In-service Performance Evaluation of Cable Median Barriers on Florida's Limited Access Facilities

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ABSTRACT

This paper presents a study to evaluate the safety performance of cable median barriers on limited access facilities in Florida. The safety evaluation was based on the percentages of barrier and median crossovers by vehicle type, crash severity, and cable median barrier type (CASS and Gibraltar systems). Twenty-three locations with cable median barriers totaling about 101 miles were identified. Police reports of 8,818 crashes from years 2003-2010 at these locations were reviewed to verify and obtain detailed crash information. A total of 549 crashes were determined to be cable median barrier related (i.e., crashes involving vehicles hitting the cable median barrier) and were reviewed in further detail to identify crossover crashes and the manner in which the vehicles crossed the barriers, i.e., either by over-riding, under-riding, or penetrating the barriers.

A relatively low 2.6% of vehicles that hit the cable median barrier crossed the median and traversed into the opposite travel lane. Overall, 98.1% of cars and 95.5% of light trucks that hit the barrier were prevented from crossing the median. Further, 16.4% of barrier related crashes crossed over the barrier but did not cross the median. Overrides were found to be more severe compared to under-rides and penetrations. The statistics showed that the Gibraltar system experienced a higher proportion of penetrations compared to the CASS system. The CASS system resulted in a slightly higher percentage of moderate and minor injury crashes compared to the Gibraltar system.

Key words: In-service Performance Evaluation, Cable Median Barriers, Crossover Crashes, Police Reports, Safety Analysis, CASS, Gibraltar

INTRODUCTION

The primary purpose of cable median barrier is to prevent errant vehicles which leave the travel lane from striking a roadside obstacle (hazard), traversing non-recoverable terrain, or colliding with traffic from the opposite direction. Alberson et al. *(1)* has identified the following five high-tension cable barrier systems as currently being installed in the United States:

1. Brifen USA Wire Rope Safety Fence (WRSF)
2. Blue Systems Safence 350 Wire Rope Barrier
3. Nucor High Tension Cable Barrier
4. Trinity Industries Cable Safety System (CASS)
5. Gibraltar Cable Barrier System

Brifen and Safence have four cables/strands while the other high-tension cable systems (i.e., Nucor, CASS, and Gibraltar) have three cables. Figure 1 shows all the five types of high-tension pre-stretched cable barrier systems being used by the Florida Department of Transportation (FDOT).

The objective of this research is to evaluate the safety performance of cable median barrier systems installed on limited access facilities (i.e., freeways and expressways) in Florida. In this research, the performance of cable median barrier systems is measured by the percentages of errant vehicles prevented from: (1) crossing the barrier, i.e., barrier crossover; and (2) crossing the median, i.e., median crossover. A crash in which an errant vehicle crosses the cable median barrier at any point during the crash is categorized as a barrier crossover crash. If after crossing the barrier the errant vehicle clears the median and traverses into the opposite travel lanes, it becomes a median crossover crash.

A barrier can be crossed over in three manners: by under-riding, over-riding, or penetrating the cable median barrier. By definition:

- An under-ride crossover crash is classified as a crash which involves an errant vehicle crossing the cable median barrier by sliding under the cables.
- An over-ride crossover crash is classified as a crash which involves an errant vehicle crossing the cable median barrier by riding on top of the cables.
- A penetration (or through-ride) crossover crash is classified as a crash which involves an errant vehicle crossing the cable median barrier by going through the cables.

A crash is categorized as non-crossover when an errant vehicle does not cross over the cable median barrier at any point during the crash. A non-crossover crash can be classified as either redirected or contained by the cable barrier system. Again, by definition:

- A redirected non-crossover crash is classified as one when an errant vehicle hits the cable median barrier and is gradually redirected away from the median due to the dynamic deflection characteristics of the cables.
- A contained non-crossover crash is classified as one when an errant vehicle hits the cable median barrier and is restrained by the cables.

a) Brifen *(2)*

b) Safence *(2)*

c) CASS *(2)*

d) Gibraltar *(1)*

e) Nucor Marion *(1)*

FIGURE 1 Types of high-tension cable barrier systems used in Florida.

Detailed analysis of crashes involving vehicles hitting the barriers is required to accurately evaluate the safety performance of cable median barriers. This information, including the underlying crash patterns, is unavailable in typical crash summary records. Crash-specific information, such as crashes that are directly related to cable median barrier, crossover crash classification, type of vehicle that hit the cable median barrier, crash severity, etc., could only be accurately determined from a detailed review of police crash reports. As such, a major effort of this research was to review the police reports to accurately evaluate the safety performance of cable median barriers in real-world conditions. Analysis is conducted based on the type of vehicle that hit the barrier, crash severity, and the type of the cable median barrier installed.

BACKGROUND

In-service Performance Evaluation (ISPE)

ISPE is the process of assessing the performance of roadside safety hardware under real-world service conditions *(3)*. Its objective is "to observe, measure, and record the performance of the hardware in a wide variety of circumstances" *(4)*. Even though roadside safety features are designed and crash tested as per the Manual for Assessing Safety Hardware (MASH) (previously tested using National Cooperative Highway Research Program (NCHRP) Report 350) *(5)*, it is difficult to determine their actual performance on field without effective in-service evaluations *(4, 6)*.

Since the early 1970s, state Departments of Transportation (DOTs) have been conducting ISPEs for several roadside safety hardware. Data quantity plays a significant role in determining the success of an ISPE. As in the case of several research projects on ISPE, data quantity becomes an issue when inadequate number of study sites over a short span of 1-3 years were analyzed *(7, 8)*.

Performance of Cable Barriers

Several studies have been conducted on the safety performance evaluation of cable barriers. In 2009, Cooner et al. *(9)* evaluated the safety performance of a total of 114 cable barriers and 78 concrete barriers and concluded that cable barriers were making a significant contribution to the reduction of fatal and incapacitating injuries on state roadways, effectively eliminating 96% of these injury types caused by cross-median crashes. Compared to concrete median barriers, cable barriers were most cost-efficient when capital and life-cycle costs were considered. Further, cable barriers were found to perform extremely well in most of the standard type collisions *(9)*. Furthermore, Sicking et al. (*10*) reviewed reported crashes on Kansas freeways from 2002-2006. They observed a total of 525 cross-median events (CMEs) and 115 cross-median crashes (CMCs) in the study period. The authors developed median barrier warrants to be representative of a number of states in the mid-western region.

The effectiveness of two types of cable median barrier systems, Brifen TL-4 and Trinity CASS, in preventing CMCs on Kentucky highways was evaluated. About 325 police reported CMCs were identified over a 21-month analysis period with an average of 0.28 CMCs per mile and 0.05 fatal CMCs per mile in 5-year period. The results from the study showed that the cable system was successful in redirecting errant vehicles; in only 0.9% of the cases had the cable system failed *(11)*.

A nationwide state-of-the-practice survey of cable median barriers was conducted and the following were the relevant excerpts from the survey *(12)*:

- There was a decrease in the severity of crashes at locations where wire rope median barriers have been installed while the total crashes have increased.
- Even though some states continued to use nonproprietary low-tension systems, usage of proprietary high-tension systems continued to increase.

- Horizontal curvature had a direct impact on deflection associated with errant vehicle impacts, and therefore on the performance of the barriers.
- With continued and increasing installations of cable median barriers, more rigorous ISPEs needed to be conducted to improve the system.

A scanning tour of the locations with cable median barriers in Ohio, Oklahoma, and Texas found that high-tension cable systems have been successfully used for median crossover protection on highways with wide medians and flat median slopes, and the general performance of the cable barrier systems at redirecting or stopping vehicles seemed to be excellent *(13)*.

Besides the in-service performance evaluations, several before-and-after evaluations have been conducted to assess the safety performance of cable barriers. A three-year before and after analysis of cable median barriers in Oregon found that zero median crossover fatalities occurred in the after period even though the total crashes and minor injuries increased *(14)*. A three-year ISPE of high-tension Brifen cable barriers on Ohio highways showed similar results. Even though crash frequency increased after the installation of cable median barriers, a significant number of possible crossover crashes were contained by the barrier. Also, the three-year ISPE identified zero crossover fatal and severe injury crashes *(15)*.

Hammond and Batiste *(16)* conducted a before-and-after safety evaluation of cable barrier installations for both median-related and cross-median collisions. The collision rate statistics before and after cable barrier installations are shown in Table 1. From the table, it is found that even though total crashes increased in the after period, both fatal and severe injury crashes reduced significantly. Further, an overall reduction in the frequency and severity of cross-median crashes was observed. Similar evaluation by crash type was conducted on Washington State highways. The study concluded that the annual societal benefits of cable barriers were approximately $420,000 per mile *(17)*.

TABLE 1 Statistics of Before-and-After Cable Barrier Installations *(16)*

Collision Statistics	Before	After	Percent Change
Total Median-Related Collisions			
Annual Median Collisions	228	594	+161%
Median collision rate (per 100 million vehicle miles traveled (VMT))	7.85	15.99	+104%
Annual serious-injury median collisions	16.8	7.0	-59%
Annual fatal median collisions	8	6	-25%
Serious-injury median collision rate (per 100 million VMT)	0.58	0.21	-64%
Fatal median collision rate (per 100 million VMT)	0.27	0.15	-44%
Cross-Median Collisions			
Annual cross-median incidents	54.8	21.6	-61%
Cross-median collision rate (per 100 million VMT)	1.88	0.66	-65%
Annual serious-injury cross-median collisions	8.6	2.3	-73%
Annual fatal cross-median collision	4.8	3.5	-28%

Additionally, comparison of the performance of cable median barrier with other types of barriers was often conducted. For example, Murphy compared the long-term safety performance of cable median barriers with all barrier types, as shown in Table 2. In addition to the above mentioned studies, several others have evaluated the safety performance of cable barriers *(7, 15, 18, 19)*.

TABLE 2 Long-Term Median Barrier Evaluation *(20)*

	All Barrier Types			Cable Median Barrier		
	Before	**After**	**% Change**	**Before**	**After**	**% Change**
Mileage (miles)	428			203		
AADT (veh/day)	26,600	34,300	29%	22,000	29,400	34%
Total crashes	2,048	3,718	82%	793	1,688	113%
Severe Injury Crashes (K and A)	120	98	-18%	47%	41	-13%
Moderate and Minor Injury Crashes (B and C)	696	1,103	58%	267	448	68%
Property Damage Only (PDO)	1,232	2,517	104%	479	1,199	104%
Cross-Median Crashes	152	30	-80%	60	23	-80%
Fatal Cross-Median Crashes	13	2	-80%	4	2	-80%
Severe Injury Cross-Median Crashes (K and A)	20	3	-87%	7	2	-87%
Crashes involving median barrier	-	1,218	-	-	568	-
% of crashes involving median barrier	-	33%	-	-	34%	-
Breach Rate	-	2.40%	-	-	4.00%	-

All crash numbers are in crashes per year.

DATA PREPARATION

Roadway Characteristics Data

The FDOT Roadway Characteristics Inventory (RCI) database does not provide detailed information on the location and type of the roadside safety feature. Therefore, other options to collect this information were investigated. Freeway segments with guardrails for the entire state were first identified and extracted from the RCI database. The extracted segments were imported into the Visual Roadway Inventory Collection System (VRICS) to identify locations installed specifically with cable barriers in the median.

The VRICS application is a web-based system developed to facilitate the process of collecting roadway data using Google Street View. A screen capture of the main interface of the system is shown in Figure 2. The system reads a linear-referenced roadway segment, converts its coordinates to the Google Maps projection, and then displays the segment using Google Street View starting from its begin milepost. This system was used to identify locations installed with cable barriers in the median. The segment list extracted from the RCI was imported into the VRICS tool and each segment was visually reviewed to verify if it was installed with a cable median barrier.

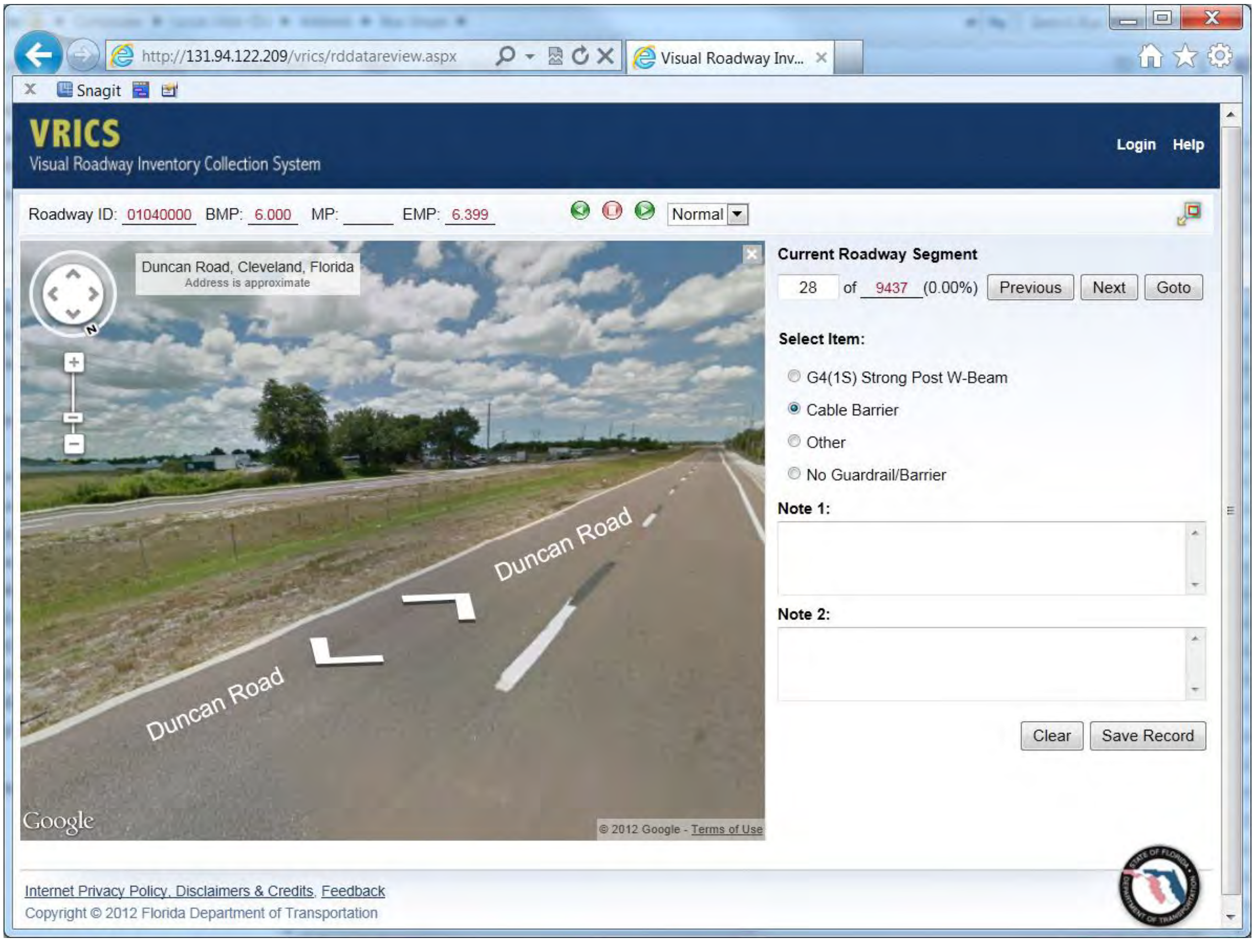

FIGURE 2 VRICS main screen.

A total of 101 miles of segments (23 locations in total) with cable median barriers were identified and used in the analysis, as shown in Table 3. The majority of the study locations were installed with either CASS or Gibraltar systems. A special case involves those installed on the Florida Turnpike (SR 821) in which three types of cable barrier systems (Brifen, CASS, and Safence) were installed along its 6.073-mile section.

TABLE 3 Cable Median Barrier Locations

Roadway ID	Begin MP	End MP	Segment Length (mi)	Type of Cable Barrier	State Road Name	County Name
17075000	10.750	12.212	1.462	CASS	I-75	Sarasota
17075000	37.102	40.028	2.926	CASS	I-75	Sarasota
75002000	19.348	30.341	10.993	CASS	SR 528	Orange
87471000[+]	3.155	9.228	6.073	Brifen, Safence, CASS	SR 821	Miami-Dade
17075000	0.000	0.545	0.545	CASS	I-75	Sarasota
17075000	32.860	34.405	1.545	CASS	I-75	Sarasota
17075000	42.104	42.615	0.511	CASS	I-75	Sarasota
75301000	13.804	14.282	0.478	CASS	SR 417	Orange
75320000	33.784	34.480	0.696	CASS	SR 429	Orange
13075000	0.000	8.151	8.151	CASS	I-75	Manatee
13075000	8.313	13.110	4.797	CASS	I-75	Manatee
13075000	13.481	16.990	3.509	CASS	I-75	Manatee
13075000	17.293	18.650	1.357	CASS	I-75	Manatee
13075000	19.100	19.290	0.190	CASS	I-75	Manatee
13075000	19.492	19.941	0.449	CASS	I-75	Manatee
03175000	54.090	63.676	9.586	Gibraltar	I-75	Collier
12075000	0.000	20.767	20.767	Gibraltar	I-75	Lee
16320000	0.000	18.852	18.852	Gibraltar	I-4	Polk
16320000	19.913	21.870	1.957	Gibraltar	I-4	Polk
16320000	23.066	24.170	1.104	Gibraltar	I-4	Polk
16320000	25.155	27.327	2.172	Gibraltar	I-4	Polk
16320000	28.113	30.096	1.983	Gibraltar	I-4	Polk
16320000	31.133	32.022	0.889	Gibraltar	I-4	Polk

[+] Milepost 3.155 to 5.655 is with Brifen; Milepost 5.655 to 6.728 is with Safence; and Milepost 6.728 to 9.228 is with CASS. Note that these mileposts are approximate.

Crash Data

For the periods covering 2003 to 2010, police reports were available for download from the Hummingbird web system hosted on FDOT's Intranet. During this eight-year period, the 23 locations experienced a total of 8,818 crashes. The police reports for all of the 8,818 crashes were downloaded and reviewed in detail. For each and every crash where the errant vehicle had hit the cable median barrier, a detailed review of the police officer's description and illustrative sketch was conducted to categorize crashes as crossover and non-crossover crashes, if a crossover crash involved vehicle encroaching into the opposite travel lanes, the type of vehicle involved, and the crash severity. Crossovers were further categorized as under-ride, over-ride, or penetrations; non-crossovers were categorized as either redirected or contained by the cable barrier system.

ANALYSIS

Safety evaluation of cable median barriers on limited access facilities in Florida was conducted based on the following:

- type of vehicle that hit the barrier,

- severity of barrier-related crashes, and
- type of cable median barriers.

Analysis by Vehicle Type

For this analysis, the vehicle types include cars, light trucks, medium trucks, heavy trucks, motorcycles, unknown vehicle types, and others. Light trucks include vans and pickup trucks with two or four rear tires; medium trucks include vehicles with four rear tires; and heavy trucks include vehicles with two or more rear axles and truck tractors. The "others" category include buses and other vehicles. Five vehicles were coded as unknown since these vehicles fled the crash site prior to the arrival of law enforcement. When a crash involved multiple vehicles, the vehicle that actually hit the cable median barrier was used in the analysis.

The crash performance statistics of cable median barriers in terms of barrier crossover and median crossover crashes by vehicle type are given in Table 4. Of the 549 cable median barrier related crashes (i.e., crashes involving vehicles hitting the cable median barrier), 90 were identified as barrier crossover crashes and the remaining 459 were barrier non-crossover crashes. Of the 90 crossover crashes, 34 were over-rides, 29 were penetrations, and only 2 were under-rides. The barrier crossover type of 25 crashes could not be determined due to insufficient information in the police reports. Of the 459 barrier non-crossover crashes, 285 were redirected while the rest (i.e., 174) were contained by the cable median barrier. Overall, 83.6% of all crashes were barrier non-crossover crashes, and 85.4% of cars that hit the cable median barrier were either redirected or contained by the cable median barrier (i.e., non-crossover). Likewise, 79.9% of light trucks did not cross over. Medium and heavy trucks were found to have a lower non-crossover rate of 50.0% and 66.7%, respectively. This is expected as the cable median barrier has not been designed for these vehicle types.

Median crossover crash statistics by vehicle type are also given in Table 4. As discussed earlier, median crossover crashes are defined as the barrier crossover crashes that resulted in vehicle traversing into the opposite travel lane. Of the 549 cable median barrier related crashes, 14 resulted in vehicles crossing the median and traversing into the opposite travel lane. Of these 14 crashes, 8 were due to over-rides, 3 were because of penetrations, and the crossover category of the remaining 3 was unknown because of insufficient information in the police reports. Seven out of the 14 median crossover crashes were cars, and the remaining 7 were light trucks. Overall, a high 98.1% of cars that hit the cable median barrier were prevented from traversing into the opposite travel lane. Likewise, 95.5% of light trucks were prevented from crossing over the median. None of the other vehicle types traversed into the opposite travel lane. Overall, a relatively high 97.4% of vehicles that hit the cable median barrier were prevented from crossing over the median and traversing into the opposite lane.

TABLE 4 Crash Performance Statistics by Vehicle Type

Vehicle Type	Barrier Crossover Crashes					Barrier Non-Crossover Crashes			Total Crashes (i) = (e)+(h)	Percent of Barrier Non-Crossover Crashes (h)/(i)
	Under-ride (a)	Over-ride (b)	Penetration (c)	Unknown Crossover (d)	Total Crossover (e) = (a)+(b)+(c)+(d)	Redirected (f)	Contained (g)	Total Non-Crossover (h) = (f)+(g)		
Car	2	16	18	18	54	193	122	315	369	85.4%
Light Truck[1]	0	17	7	7	31	81	42	123	154	79.9%
Medium Truck[2]	0	0	1	0	1	0	1	1	2	50.0%
Heavy Truck[3]	0	1	3	0	4	3	5	8	12	66.7%
Motorcycle	0	0	0	0	0	1	1	2	2	100.0%
Unknown	0	0	0	0	0	4	1	5	5	100.0%
Other	0	0	0	0	0	3	2	5	5	100.0%
Total	**2**	**34**	**29**	**25**	**90**	**285**	**174**	**459**	**549**	**83.6%**

Vehicle Type	Median Crossover Crashes					Median Non-Crossover Crashes (f)	Total Crashes (g) = (e)+(f)	Percent of Median Non-Crossover Crashes (f)/(g)
	Under-ride (a)	Over-ride (b)	Penetration (c)	Unknown Crossover (d)	Total Crossover (e) = (a)+(b) (c)+(d)			
Car	0	4	2	1	7	362	369	98.1%
Light Truck[1]	0	4	1	2	7	147	154	95.5%
Medium Truck[2]	0	0	0	0	0	2	2	100.0%
Heavy Truck[3]	0	0	0	0	0	12	12	100.0%
Motorcycle	0	0	0	0	0	2	2	100.0%
Unknown	0	0	0	0	0	5	5	100.0%
Other	0	0	0	0	0	5	5	100.0%
Total	**0**	**8**	**3**	**3**	**14**	**535**	**549**	**97.4%**

[1] Light Trucks include vans and pickup trucks with two or four rear tires.
[2] Medium Trucks are vehicles with four rear tires.
[3] Heavy Trucks include truck tractors.

Analysis by Crash Severity

The crash performance statistics of cable median barriers in terms of barrier crossover and median crossover crashes by crash severity are given in Tables 5 and 6, respectively. Data from the police crash reports was used to identify crash severity using the following codes:

- K – Fatal Injury
- A – Incapacitating Injury
- B – Non-Incapacitating Injury
- C – Possible Injury
- PDO – Property Damage Only

As shown in Table 5, of the 90 barrier crossover crashes, 3.3% were fatal; of the 459 barrier non-crossover crashes, 1.1% were fatal. Slightly over one-third (35.6%) of the barrier crossover crashes were PDOs, while about two-thirds (63.2%) of barrier non-crossovers were PDOs. From these statistics, it could be inferred that barrier crossover crashes, as expected, are more severe compared to barrier non-crossover crashes. In addition, over-rides are found to be more severe compared to under-rides and penetrations.

Of the 14 median crossover crashes, 1 was a fatal crash, 1 resulted in an incapacitating injury, 4 were non-incapacitating injury crashes, 3 were possible injury, and 4 were PDOs. These numbers show that the median crossover crashes are slightly more severe compared to barrier crossover crash statistics.

TABLE 5 Barrier Crossover Crash Statistics by Crash Severity

Crash Severity[a]	Barrier Crossover Crashes						Barrier Non-Crossover Crashes			
	Under-ride (a)	Over-ride (b)	Penetration (c)	Unknown Crossover (d)	Total Crossover (e) = (a)+(b)+(c)+(d)	Percent of Total Barrier Crossover Crashes (e)/90	Redirected (f)	Contained (g)	Total Non-Crossover (h) = (f)+(g)	Percent of Total Barrier Non-Crossover Crashes (h)/459
K	0	2	1	0	3	3.3%	3	2	5	1.1%
A	0	5	3	1	9	10.0%	9	6	15	3.3%
B	0	13	4	2	19	21.1%	26	10	36	7.8%
C	0	7	8	8	23	25.6%	49	33	82	17.9%
O	2	6	10	14	32	35.6%	178	112	290	63.2%
Unknown[b]	0	1	3	0	4	4.4%	20	11	31	6.8%
Total	**2**	**34**	**29**	**25**	**90**	**100.0%**	**285**	**174**	**459**	**100.0%**

[a] K = fatal injury; A = incapacitating injury; B = non-incapacitating injury; C = possible injury; O = property damage only.
[b] The severity of a crash is unknown when the driver fled the crash site prior to the arrival of law enforcement or when a discrepancy exists between the coded crash severity in the crash summary statistics and that in the actual police report.

TABLE 6 Median Crossover Crash Statistics by Crash Severity

Crash Severity[a]	Under-ride (a)	Over-ride (b)	Penetration (c)	Unknown Crossover (d)	Total Median Crossover (e) = (a)+(b)+(c)+(d)	Percent of Total Median Crossover Crashes (e)/14
K	0	1	0	0	1	7.1%
A	0	0	0	1	1	7.1%
B	0	3	1	0	4	28.6%
C	0	3	0	0	3	21.4%
O	0	1	1	2	4	28.6%
Unknown[b]	0	0	1	0	1	7.1%
Total	**0**	**8**	**3**	**3**	**14**	**100.0%**

[a] K = fatal injury; A = incapacitating injury; B = non-incapacitating injury; C = possible injury; O = property damage only.
[b] The severity of a crash is unknown when the driver fled the crash site prior to the arrival of law enforcement or when a discrepancy exists between the coded crash severity in the crash summary statistics and that in the actual police report.

Analysis by Cable Median Barrier Type

The 23 study locations were installed with one of the four types of cable barrier systems: Brifen, CASS, Safence, or Gibraltar systems. Florida Turnpike (SR 821) was considered as a location for pilot study, and Brifen, CASS, and Safence were installed along the approximate 6-mile stretch. The rest of the study locations were installed with either Gibraltar or CASS systems. Cable median barrier related crashes along SR 821 are considered as a "mixed" type since the section was installed with three types of cable barrier systems and it is difficult to accurately associate crashes to each cable barrier system. This section, therefore, focuses on the comparison of the performance of CASS and Gibraltar systems.

The crash performance statistics of CASS and Gibraltar cable barrier systems in terms of barrier crossover and barrier non-crossover crashes are given in Table 7. A total of 37.61 miles of limited access facilities were installed with the CASS system (excluding the section with CASS on SR 821) and 57.31 miles were installed with Gibraltar cable barriers. The CASS system was hit 129 times and the Gibraltar system was hit 345 times. Of all crashes that hit the CASS system, 83.3% were barrier non-crossover crashes. Similarly, the barrier non-crossover percentage was 81.7% for Gibraltar. This implies that 81.7% of all vehicles that hit the Gibraltar system were either redirected or contained by the system. The location on SR 821 was installed with the three types of cable barrier systems, and this location had a high barrier non-crossover percentage of 92.4%.

Of the 129 crashes that hit the CASS barrier system, 21 were barrier crossovers. Three of the 21 CASS barrier crossover crashes (14.3%) were penetrations; 16 (76.2%) were over-rides and 2 (9.5%) were unknown. In contrast, of the 345 crashes that hit the Gibraltar system, 63 were barrier crossover crashes. Of these 63 crashes, 24 (38.1%) were penetrations; 17 (27.0%) were over-rides; 20 (31.7%) were unknown; and 2 (3.2%) were under-rides. The statistics show that the Gibraltar system experienced greater proportion of penetrations compared to the CASS system.

The barrier crossover crash statistics of CASS and Gibraltar systems by vehicle type are given in Table 8. For cars, 86.8% that hit the CASS system were either redirected or contained by the barrier; the percentage was a little lower at 82.6% for Gibraltar system. The CASS system prevented 78.4% of light trucks from crossing the barrier; while a similar percentage (79.6%) of light trucks were prevented by the Gibraltar system. For heavy trucks, the Gibraltar system was more successful in preventing barrier crossovers as the non-crossover percentage was 80.0% compared to 57.1% for the CASS system. Further, medium trucks and motorcycles were too few to yield meaningful results.

TABLE 7 Barrier Crossover Crash Statistics by Cable Median Barrier Type

Type of Cable Median Barrier	Total Section Length (miles)	Barrier Crossover Crashes					Barrier Non-Crossover Crashes			Total Crashes (i) = (e)+(h)	Percent of Barrier Non-Crossover Crashes (h)/(i)
		Under-ride (a)	Over-ride (b)	Penetration (c)	Unknown Crossover (d)	Total Crossover (e) = (a)+(b)+(c)+(d)	Redirected (f)	Contained (g)	Total Non-Crossover (h) = (f)+(g)		
CASS	37.61	0	16	3	2	21	55	50	105	126	83.3%
Gibraltar	57.31	2	17	24	20	63	186	95	281	344	81.7%
Mixed[+]	6.07	0	1	2	3	6	44	29	73	79	92.4%
Total	**100.99**	**2**	**34**	**29**	**25**	**90**	**285**	**174**	**459**	**549**	**83.6%**

[+]Three types of cable median barrier systems (i.e., CASS, Safence, and Brifen) were installed along the 6.07-mile stretch on SR 821.

TABLE 8 Barrier Crossover Crash Statistics of CASS and Gibraltar Systems by Vehicle Type

Vehicle Type	Barrier Crossover Crashes					Barrier-Non-Crossover			Total Crashes (i) = (e)+(h)	Percent of Barrier Non-Crossover Crashes (h)/(i)
	Under-ride (a)	Over-ride (b)	Penetration (c)	Unknown Crossover (d)	Total Crossover (e) = (a)+(b)+(c)+(d)	Redirected (f)	Contained (g)	Total Non-Crossover (h) = (f)+(g)		
CASS										
Car	0	8	1	1	10	35	31	66	76	86.8%
Light Truck[1]	0	7	0	1	8	16	13	29	37	78.4%
Medium Truck[2]	0	0	0	0	0	0	0	0	0	---
Heavy Truck[3]	0	1	2	0	3	1	3	4	7	57.1%
Motorcycle	0	0	0	0	0	0	0	0	0	---
Unknown	0	0	0	0	0	1	1	2	2	100.0%
Other	0	0	0	0	0	2	2	4	4	100.0%
Total	**0**	**16**	**3**	**2**	**21**	**55**	**50**	**105**	**126**	**83.3%**
Gibraltar										
Car	2	7	16	15	40	124	66	190	230	82.6%
Light Truck[1]	0	10	6	5	21	56	26	82	103	79.6%
Medium Truck[2]	0	0	1	0	1	0	0	0	1	0.0%
Heavy Truck[3]	0	0	1	0	1	2	2	4	5	80.0%
Motorcycle	0	0	0	0	0	1	1	2	2	100.0%
Unknown	0	0	0	0	0	3	0	3	3	100.0%
Other	0	0	0	0	0	0	0	0	0	---
Total	**2**	**17**	**24**	**20**	**63**	**186**	**95**	**281**	**344**	**81.7%**

[1] Light Trucks include vans and pickup trucks with two or four rear tires; [2] Medium Trucks are vehicles with four rear tires; [3] Heavy Trucks include truck tractors.

The performance of different types of cable barrier systems by crash severity is given in Table 9. In this analysis, the severity is divided into fatal and severe injury (K+A) crashes, moderate and minor injury (B+C) crashes, PDO crashes, and "Unknown" crashes. From Table 9, it is found that 5.8% of all crashes that hit the cable median barrier were either fatal or incapacitating injury, 29.1% resulted in moderate or minor injury, 58.7% were PDOs, and the rest (6.4%) were of unknown severity. The CASS and Gibraltar systems performed similarly in terms of fatal and severe injury crashes; the proportion of K+A crashes were 5.6% and 5.8% for CASS and Gibraltar systems, respectively. Less than half of total crashes (i.e., 49.2%) that hit the CASS system were PDOs, while 62.2% of the crashes that hit the Gibraltar system were PDOs. From these statistics, it could be concluded that the CASS system resulted in a slightly higher percentage of moderate and minor injury crashes compared to the Gibraltar system.

TABLE 9 Performance of Different Cable Median Barrier Types by Crash Severity

Type of Cable Median Barrier	Crash Severity[a]									
	K+A		B+C		O		Unknown[b]		Total	
	Number (a)	% (a)/(e)	Number (b)	% (b)/(e)	Number (c)	% (c)/(e)	Number (d)	% (d)/(e)	Number (e)= (a)+(b)+(c)+(d)	%
CASS	7	5.6%	48	38.1%	62	49.2%	9	7.1%	126	100%
Gibraltar	20	5.8%	89	25.9%	214	62.2%	21	6.1%	344	100%
Mixed	5	6.3%	23	29.1%	46	58.2%	5	6.3%	79	100%
Total	**32**	**5.8%**	**160**	**29.1%**	**322**	**58.7%**	**35**	**6.4%**	**549**	**100%**

[a] K = fatal injury; A = incapacitating injury; B = non-incapacitating injury; C = possible injury; O = property damage only.

[b] The severity of a crash is unknown when the driver fled the crash site prior to the arrival of law enforcement or when a discrepancy exists between the coded crash severity in the crash summary statistics and that in the actual police report.

Summary and Conclusions

Safety performance evaluation of cable median barriers on limited access facilities in Florida was performed using the percentages of barrier and median crossover crashes as they relate to vehicle type, crash severity, and cable median barrier type. The 23 study locations experienced a total of 549 cable median barrier related crashes, i.e., crashes in which errant vehicles hit the cable median barrier at any point during the crash. Police reports of these 549 crashes were reviewed in detail to identify crossover and non-crossover crashes. Based on the descriptions and illustrative sketches in the police reports, crossover crashes were further classified as under-ride, over-ride, or penetration. Non-crossover crashes were classified as either redirected or contained. Crashes that resulted in vehicles traversing into the opposite travel lane (i.e., median crossover crashes) were also identified and analyzed.

Overall, 83.6% of vehicles that hit the cable median barrier were prevented from crossing over the barrier. Of all cars that hit the cable median barrier, 85.4% were either redirected or contained by the cable median barrier. Likewise, 79.9% of light trucks were barrier non-crossover crashes. Fewer medium and heavy trucks that hit the barrier were prevented from crossing the barrier. This is expected as the cable median barrier has not been designed for these vehicle types. Further, of the 549 crashes that involved vehicles hitting the cable median barrier, only 14 traversed into the opposite travel lane.

The 23 study locations were installed with one of the four types of cable barrier systems: Brifen, CASS, Safence, or Gibraltar systems. A total of 37.61 miles of limited access facilities in Florida were installed with the CASS system and 57.31 miles were installed with Gibraltar cable barriers. The CASS system was hit 129 times and the Gibraltar system was hit 345 times. The statistics show that the Gibraltar system experienced a greater proportion of penetrations compared to the CASS system.

Of all the crashes that hit the cable median barrier, 5.8% were either fatal or incapacitating injury crashes, 29.1% resulted in moderate or minor injury, 58.7% were PDOs, and the rest (6.4%) were of unknown severity. The CASS and Gibraltar systems performed very similarly in terms of fatal and severe injury crashes; however, the CASS system resulted in a slightly higher percentage of moderate and minor injury crashes compared to the Gibraltar system.

In summary, cable median barriers are successful in preventing median crossover crashes; a relatively high 97.4% of vehicles that hit the cable median barrier were prevented from crossing over the median. Of all the vehicles that hit the barrier, 83.6% were either redirected or contained by the cable barrier system.

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