Outer Shoulder Type	All Selected
Outer Shoulder Width	All Selected
Traffic Control	All Selected
Intersection Related Only	Unchecked
Terminal Locations Only Within Interchanges	Unchecked
CMV Collisions Only	Unchecked

UNIT CRITERIA :	
Unit Type	All Selected
Vehicle Type	All Selected
Vehicle Cond	All Selected
Vehicle Action	All Selected
Direction of Travel_1	All Selected
Direction of Travel_2	All Selected
PERSON CRITERIA :	
Restraint Used	All Selected
Person Conditions	All Selected
Age	All Selected
Sex	All Selected
ENVIROMENT CRITERIA :	
Manner of Coll.	All Selected
Agency	All Selected
Road Conditions	All Selected
Light	All Selected
Weather	All Selected
Relation Junction	All Selected
Hour	All Selected

QUERY CRITERIA RAN
01-01-1998 Thru 12-31-2010
CROSS-OVER MEDIAN COLLISION WITH CABLE BARRIER

Program Provided by:
Traffic Engineering Division
Collision Analysis and Safety Branch
(405) 522-0985
Created: 03/29/2011 by Chris Ramseyer

Query Number	Query on	Query By	Mileage Range	Date range
1	Entire County: 55-OKLAHOMA	-	-	01-01-1998 to 12-31-2010

FILTER DATA BY :	
Severity	All Selected
Special Feature	All Selected
Unsafe Unlawful	All Selected
Type of Collision	All Selected
Harmful Event for Collision	40
Roadway Departure	All Selected
ROADWAY CRITERIA :	
Average Daily Traffic	All Selected
National Functional Class	All Selected
Number of Lanes	All Selected
Access Control	All Selected
Median Type	All Selected
Median Width	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99
Outer Shoulder Type	All Selected
Outer Shoulder Width	All Selected
Traffic Control	All Selected
Intersection Related Only	Unchecked
Terminal Locations Only Within Interchanges	Unchecked
CMV Collisions Only	Unchecked

UNIT CRITERIA :	
Unit Type	All Selected
Vehicle Type	All Selected
Vehicle Cond	All Selected
Vehicle Action	All Selected
Direction of Travel_1	All Selected
Direction of Travel_2	All Selected
PERSON CRITERIA :	
Restraint Used	All Selected
Person Conditions	All Selected
Age	All Selected
Sex	All Selected
ENVIROMENT CRITERIA :	
Manner of Coll.	All Selected
Agency	All Selected
Road Conditions	All Selected
Light	All Selected
Weather	All Selected
Relation Junction	All Selected
Hour	All Selected

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