Performance Evaluation of Cable Median Barrier System on Oregon Highway with Narrow Median

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ABSTRACT

The Mt. Hood Highway (US-26) Safety Corridor has historically experienced a high rate of crossover crashes resulting in fatalities and severe injuries. For much of the corridor, there is no physical barrier separating travel lanes from opposing traffic. Many locations have less than four feet of separation between opposing traffic. In an attempt to reduce crossover crashes on US-26, a cable median barrier (CMB) system was installed within a 1.5 mile segment in August 2007.

The US-26 CMB is unique in that it is a non-freeway application and in a narrow paved median. As far as the authors are aware, the US-26 CMB system is the only CMB system in the U.S that is on a non-freeway in a median less than eight feet wide. This study finds that the US-26 cable median barrier system has continued to prevent crossover crashes and reduce crash severity. The results indicate that the section crash rate increased 72% following installation, which is a considerable amount. However, the Fatal/Injury crash rates declined by 29% and the Severity Indicator for crashes in the CMB Section decreased 59%. These changes suggest that although there has been an increase in crashes due to the installment of a fixed object in the middle of the road, the CMB has prevented more severe crashes such as head-on collisions. First responders and the state maintenance crew provided positive feedback for the narrow cable median barrier system.
INTRODUCTION
The Mt. Hood Highway (US-26) from MP 25.20 to MP 57.45 was designated as a Safety Corridor in November 1996. Safety Corridors are defined by the Oregon Department of Transportation (ODOT) as, “stretches of state highway with an incidence of fatal and serious injury traffic crashes higher than the statewide average for a similar type of roadway” (9). The US-26 Safety Corridor has historically experienced a high rate of crossover crashes resulting in fatalities and severe injuries. For much of the corridor, there is no physical barrier separating travel lanes from opposing traffic. Many locations have less than four feet of separation between opposing traffic. In an attempt to reduce crossover crashes on Mt. Hood Highway, a narrow cable median barrier (CMB) system was installed from MP 30.56 to MP 31.31 and MP 31.55 to MP 32.32 in August 2007. Although no fatalities have occurred within this specific segment of US-26 since at least 2001, there have been several severe injuries. This segment of US-26 was chosen for installation of a CMB because of the severity of the crashes and because there are only a few private driveways and the connecting county roads are low volume roads (3).

The US-26 CMB is unique in that it is a non-freeway application and in a narrow (less than eight feet wide) paved median. CMBs are typically used on freeways; however, US-26 is designated as a Rural Principal Arterial. As far as the authors are aware, the Mt. Hood CMB system is the only CMB system in a narrow median on a non-freeway in the U.S.

The study includes:

- Comparison of the US-26 CMB system design to other CMB systems
- Traffic engineering analysis including crash rates and a comparison study
- Operational review (review of maintenance and police records, review of feedback from a variety of project stakeholders)

LITERATURE REVIEW
CMB Design Guidelines & Standards
Factors that could influence the effectiveness of CMB systems in redirecting or containing errant vehicles include placement considerations (i.e., lateral position), terrain geometry and shape, speeds and angles of the vehicles as they approach the CMB, barrier system configuration (number, height and arrangement of cables), vehicle type (geometry and mass), post type and spacing, and barrier lengths (7).

At the time that the Mt. Hood CMB system was installed in 2007, CMBs were not a standard specification in the Oregon Standard Specifications for Construction (OSSC) (8). It was not until the 2008 edition of the OSSC that “Section 00811 – Cable Barrier” was included in the OSSC (11).

The typical design for CMB systems on freeways includes post spacing of 15-20'. The cable deflection expected with this post spacing is considered acceptable for wide medians such as those typical on freeways. CMB run lengths are typically a function of roadway environment and the need for access; gaps in runs typically occur at intersecting roads or emergency median access points. In most CMB systems, the bottom cable is 17 to 21 inches high while the top cable is typically 30 to 34 inches high on three-cable systems, or 30 to 42 inches high on four-cable systems. A bottom cable that is too high can lead to underrides; a top cable that is too low can lead to overrides; too much space between the cables can lead to failure to engage and capture a vehicle (7).

Many guidelines for CMB systems suggest that CMBs require a median that is at least 24 feet wide (1,6,14). A more rigid (i.e., concrete) barrier is recommended for use in more narrow medians. A concern is that in a narrow median a typical CMB does not have enough room to deflect laterally during impact without encroaching on the opposite lane. However, CMB systems have been installed in narrow/paved medians in Utah and Sweden (5). In fact, Utah DOT’s standard drawings for high tension CMB (created in 2012) only require a fifteen-foot wide median (5). However, UDOT requires a CMB design that allows less lateral deflection than typical CMB designs.

US-189 CMB Design (Utah)
The Utah DOT (UDOT) installed a high-tension CMB within a narrow median on US-189 in Provo Canyon. As of September 2014, the CMB has performed well with no crashes resulting in a head on collision. The system has 6.5 foot post spacing in a twelve to fourteen foot wide median. The US-189 CMB system consists of CASS™ C-Shaped Posts from Trinity Highway Products. It is a three-cable system with a bottom cable height of approximately 21
inches and a top cable height of approximately 29.5 inches (Figure 1). The shape of the post and the minimal distance between posts allow for lower deflections during crash tests (17). Run lengths of the US-189 system vary from 1400 to 4500 feet in length. It should be noted that instead of using the manufacturer’s cable anchor system, UDOT uses a Cable Barrier W-Beam Anchor Assembly with type C crash cushion.

FIGURE 1 Utah DOT Narrow Paved-Median Barrier

US-26 CMB Design (Oregon)
The cable size and tightness of the US-26 CMB are the same as typical freeway installations. However, the US-26 CMB design differs from typical installations in its post-spacing. The spacing has been reduced to decrease the level of cable deflection that occurs when the CMB is impacted by a vehicle. The post-spacing for the US-26 CMB is six feet, which is comparable to the 6.5’ spacing used for the UDOT system, rather than a typical post spacing of 15-20’. The support structure of the US-26 CMB system also differs from the UDOT installation in its use of “S4 I-beam” steel yielding posts rather than the C-Shaped posts installed on US-189 (Figure 2).
The heavier post used for the US-26 system reduces deflection. The six-foot post spacing combined with the S4 I-beam posts is expected to allow approximately five feet of deflection from a 4500 lb. vehicle during a NCHRP 350 crash test, or seven feet from an 18,000 lb. vehicle (single axle truck). (3,14). The Special Provisions for the US-26 CMB project required that the system meet NCHRP 350 TL-4 standards (10).

The bottom cable of the US-26 CMB is at 17” high, which is the low end of the range for typical CMB systems. The top cable is at just over 38” high (17). This is at least four inches higher than the top cables on most three-cable CMB systems; it is also higher than the top cable on Utah DOT’s US-189 CMB.

“Section 00811 – Cable Barrier” was not a Standard Specification in the OSSC at the time of the US-26 CMB project delivery (8). As such, the specifications associated with the US-26 CMB installation were included in the project documents as a Special Provision (10). The project’s Special Provision differs slightly from the 2008 Standard Specifications for CMBs. The 2008 specifications require the contractor to install the cable barrier “according to the manufacturer’s directions” and to locate the anchors “according to manufacturer’s instructions” (11). However, the US-26 project’s Special Provisions are more specific in requiring a “maximum post spacing of six feet.”

METHODOLOGY AND RESULTS

Control Section
In order to analyze the CMB system and how it has impacted the safety performance of this section of highway, a Control Section was chosen for comparison. The selected Control Section currently has no median barrier. It is adjacent to the CMB Section and was chosen due to the similarity in crash types, length, accesses and proximity to the CMB Section. The Control Section is located just west of the existing CMB Section on the Mt. Hood Highway. It is 1.88 miles long (assuming 1.51 miles of CMB with a 0.37 mile gap in the barrier), while the CMB Section is 1.76 miles long (1.52 miles of CMB with a 0.24 mile gap). The time period analyzed for both sections is April 2001 through December 2013.

Crash List
Unless otherwise noted, the crash data used for the analysis of this section is from the Oregon’s State Highway Crash Database. Crashes in this database include those reported by involved citizens and by law enforcement when
they are on the scene. Crash reports from citizens and law enforcement that represent the same crash are matched and reviewed for consistency by ODOT.

Within the CMB Section there is a 0.24 mile gap where no CMB is installed in order to allow cross-traffic on E. Terra Fern Road. The crashes in this gap are excluded in the analyses presented herein as it is assumed that the crashes in the gap would not be affected by the CMB installation. Within the Control Section, it is assumed that a 0.37 mile gap would include the intersections of US-26 with SE Rainbow Hill Rd and with the west end of SE Wagoneer Loop Drive. Crashes occurring within the assumed gap location are also excluded from the crash analysis.

Control Section vs. CMB Section – Crash Rates and Crash Severity
The crash rates of a section of highway allow for comparison between different segments of highway. The section crash rate analysis standardizes the length of time, the length in mileage and the volume of traffic being considered for each section. Section crash rates are calculated as referred to in the ODOT Traffic Manual (13).

The following figure shows the crash rates for the Control Section and the CMB Section. The “gap” areas between CMB installations are excluded from the analysis. As demonstrated by the figure, the crash rate for the Control Section decreased by 26% and that for the CMB Section increased by 72%. The increase in crashes in the CMB Section was primarily an increase in fixed object crashes (vehicles striking the CMB) (Figure 3).

![Crash Rates](image)

**FIGURE 3 Crash Rates – Control Section and CMB Section**

It is important to also further consider how the CMB system has impacted the severity of crashes. The following figure shows the Fatal/Injury crash rates for the sections excluding the “gap” areas between CMB installations. As shown in the figure, the Control Section increased in Fatal/Injury crashes by 17% whereas the CMB Section decreased by 29% in fatal/injury crashes. Thus although the overall crash rate increased in the CMB Section, the crash rate for the more severe crashes decreased substantially (Figure 4).
FIGURE 4 Fatal/Injury Crash Rates – Control Section and CMB Section

To further consider how the cable barrier system has impacted the frequency and severity of crashes, a modified Safety Priority Index System (SPIS) formulation was used, taking into account crash frequency, crash rate and crash severity. SPIS is a method developed by ODOT for identifying potential safety problems on state highways. SPIS has been accepted by the Federal Highway Administration (FHWA) as fulfilling the requirements of the Federal Highway Safety Improvement Program (HSIP). The advantage of the SPIS formulation is it overcomes the problems with any one measure alone (i.e., crash rates are high when volumes are low, frequencies are higher on higher volume roads, crash rates and frequencies do not take into account crash severity) (12). As with the standard SPIS score, the modified SPIS score used for this study is the sum of three values:

- Crash frequency indicator value, $IV_{Freq}$
- Crash rate indicator value, $IV_{Rate}$
- Crash severity indicator value, $IV_{Severity}$

Where,

$$IV_{Freq} = \frac{\log(TotalCrashes + 1)}{\log(151)}$$

$$IV_{Rate} = \frac{\log\left(\frac{(TotalCrashes)(1,000,000)}{(Years)(365 \text{ days})(ADT)}\right)}{\log(7 + 1)}$$

$$IV_{Severity} = \frac{100(FATAL + INJ_A) + (10)(INJ_B + INJ_C) + (PDO)}{300}$$
A typical SPIS score calculation is performed using three years of data ("Years" = 3); however, over six years of data is used for the modified score ("Years" = 6.3). Further, a typical SPIS score allows a maximum IV_Severity of 50; the modified score will not restrict this value to a maximum in order to fully understand the change in crash severity following CMB installation.

The results show that the modified SPIS score increased by 23% in the Control Section following CMB installation, while it decreased by 34% in the CMB Section (Table 1) (Figure 5). The severity indicator, specifically, increased by 39% (from 52 to 73) in the Control Section and decreased by 59% (from 51 to 21) in the CMB section. Thus, although installation of the CMB is associated with an increase in crashes, there has also been a decrease in the severity of crashes by preventing drivers from crossing into oncoming traffic. The crash data from the Control Section indicates that this might not have been the case had the CMB not been installed.

**TABLE 1 Severity Indicator – Control Section and CMB Section**

<table>
<thead>
<tr>
<th></th>
<th>Control Section</th>
<th>CMB Section</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PRE CMB</td>
<td>POST CMB</td>
</tr>
<tr>
<td>IV_Freq</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>IV_Rate</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>IV_Severity</td>
<td>52</td>
<td>73</td>
</tr>
<tr>
<td><strong>TOTAL (Modified SPIS Score):</strong></td>
<td><strong>78</strong></td>
<td><strong>96</strong></td>
</tr>
<tr>
<td><strong>Change</strong></td>
<td><strong>23%</strong></td>
<td><strong>-34%</strong></td>
</tr>
</tbody>
</table>
Typically, head-on crashes are the collision type that results in the most severe crashes. Before the CMB installation there were three head-on crashes; all three of the pre-installation head-on collisions were crossover crashes. No head-on collisions or opposite direction crashes have been reported in the time since the CMB was installed. Further, there is no indication in the crash data that deflection of the CMB at the time of a crash contributed to any of the reported crashes. Fixed object crashes have increased with the majority of fixed object crashes hitting the CMB (Figure 6).

**FIGURE 6 Collision Type Comparison**

The second characteristic that is analyzed is severity. No fatal crashes occurred prior to or after installation of the CMB system. Before installation of the CMB system, 67% of crashes (12 of 18) resulted in an injury while 33% (6 of 18) were Property Damage Only (PDO). After installation of the CMB system, 28% of crashes (10 of 36) resulted in an injury and 72% (26 of 36) resulted in PDO (Figure 7).
Due to the limited sample size of post-CMB installation injury crashes, it is difficult to draw firm conclusions as to why the post-installation injuries occurred when they did. However, it should be noted that of the ten post-installation injury crashes that occurred within the extent of the CMB, only three involved the CMB. For injury B crashes specifically, all six were fixed object crashes; however, only two of the six involved the CMB (Table 2).

**TABLE 2 Post-Installation Crashes – PDO & Injury**

<table>
<thead>
<tr>
<th>Driver &lt; 25 mi of home</th>
<th>PDO # of Crashes: 13 of 26</th>
<th>PDO %: 50%</th>
<th>Injury # of Crashes: 8 of 10</th>
<th>Injury %: 80%</th>
<th>TOTAL # of Crashes: 21 of 36</th>
<th>TOTAL %: 58%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involved CMB</td>
<td>24 of 26</td>
<td>92%</td>
<td>3 of 10</td>
<td>30%</td>
<td>27 of 36</td>
<td>75%</td>
</tr>
<tr>
<td>Overturned Vehicle</td>
<td>1 of 26</td>
<td>4%</td>
<td>2 of 10</td>
<td>20%</td>
<td>3 of 36</td>
<td>8%</td>
</tr>
</tbody>
</table>

Four of the pre-CMB installation crashes involved a vehicle crossing left of center. These vehicles would presumably have struck the CMB if it had been in place at that time. Of the pre-installation left-of-center crashes, 75% (3 of 4) were injury crashes. In comparison, of the post-CMB installation left-of-center crashes (crashes involving the CMB), only 11% (3 of 28) were injury crashes. Thus, the proportion of left-of-center crashes resulting in injury decreased substantially following installation of the CMB (Figure 8).
All three of the Post-Installation overturned vehicle crashes were passenger vehicles traveling westbound within 25 miles of home in wet surface conditions. Two were Injury B crashes; one was a PDO crash. The Injury B crashes involved the guard rail but not the CMB; the PDO crash involved the CMB. 22% of crashes (4 of 18) from the pre-installation time-period resulted in an overturned vehicle. These pre-installation crashes resulted in one Injury A, two Injury B’s and one Injury C (Figure 9).
Crash Analysis Summary
The analysis of crash rates shows that while the Control Section crash rate decreased following CMB installation, the CMB Section crash rate increased. The increase in crash rate in CMB Section is likely due to installing a fixed object in the median of the roadway. There is less room for drivers to recover when crossing over the median. However, the severity indicator for the Control Section increased while the CMB Section indicator decreased substantially. Although installation of the CMB is associated with an increase in crashes, there has also been a decrease in the severity of crashes by preventing drivers from crossing into oncoming traffic. No head-on collisions or opposite direction crashes have been reported in the time since the CMB was installed. Further, there is no indication in the crash data that deflection of the CMB at the time of a crash contributed to any of the reported crashes. These results are similar to results in other studies that analyzed median barrier installation and found a decrease on opposite-direction crashes and increase of single vehicle collisions (14). A study in North Carolina also found decreased head-on crashes, decreased severity and increased fixed object crashes on their cable median barrier sections (2).

OPERATIONAL REVIEW
This section covers operational aspects of the CMB system based on feedback and records from a variety of project stakeholders. Comments and opinions were obtained from representatives of Mt. Hood Safety Corridor Citizen Advisory Committee, Oregon State Police (OSP), Sandy Fire Department, Hoodland Fire Department and ODOT Sandy Maintenance Unit, as well as an independent motorist. Stakeholders provided input related to their perception of how the system functions. Also included in this section is information on how the cable barrier system is repaired and the cost of repairs.

Stakeholder Feedback
According to the Chair of the Mt. Hood Safety Corridor Citizen Advisory Commission, when the CMB was installed, there were initially concerns from a few property owners that owned properties adjacent to the CMB. The property owners were concerned that access to their properties would be restricted by the CMB. However, the property owners are now familiar with the system and are supportive. The perception from citizens is that drivers slow down as they approach the CMB, especially in the westbound direction, and especially during snow season. The Advisory Commission Chair stated that maintenance and repairs to the system after crashes seems to be very quick and there does not seem to be much, if any, disruption to traffic. General feedback from citizens in the area is that they are glad that the CMB was installed. However, the commission does not think similar systems should be installed in areas along the corridor that are more residential as the access restrictions would be an annoyance. The general perception is that traffic safety has improved.

Prior to CMB installation, first responders voiced concern that the CMB installation might result in increased response times. However, post-installation comments from first responders indicate that their initial worries regarding response times are no longer of concern as they have not had any problems accessing crashes in an efficient manner. Police officers commented that the cable barrier has indeed reduced crash severity and that deflection of cables has not been a concern. First responders from the local fire departments echoed comments from the Advisory Commission, stating that drivers seem to slow down when they approach the barrier, especially during snow season.

Maintenance and Repairs
The ODOT Sandy Maintenance Unit tracked all hits on the CMB system through July 2012 and provided a repair log. The Maintenance Unit reported 30 incidents that required repairs to the CMB through July 2012. 21 of these incidents could be linked to crashes that were reported to the State Highway Crash Database. 30% of cable barrier collisions went unreported, which is similar to the rate of unreported cable barrier collisions in Missouri, 26% (14).

The number of posts requiring replacement with each hit ranged from one to 141. The total material cost for repairs is approximately $70,400 with 92 hours of labor. Due to the narrow median, the maintenance crew must usually close down one lane in each direction in order to repair the barrier. Not only does this require labor and equipment, but time. Sometimes the maintenance crew can close down just one lane depending on how severe the damage is to the CMB.

Thus far, all repairs have included only replacing damaged posts; no cable tensioning or cable replacement has been required. Replacing posts involves a couple of people; one who pulls out the damaged post and the other
lifting the cable with an auto crane. Generally, more time is involved in setting up traffic control than in replacing
the posts.

**Operational Review Summary**

Overall, the operational review of the cable barrier system is satisfactory. The cable barrier is simple and low-cost to
install and repair. There have been no problems with the cable barrier deflecting into oncoming lanes or with it
slowing down response times for emergency vehicles. Plowing concerns from the maintenance crew were addressed
with snow poles, which also add visibility to the cable barrier.

**CONCLUSION**

This study finds that the CMB system is successful in preventing head-on collisions from crossover movements and
in reducing the severity of crashes. There have been more crashes in the CMB Section following installation of the
system; however, the severity of crashes has decreased substantially. The results of this study are similar to other
studies even though the median is much narrower than other installations.

Maintenance of the CMB system is minimal, relatively easy and low in cost. The maintenance crew has a
positive attitude towards maintaining the CMB system. First responders and local residents also provided positive
feedback regarding their perceptions of, and experience with, the CMB system. Overall, stakeholders’ experiences
with the operations of the CMB have been positive.

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REFERENCES


