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# Effectiveness of Countermeasures for Roadway Departure Crashes

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***Toolbox Of Countermeasures***
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# Toolbox of Countermeasures and Their Potential Effectiveness for Roadway Departure Crashes

## Introduction

This issue brief documents estimates of the crash reduction that might be expected if a specific countermeasure or group of countermeasures is implemented with respect to roadway departure crashes and other non-intersection crashes. The crash reduction estimates are presented as Crash Reduction Factors (CRFs).

Traffic engineers and other transportation professionals can use the information contained in this issue brief when asking the following types of question: Which countermeasures might be considered along a particular section of a highway that is experiencing a high number of roadway departure crashes? What changes in the number of roadway departure crashes can be expected with the implementation of the various countermeasures?

When selecting countermeasures to reduce the number and/or severity of roadway departure crashes, the practitioner should first consider countermeasures designed to reduce the likelihood of vehicles leaving the roadway. Next, the practitioner should select strategies which minimize the likelihood of crashing into an object or overturning if the vehicle travels beyond the edge of the shoulder. Finally, the practitioner should consider countermeasures which reduce the severity of the crash such as improving the design and application of barrier and attenuation systems.

When selecting countermeasures to reduce the number and/or severity of crashes associated with hazardous roadside obstacles, the practitioner should refer to the AASHTO Roadside Design Guide which recommends these design options in order of preference:

1. Remove the obstacle;
2. Redesign the obstacle so it can be safely traversed;
3. Relocate the obstacle to a point where it is less likely to be struck;
4. Reduce impact severity by using an appropriate breakaway device;
5. Shield the obstacle with a longitudinal traffic barrier designed for redirection or use a crash cushion; and
6. Delineate the obstacle if the above alternatives are not appropriate.

## Crash Reduction Factors

A CRF is the percentage crash reduction that might be expected after implementing a given countermeasure. In some cases, the CRF is negative, i.e. the implementation of a countermeasure is expected to lead to a percentage increase in crashes.

One CRF estimate is provided for each countermeasure. Where multiple CRF estimates were available from the literature, selection criteria were used to choose which CRFs to include in the issue brief:

- Firstly, CRFs from studies that took into account regression to the mean and changes in traffic volume were preferred over studies that did not.
- Secondly, CRFs from studies that provided additional information about the conditions under which the countermeasure was applied (e.g. road type, area type) were preferred over studies

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FHWA-SA-07-013

that did not.

Where these criteria could not be met, a CRF may still be provided. In these cases, it is recognized that the reliability of the estimate of the CRF is low, but the estimate is the best available at this time. The CRFs in this issue brief may be periodically updated as new information becomes available.

The *Desktop Reference for Countermeasures* lists all of the CRFs included in this issue brief, and adds many other CRFs available in the literature. A few CRFs found in the literature were not included in the *Desktop Reference*. These CRFs were considered to have too large a range or too large a standard error to be meaningful, or the original research did not provide sufficient detail for the CRF to be useful.

*A CRF should be regarded as a generic estimate of the effectiveness of a countermeasure. The estimate is a useful guide, but it remains necessary to apply engineering judgment and to consider site-specific environmental, traffic volume, traffic mix, geometric, and operational conditions which will affect the safety impact of a countermeasure*. The user must ensure that a countermeasure applies to the particular conditions being considered. The reader is also encouraged to obtain and review the original source documents for more detailed information, and to search databases such as the National Transportation Library (ntlsearch.bts.gov) for information that becomes available after the publication of this issue brief.

## Presentation of the Crash Reduction Factors

In the Tables presented in this issue brief, the crash reduction estimates are provided in the following format:

CRF(standard error)$^{REF}$

The CRF is the value selected from the literature.

The standard error is given where available. The standard error is the standard deviation of the error in the estimate of the CRF. The true value of the CRF is unknown. The standard error provides a measure of the precision of the estimate of the true value of the CRF. A relatively small standard error indicates that a CRF is relatively precisely known. A relatively large standard error indicates that a CRF is not precisely known. The standard error may be used to estimate a confidence interval of the true value of the CRF. (An example of a confidence interval calculation is given below.)

The REF is the reference number for the source information.

As an example, the CRF for the countermeasure *remove or relocate fixed objects outside of clear zone* for all crashes is:

**38**(10)$^{17}$

The following points should be noted:

- The CRF of 38 means that a 38% reduction in all crashes is expected after removing or relocating fixed objects outside of the clear zone.
- This CRF is bolded which means that a) a rigorous study methodology was used to estimate the CRF, and b) the standard error is relatively small. A CRF which is not bolded indicates that a less rigorous methodology (e.g. a simple before-after study) was used to estimate the CRF and/or the standard error is large compared with the CRF.
- The standard error for this CRF is 10. Using the standard error, it is possible to calculate the 95% confidence interval for the potential crash reduction that might be achieved by implementing the countermeasure. The 95% confidence interval is ±2 standard errors from the CRF. Therefore, the 95% confidence interval for removing or relocating fixed objects outside of the clear zone is between 18% and 58% (38 - 2×10 = 18%, and 38 + 2×10 = 58%).
- The reference number is 17 (Hovey and Chowdhury, as listed in the References at the end of this issue brief).

## Using the Tables

The CRFs for roadway departure crashes and other non-intersection crashes are presented in six tables which summarize the available information. The Tables are:

Table 1: Barrier Countermeasures
Table 2: Bridge Countermeasures
Table 3: Geometric Countermeasures
Table 4: Median Countermeasures
Table 5: Roadside Countermeasures
Table 6: Signs/Markings/Operational Countermeasures

The following points should be noted:

- Where available, separate CRFs are provided for different crash severities. The crash severities are: all, fatal/injury, fatal, injury, or property damage only (PDO).
- Where available, road type information is provided.
- Where available, daily traffic volume (vehicles/day) is provided.
- Blank cells mean that no information is reported in the source document.
- For additional information, please visit the FHWA Office of Safety website (safety.fhwa.dot.gov).

**Legend**

**CRF(standard error)[REF]**

**CRF is a crash reduction factor, which is an estimate of the percentage reduction that might be expected after implementing a given countermeasure. A number in bold indicates a rigorous study methodology and a small standard error in the value of the CRF.**
**Standard error, where available, is the standard deviation of the error in the estimate of the CRF.**
**REF is the reference number for the source information.**

**Additional crash types identified in the *Other Crashes* column are:**
**a: Sideswipe b: Night c: Right-angle d: Left-turn e: Wet pavement f: Overturn g: Pedestrian h: Right-turn i: Animal**
**j: Parking k: Wet weather l: Head-on/sideswipe m: Snow n: Truck-related o: Speed related**

## Table 1: Barrier Countermeasures

| Countermeasure(s) | Crash Severity | Area Type | Road Type | All Crashes | Run-off-Road Crashes | Head-on Crashes | Rear-end Crashes | Fixed Object Crashes | Other Crashes | Daily Traffic Volume (vehicles/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| Improve guardrail | All | | | 18[9] | | | 41[9] | 23[9] | f 41[9] | <5,000/lane |
| | All | | | 9[9] | 32[9] | | 27[9] | 18[9] | f 27[9] | >5,000/lane |
| | All | | | | 26[9] | | | | | |
| | Fatal | | All | 50[1] | | | | | | |
| | Injury | | | 35[9] | | | | | | |
| Install animal fencing | All | | | | | | | | i 80[9] | |
| | Injury | | | | | | | | i 91[9] | |
| | PDO | | | | | | | | i 61[9] | |
| Install barrier (concrete) inside and outside curve | Fatal/Injury | | | 39[9] | | | | | | |
| Install guardrail (as shield for rocks and posts) | All | | | 14[9] | | | | 100[9] | | |
| | Injury | | | 31[9] | | | | | | |
| Install guardrail (as shield for trees) | Fatal | | | 65[9] | | | | | | |
| | Injury | | | 51[9] | | | | | | |
| Install guardrail (at culvert) | All | | | 27[9] | | | | | | |
| Install guardrail (at ditch) | Injury | | | 26[9] | | | | | | |
| Install guardrail (at embankment) | All | | All | | 7(31)[4] | | | | | |
| | Fatal | | All | | 44(10)[4] | | | | | |
| | Injury | | | 42[9] | | | | | | |
| | Injury | | All | | 47(5)[4] | | | | | |
| Install guardrail (inside curves) | Fatal/Injury | | | 28[9] | | | | | | |
| Install guardrail (outside curves) | Fatal/Injury | | | 63[9] | | | | | | |
| Install impact attenuators | All | | | 29[9] | 45[9] | | | | | |
| | Fatal | All | All | 75[1] | | | | 69(28)[4] | | |
| | Injury | All | All | 50[1] | | | | 69(10)[4] | | |
| | PDO | | | | | | | 46(30)[4] | | |
| Replace guardrail with a softer material (concrete→steel→wire) | Fatal | | All | | 41(31)[4] | | | | | |
| | Injury | | All | | **32**(10)[4] | | | | | |

**Table 1 (continued on page 5)**

## Table 2: Bridge Countermeasures

| Countermeasure(s) | Crash Severity | Area Type | Road Type | All Crashes | Run-off-Road Crashes | Head-on Crashes | Rear-end Crashes | Fixed Object Crashes | Other Crashes | Daily Traffic Volume (vehicles/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| Install bridge lighting | All | | | 59[9] | | | | | | |
| Install delineators (on bridges) | All | | | 43[9] | | | | | | |
| Install guardrail (at bridge) | All | | | 22[9] | | | 37[9] | | f 41[9] | <5,000/lane |
| | All | | | 20[9] | | | 32[9] | | f 32[9] | >5,000/lane |
| | All | | | | | | | | k 50[9] | |
| | Fatal | | | 90[9] | | | | | | |
| | Injury | | | 45[9] | | | | | | |
| Repair bridge deck | All | | | 14[9] | | | | | | |
| Replace bridge (general) | All | | All | 45[1] | | | | | | |
| Replace bridge (2-lane) | All | | | 45[9] | | | | | | |
| Upgrade bridge parapet | All | | | 5[9] | | | | | | |
| Upgrade bridge railing | All | | | 20[9] | | | | | | |
| | Fatal | | | 76[9] | | | | | | |
| | Injury | | | 61[9] | | | | | | |
| | PDO | | | 50[9] | | | | | | |
| Widen bridge | All | | | 45[9] | 44[9] | 45[9] | | 45[9] | a 49[9] | |
| | Fatal/Injury | | | 92[9] | | | | | | |
| | PDO | | | 95[9] | | | | | | |
| Widen bridge (18 to 24 ft) | All | | | 68[9] | | | | | | |
| Widen bridge (18 to 30 ft) | All | | | 93[9] | | | | | | |
| Widen bridge (20 to 24 ft) | All | | | 56[9] | | | | | | |
| Widen bridge (20 to 30 ft) | All | | | 90[9] | | | | | | |
| Widen bridge (22 to 24 ft) | All | | | 36[9] | | | | | | |
| Widen bridge (22 to 30 ft) | All | | | 86[9] | | | | | | |

## Table 3: Geometric Countermeasures

| Countermeasure(s) | Crash Severity | Area Type | Road Type | All Crashes | Run-off-Road Crashes | Head-on Crashes | Rear-end Crashes | Fixed Object Crashes | Other Crashes | Daily Traffic Volume (vehicles/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| Flatten crest vertical curve | All | All | All | 20(19)[17] | | | | | | |
| | Fatal/Injury | All | All | **51**(19)[17] | | | | | | |
| | Fatal/Injury | Rural | 2-lane | 50[18] | | | | | | |
| Flatten horizontal curve | All | | | 39[9] | | | | | | |
| | All | | | | 90[9] | 67[9] | 73[9] | 68[9] | f 73[9] | <5,000/lane |
| | All | | | | 79[9] | 64[9] | 24[9] | 87[9] | f 24[9] | >5,000/lane |

**Table 3 (continued on page 6)**

## Table 3 (continued)
## Geometric Countermeasures

| Countermeasure(s) | Crash Severity | Area Type | Road Type | All Crashes | Run-off-Road Crashes | Head-on Crashes | Rear-end Crashes | Fixed Object Crashes | Other Crashes | Daily Traffic Volume (vehicles/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| Flatten horizontal curves (10 to 5 degrees) | All | | | 45[9] | | | | | | |
| Flatten horizontal curves (15 to 5 degrees) | All | | | 63[9] | | | | | | |
| Flatten horizontal curves (20 to 10 degrees) | All | | | 48[9] | | | | | | |
| Flatten side slopes | All | | | 43[9] | | | | | | <5,000/lane |
| | All | | | 45[9] | | | | | | >5,000/lane |
| | All | | | | 10[9] | | | 62[9] | | |
| Flatten side slopes (11 to 8 degrees) | All | | | 8[9] | | | | | g 14[9] | |
| | All | | | | | | | | h 14[9] | |
| Flatten side slopes (14 to 9 degrees) | Injury | Rural | 2-lane | **22**(4)[4] | | | | | | |
| | PDO | Rural | 2-lane | **24**(2)[4] | | | | | | |
| | All | | | 7[9] | | | | | g 12[9] | |
| | All | | | | | | | | h 12[9] | |
| Flatten side slopes (18 to 9 degrees) | All | Rural | 2-lane | 11[9] | | | | | g 19[9] | |
| | All | | | | | | | | h 19[9] | |
| Flatten side slopes (18 to 11 degrees) | All | | | 8[9] | | | | | g 14[9] | |
| | All | | | | | | | | h 14[9] | |
| Flatten side slopes (18 to 14 degrees) | Injury | Rural | 2-lane | **42**(4)[4] | | | | | | |
| | PDO | Rural | 2-lane | **29**(4)[4] | | | | | | |
| | All | | | 5[9] | | | | | g 8[9] | |
| | All | | | | | | | | h 8[9] | |
| Flatten side slopes (27 to 9 degrees) | All | | | 12[9] | | | | | g 21[9] | |
| | All | | | | | | | | h 21[9] | |
| Flatten side slopes (27 to 11 degrees) | All | | | 9[9] | | | | | g 15[9] | |
| | All | | | | | | | | h 15[9] | |
| Flatten side slopes (27 to 14 degrees) | All | | | 6[9] | | | | | g 10[9] | |
| | All | | | | | | | | h 10[9] | |
| Flatten side slopes and remove guardrail | All | All | All | 42(58)[17] | | | | | | |
| Improve gore area | All | | | 25[9] | | | | | | |
| Improve horizontal and vertical alignments | All | | | 58[9] | | | | | | |
| Improve longitudinal grade | All | | | 49[9] | | | | | | |
| | Fatal/Injury | | | 87[9] | | | | | | |
| | PDO | | | 83[9] | | | | | | |
| Improve superelevation | All | | | 40[9] | 50[9] | | | | | |
| Improve superelevation (for drainage) | All | | | 45[9] | | | | | | |
| Increase number of lanes | All | | | | | | | | d 71[9] | |
| | All | | | 20[9] | | 38[9] | 42[9] | | a 38[9] | <5,000/lane |
| | All | | | | | | | | c 35[9] | <5,000/lane |
| | All | | | | | | | | f 42[9] | <5,000/lane |
| | All | | | 31[9] | | 44[9] | 52[9] | | a 44[9] | >5,000/lane |
| | All | | | | | | | | c 45[9] | >5,000/lane |
| | All | | | | | | | | f 52[9] | >5,000/lane |
| | Fatal | | | 39[9] | | | | | | |
| | Injury | | | 23[9] | | | | | | |

**Table 3 (continued on page 7)**

## Table 3 (continued)
## Geometric Countermeasures

| Countermeasure(s) | Crash Severity | Area Type | Road Type | All Crashes | Run-off-Road Crashes | Head-on Crashes | Rear-end Crashes | Fixed Object Crashes | Other Crashes | Daily Traffic Volume (vehicles/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| Increase number of lanes (continued) | PDO | | | 27[9] | 50[9] | 50[9] | 53[9] | | a 64[9] | |
| | PDO | | | | | | | | c 46[9] | |
| | PDO | | | | | | | | d 67[9] | |
| Install acceleration/deceleration lanes | All | | | 26[9] | | | 75[9] | | a 75[9] | |
| Install channelized lane | All | | | 67[9] | | | 93[9] | | | |
| | PDO | | | 62[9] | | | | | | |
| Install climbing lane (where large difference between car and truck speed) | Fatal/Injury | Rural | 2-lane | 33[18] | | | | | | |
| Install passing/climbing lane | All | All | All | 20[1] | | | | | | |
| | Fatal/Injury | Rural | 2-lane | 33[18] | | | | | | |
| Install shoulder | All | | | 9[9] | | | | | | |
| Install shoulder bus lanes | Fatal/Injury | | | | | 50[9] | | | a 27[9] | |
| | Fatal/Injury | | | | | | | | c 34[9] | |
| | Fatal/Injury | | | | | | | | d 42[9] | |
| | PDO | | | | 27[9] | 86[9] | | | a 8[9] | |
| | PDO | | | | | | | | c 31[9] | |
| | PDO | | | | | | | | d 57[9] | |
| Install truck escape ramp | All | | | 18[9] | 75[9] | | 33[9] | | | |
| Lengthen culverts | All | | | 44[9] | | | | | | |
| Narrow cross section (4 to 3 lanes with two-way left turn lane) | All | Urban | 4-lane highway | **37**(1)[11] | | | **31**(2)[11] | | c **37**(1)[11] | 8,000 - 17,400 |
| | All | Urban | 4-lane highway | | | | | | d **24**(2)[11] | 8,000 - 17,400 |
| | Fatal/Injury | Urban | 4-lane highway | **0**(2)[11] | | | | | | 8,000 - 17,400 |
| | PDO | Urban | 4-lane highway | **46**(1)[11] | | | | | | 8,000 - 17,400 |
| Reduce horizontal curve angle | All | | | 38[9] | | | | | | |
| Reduce shoulder width (6 ft to 0 ft) | All | Rural | 2-lane | -12(3)[14] | | | | | | |
| Reduce shoulder width (6 ft to 1 ft) | All | Rural | 2-lane | -17(6)[14] | | | | | | |
| Reduce shoulder width (6 ft to 2 ft) | All | Rural | 2-lane | -11(2)[14] | | | | | | |
| Reduce shoulder width (6 ft to 4 ft) | All | Rural | 2-lane | -6(2)[14] | | | | | | |
| Reduce shoulder width (6 ft to 5 ft) | All | Rural | 2-lane | -2(2)[14] | | | | | | |
| Resurface pavement and improve superelevation | All | | | 28[9] | | | | | e 51[9] | |
| Stabilize shoulder | All | | | 25[9] | | | | | | |
| Stabilize shoulder and dropoff | All | All | All | 25[1] | | | | | | |
| Widen lane (add 1 ft to both sides) | All | | | | 12[9] | 12[9] | | | a 12[9] | |
| Widen lane (add 2 ft to both sides) | All | | | | 23[9] | 23[9] | | | a 23[9] | |
| Widen lane (add 3 ft to both sides) | All | | | | 32[9] | 32[9] | | | a 32[9] | |
| Widen lane (add 4 ft to both sides) | All | | | | 40[9] | 40[9] | | | a 40[9] | |
| Widen lane (initially less than 9 ft) | Fatal/Injury | Rural | 2-lane | 28[18] | | | | | | 400 - 2,000 |
| Widen lane (initially between 9 ft and 10.75 ft) | Fatal/Injury | Rural | 2-lane | 16[18] | | | | | | 400 - 2,000 |
| Widen lanes | All | | | 50[9] | 49[9] | 70[9] | | 5[9] | a 52[9] | |
| | All | | | | | | | | f 5[9] | |

**Table 3 (continued on page 8)**

## Table 3 (continued)
## Geometric Countermeasures

| Countermeasure(s) | Crash Severity | Area Type | Road Type | All Crashes | Run-off-Road Crashes | Head-on Crashes | Rear-end Crashes | Fixed Object Crashes | Other Crashes | Daily Traffic Volume (vehicles/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| Widen shoulder (from 6 to 7 ft) | All | Rural | 2-lane | -1(4)[14] | | | | | | |
| Widen shoulder (from 6 to 8 ft) | All | Rural | 2-lane | 4(2)[14] | | | | | | |
| Widen shoulder (from 6 to 9 ft) | All | Rural | 2-lane | 21(6)[14] | | | | | | |
| Widen shoulder (from 6 to >9 ft) | All | Rural | 2-lane | 18(3)[14] | | | | | | |
| Widen shoulder (initially less than 1 ft) | Fatal/Injury | Rural | 2-lane | 25[18] | | | | | | 400 - 2,000 |
| Widen shoulder (initially between 1 ft and 3.3 ft) | Fatal/Injury | Rural | 2-lane | 13[18] | | | | | | 400 - 2,000 |
| Widen shoulder (paved)(from 0 to 2 ft) | All | | | | 16[9] | | | 16[9] | | |
| Widen shoulder (paved)(from 0 to 4 ft) | All | | | | 29[9] | | | 29[9] | | |
| Widen shoulder (paved)(from 0 to 6 ft) | All | | | | 40[9] | | | 40[9] | | |
| Widen shoulder (paved)(from 0 to 8 ft) | All | | | | 49[9] | | | 49[9] | | |
| Widen shoulder (unpaved)(from 0 to 2 ft) | All | | | | 13[9] | | | 13[9] | | |
| Widen shoulder (unpaved)(from 0 to 4 ft) | All | | | | 25[9] | | | 25[9] | | |
| Widen shoulder (unpaved)(from 0 to 6 ft) | All | | | | 34[9] | | | 34[9] | | |
| Widen shoulder (unpaved)(from 0 to 8 ft) | All | | | | 43[9] | | | 43[9] | | |

## Table 4: Median Countermeasures

| Countermeasure(s) | Crash Severity | Area Type | Road Type | All Crashes | Run-off-Road Crashes | Head-on Crashes | Rear-end Crashes | Fixed Object Crashes | Other Crashes | Daily Traffic Volume (vehicles/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| Install median | All | All | All | 15[1] | | | | | | |
| | Injury | Rural | Multilane | 12(3)[4] | | | | | | |
| | Fatal/Injury | Rural | 2-lane | -94(56)[4] | | | | | | |
| | Injury | Urban | Multilane | 22(2)[4] | | | | | | |
| | Fatal/Injury | Urban | 2-lane | 39(10)[4] | | | | | | |
| | PDO | Rural | Multilane | 18(3)[4] | | | | | | |
| | PDO | Rural | 2-lane | -128(55)[4] | | | | | | |
| | PDO | Urban | Multilane | -9(2)[4] | | | | | | |
| Install median (flush) | All | | | 44[9] | | | | | d 72[9] | <5,000/lane |
| | All | | | 52[9] | | | | | d 78[9] | >5,000/lane |
| | Fatal | | | 90[9] | | | | | | |
| Install median barrier | All | | | | | | | | c 58[9] | <5,000/lane |
| | All | | | | | | | | c 54[9] | >5,000/lane |
| | All | | | 19[9] | 35[9] | | | | | |
| | All | All | All | **86**(3)[17] | | | | | | |
| | All | | Multilane divided | -24(3)[4] | | | | | | |
| | Fatal | | Multilane divided | 43(10)[4] | | | | | | |
| | Injury | | | 40[9] | | | | | | |
| | Fatal/Injury | All | All | **88**(5)[17] | | | | | | |
| | Injury | | Multilane divided | 30(6)[4] | | | | | | |

**Table 4 (continued on page 9)**

## Table 4 (continued)
## Median Countermeasures

| Countermeasure(s) | Crash Severity | Area Type | Road Type | All Crashes | Run-off-Road Crashes | Head-on Crashes | Rear-end Crashes | Fixed Object Crashes | Other Crashes | Daily Traffic Volume (vehicles/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| Install median barrier (cable) | All | | Highway (3-lane) | -34(74)[4] | | | | | | |
| | Fatal | Rural | Highway | | | 92[6] | | | | |
| | Injury | | Highway (3-lane) | 26(84)[4] | | | | | | |
| | Injury | | Multilane divided | 29(11)[4] | | | | | | |
| Install median barrier (concrete) | Injury | | Multilane divided | -15(36)[4] | | | | | | |
| | Fatal | | | 90[9] | | | | | | |
| | Injury | | | 10[9] | | | | | | |
| Install median barrier (steel) | Injury | | Multilane divided | 35(8)[4] | | | | | | |
| Install or upgrade median barrier near gore area | All | | | 17[9] | 56[9] | | 39[9] | | | <5,000/lane |
| Install raised median | All | | | 20[9] | | 75[9] | | | g 25[9] | |

## Table 5: Roadside Countermeasures

| Countermeasure(s) | Crash Severity | Area Type | Road Type | All Crashes | Run-off-Road Crashes | Head-on Crashes | Rear-end Crashes | Fixed Object Crashes | Other Crashes | Daily Traffic Volume (vehicles/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| Install frontage road | All | | | 40[9] | | | | | | |
| Install snow fencing | All | | | | | | | | m 53[9] | |
| Remove poles by burying utility lines | All | | | 40[9] | | | | | | |
| Remove obstacles on curves to improve sight distance | Fatal/Injury | Rural | 2-lane | 5[18] | | | | | | |
| Remove or relocate fixed objects outside of clear zone | All | All | All | **38**(10)[17] | | | | | | |
| | All | | | 18[9] | | | | | f 42[9] | <5,000/lane |
| | All | | | 17[9] | | | | | f 44[9] | >5,000/lane |
| | All | | | | | | | 65[9] | | |
| | All | Urban | | | | | | 20[9] | | |
| | All | | | | 71[9] | | | | | |
| | Fatal/Injury | All | All | **38**(13)[17] | | | | | | |
| Widen clear zone (add 5 ft) | All | | | | | | | 13[9] | | |
| Widen clear zone (add 8 ft) | All | | | | | | | 21[9] | | |
| Widen clear zone (add 10 ft) | All | | | | | | | 25[9] | | |
| Widen clear zone (add 15 ft) | All | | | | | | | 35[9] | | |
| Widen clear zone (add 20 ft) | All | | | | | | | 44[9] | | |

# Table 6: Sign/Marking/Operational Countermeasures

| Countermeasure(s) | Crash Severity | Area Type | Road Type | All Crashes | Run-off-Road Crashes | Head-on Crashes | Rear-end Crashes | Fixed Object Crashes | Other Crashes | Daily Traffic Volume (vehicles/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| **SIGNS** | | | | | | | | | | |
| Implement sign corrections to MUTCD standards | Injury | Urban | Local | 15(10)[4] | | | | | | |
| | PDO | Urban | Local | **7**(6)[4] | | | | | | |
| Install chevron signs on horizontal curves | All | | | 35[9] | | | | | | |
| | Fatal/Injury | Rural | 2-lane | 20[18] | | | | | | |
| Install curve advance warning signs | All | | | 30[9] | 30[9] | 29[9] | | | | |
| | Fatal | | | 55[9] | | | | | | |
| | Fatal/Injury | Rural | 2-lane | 10[18] | | | | | | |
| | Injury | | | 30(71)[4] | | | | | | |
| | PDO | | | 8(76)[4] | | | | | | |
| Install curve advance warning signs (advisory speed) | All | | | 29[9] | | | | | | |
| | Injury | | | 13(9)[4] | | | | | | |
| | PDO | | | 29(23)[4] | | | | | | |
| Install curve advance warning signs (flashing beacon) | All | | | 30[9] | | | | | | |
| Install delineators (general) | All | | | 11[9] | 34[9] | 67[9] | | | a 67[9] | |
| | All | | | | | | | | b 25[9] | |
| Install dynamic/variable accident warning signs | Injury | | Freeway | 44(17)[4] | | | 16(10)[4] | | | |
| Install dynamic/variable queue warning signs | PDO | | Freeway | | | | -16(15)[4] | | | |
| Install dynamic/variable speed warning signs | All | | | 46(17)[4] | | | | | | |
| | Injury | | | 41(62)[4] | | | | | | |
| Install guide signs (general) | All | | | 15[9] | | | | | | |
| Install guideposts or barrier reflectors | Fatal/Injury | Rural | 2-lane | 8[18] | | | | | | |
| Install illuminated signs | All | | | 15[9] | | | | | | |
| Install lane assignment signs | All | | | | | | 10[9] | | a 20[9] | |
| Install nonvehicular (animal) reflectors | All | | | 10[9] | | | | | b 25[9] | |
| Install pavement condition warning signs | All | All | All | | | | | | k 20[1] | |
| | All | | | 5[9] | | | | | e 20[9] | |
| Install post-mounted delineators (curves) | All | All | All | | | | | | b 30[1] | |
| | All | | | 25[9] | | | | | | |
| Install post-mounted delineators (tangents and curves combined) | Injury | Rural | 2-lane | -4(10)[4] | | | | | | |
| | PDO | Rural | 2-lane | -5(7)[4] | | | | | | |
| **PAVEMENT** | | | | | | | | | | |
| Improve pavement friction | All | | | | | | | | g 10[9] | |
| Improve pavement friction (groove shoulder) | All | | | 22[9] | | | | | | |
| Improve pavement friction (grooving) | All | | | 37[9] | 41[9] | | 54[9] | 36[9] | f 54[9] | <5,000/lane |
| | All | | | 21[9] | 40[9] | | 35[9] | 19[9] | f 35[9] | >5,000/lane |
| | All | | | | | | | | e 64[9] | <5,000/lane |
| | All | | | | | | | | e 54[9] | >5,000/lane |
| Improve pavement friction (increase skid resistance) | Fatal/Injury | Rural | 2-lane | | | | | | e 30[18] | |

**Table 6 (continued on page 11)**

## Table 6 (continued)
## Sign/Marking/Operational Countermeasures

| Countermeasure(s) | Crash Severity | Area Type | Road Type | All Crashes | Run-off-Road Crashes | Head-on Crashes | Rear-end Crashes | Fixed Object Crashes | Other Crashes | Daily Traffic Volume (vehicles/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| **PAVEMENT** | | | | | | | | | | |
| Improve pavement friction (overlay) | All | | | 13[9] | | 43[9] | | 43[9] | a 43[9] | <5,000/lane |
| | All | | | 20[9] | | 61[9] | | 34[9] | a 61[9] | >5,000/lane |
| | All | | | | | | | | c 23[9] | |
| | All | | | | | | | | e 23[9] | <5,000/lane |
| | All | | | | | | | | e 50[9] | >5,000/lane |
| | Fatal/Injury | | | | 28[9] | | 12[9] | | d 41[9] | |
| | PDO | | | | 29[9] | 30[9] | 21[9] | | a 27[9] | |
| | PDO | | | | | | | | c 31[9] | |
| | PDO | | | | | | | | d 34[9] | |
| Improve pavement friction (curve overlay) | All | | | 17[9] | | 86[9] | | | e 51[9] | |
| Improve pavement friction (resurface with deicing additives) | All | | | | | 31[9] | | | | |
| Improve pavement friction (resurface with open grade mix) | All | | | 75[9] | | 90[9] | | 93[9] | a 90[9] | |
| | All | | | | | | | | e 91[9] | |
| Improve pavement friction (skid treatment with overlay) | Fatal/Injury | | | | | | | | g 3[9] | |
| Install centerline rumble strips | All | Rural | 2-lane | **14**(5)[4] | | | | | l 21(12)[4] | 5,000 - 22,000 |
| | All | Rural | 2-lane highway | | | 55[16] | | | | |
| | Fatal | Rural | 2-lane highway | | | 68[16] | | | | |
| | Injury | Rural | 2-lane | 15(8)[4] | | | | | l 25(15)[4] | 5,000 - 22,000 |
| | Injury (minor) | Rural | 2-lane highway | | | 26[16] | | | | |
| | Injury (major) | Rural | 2-lane highway | | | 33[16] | | | | |
| Install or upgrade curbing | All | All | | | | | | 50[9] | | |
| Install shoulder rumble strips | All | All | Freeway | | 18(7)[13] | | | | | |
| | All | Rural | All | | 34[21] | | | | | |
| | All | Rural | Arterial | | 16[21] | | | | | |
| | All | Rural | Between ramps | | 34[21] | | | | | |
| | All | Rural | Freeway | | 21(10)[13] | | | | | |
| | All | Rural | Highway | | 27(22)[10] | | | | | |
| | All | Rural | Highway | | 38[21] | | | | | |
| | All | Rural | Multilane divided | 16[5] | 10[5] | | | | | |
| | All | Rural | 3-lane | | 36[21] | | | | | |
| | All | Rural | 2-lane | | 13(8)[19] | | | | | >4,000 |
| | Fatal/Injury | Rural | 2-lane | | 18(12)[19] | | | | | >4,000 |
| | Injury | All | Freeway | | 13(12)[13] | | | | | |
| | Injury | Rural | Freeway | | 7(16)[13] | | | | | |
| | Injury | Rural | Multilane divided | 17[5] | 22[5] | | | | | |
| Install shoulder rumble strips on illuminated highways | All | Rural | All | | 41[21] | | | | | |
| Install shoulder rumble strips on unilluminated highways | All | Rural | All | | 31[21] | | | | | |
| Pave shoulder | All | | | 15[9] | | 86[9] | | | b 62[9] | |

**Table 6 (continued on page 12)**

## Table 6 (continued)
## Sign/Marking/Operational Countermeasures

| Countermeasure(s) | Crash Severity | Area Type | Road Type | All Crashes | Run-off-Road Crashes | Head-on Crashes | Rear-end Crashes | Fixed Object Crashes | Other Crashes | Daily Traffic Volume (vehicles/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| **MARKINGS** | | | | | | | | | | |
| Delineate multiple lanes (painted lane lines) | All | Urban | Multilane | 18(22)[8] | | | | | | |
| Install centerline markings | All | | | 33[9] | | | | | | |
| | Injury | All | 2-lane | 1(6)[8] | | | | | | |
| | PDO | All | 2-lane | -1(5)[8] | | | | | | |
| Install chevron converging pattern markings on pavement | All | Urban | | 38(6)[12] | | | | | | |
| | Injury | | Freeway | 56(26)[4] | | | | | | |
| Install edgelines and centerlines | All | Rural | Undivided | -3(21)[2] | | | | | | 1,000 - 4,000 |
| | Injury | All | All | **24**(11)[8] | | | | | | |
| Install edgelines, centerlines and delineators | Injury | All | All | **45**(11)[8] | | | | | | |
| Install edgeline markings | All | | | 44[9] | | | 45[9] | 66[9] | f 45[9] | <5,000/lane |
| | All | | | 38[9] | | | 50[9] | 59[9] | f 50[9] | >5,000/lane |
| | All | | | | 30[9] | | | | | |
| | Injury | | | 15[9] | | | | | | |
| | PDO | | | 8[9] | | | | | | |
| Install edgeline markings (from 4 to 6 in) | Injury | Rural | 2-lane | 3(4)[8] | | | | | | |
| | PDO | Rural | 2-lane | 3(11)[8] | | | | | | |
| Install edgeline markings (8 in) | Injury | Rural | 2-lane | -5(8)[8] | | | | | | |
| | PDO | Rural | 2-lane | 1(15)[8] | | | | | | |
| Install raised pavement markers (snowplowable) where DOC = degree of curvature | All | Mostly Rural | 4-lane freeway | | | | | | b -13(14)[3] | ≤20,000 |
| | All | Mostly Rural | 4-lane freeway | | | | | | b 33(21)[3] | <60,000 |
| | All | Mostly Rural | 4-lane freeway | | | | | | b 6(21)[3] | 20,001 - 60,000 |
| | All | Mostly Rural | 2-lane, DOC>3.5 | | | | | | b **-43**(9)[3] | ≤5,000 |
| | All | Mostly Rural | 2-lane, DOC>3.5 | | | | | | b **-26**(10)[3] | 5,001 - 15,000 |
| | All | Mostly Rural | 2-lane, DOC>3.5 | | | | | | b -3(11)[3] | 15,001 - 20,000 |
| | All | Mostly Rural | 2-lane, DOC<3.5 | | | | | | b **-16**(3)[3] | ≤5,000 |
| | All | Mostly Rural | 2-lane, DOC<3.5 | | | | | | b **1**(5)[3] | 5,001 - 15,000 |
| | All | Mostly Rural | 2-lane, DOC<3.5 | | | | | | b **24**(7)[3] | 15,001 - 20,000 |
| **REGULATORY** | | | | | | | | | | |
| Install no-passing line | All | | | 53[9] | | 40[9] | | | a 40[9] | |
| Prohibit on-street parking | All | Urban | Arterial (64ft) | 42(8)[4] | | | | | | 30,000 |
| | All | | | 22[9] | | | | 40[9] | | |
| | Injury | Urban | Arterial | 20(5)[4] | | | | | | |
| | Injury | Urban | Arterial (64ft) | 35(14)[4] | | | | | | 30,000 |
| | PDO | Urban | Arterial | 27(2)[4] | | | | | | |
| | PDO | Urban | Arterial (64ft) | 48(1)[4] | | | | | | 30,000 |
| Reduce mean speed by 5% through speed limit change and enforcement | Fatal | All | All | 17(5)[4] | | | | | | |
| | Injury | All | All | 7(3)[4] | | | | | | |
| | PDO | All | All | 5(4)[4] | | | | | | |
| Reduce mean speed by 10% through speed limit change and enforcement | Fatal | All | All | 32(9)[4] | | | | | | |
| | Injury | All | All | 15(5)[4] | | | | | | |
| | PDO | All | All | 10(8)[4] | | | | | | |

**Table 6 (continued on page 13)**

## Table 6 (continued)
## Sign/Marking/Operational Countermeasures

| Countermeasure(s) | Crash Severity | Area Type | Road Type | All Crashes | Run-off-Road Crashes | Head-on Crashes | Rear-end Crashes | Fixed Object Crashes | Other Crashes | Daily Traffic Volume (vehicles/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| **REGULATORY (CONTINUED)** | | | | | | | | | | |
| Reduce mean speed by 15% through speed limit change and enforcement | Fatal | All | All | 44(14)[4] | | | | | | |
| | Injury | All | All | 22(8)[4] | | | | | | |
| | PDO | All | All | 15(12)[4] | | | | | | |
| **LIGHTING** | | | | | | | | | | |
| Improve lighting | All | | | | | | | | b 37[9] | |
| | Fatal | All | Freeway | 73(71)[4] | | | | | | |
| | Fatal | All | Highway | 69(36)[4] | | | | | | |
| | Fatal | Rural | Highway | 73(72)[4] | | | | | | |
| | Fatal | Urban | Highway | 63(52)[4] | | | | | | |
| | Injury | All | Freeway | 27(12)[4] | | | | | | |
| | Injury | All | Highway | 28(6)[4] | | | | | | |
| | Injury | Rural | Highway | 20(12)[4] | | | | | | |
| | Injury | Urban | Highway | 31(7)[4] | | | | | | |
| | PDO | All | Freeway | 32(26)[4] | | | | | | |
| | PDO | All | Highway | 18(7)[4] | | | | | | |
| | PDO | Rural | Highway | 30(43)[4] | | | | | | |
| | PDO | Urban | Highway | 16(8)[4] | | | | | | |
| Install lighting at interchanges | All | All | All | **50**(17)[17] | | | | | | |
| | Fatal/Injury | All | All | 26(38)[17] | | | | | | |
| **OPERATIONAL** | | | | | | | | | | |
| Add two-way left-turn lane | All | | All | 8(16)[17] | | | | | | |
| | All | | | | 37[9] | 36[9] | 36[9] | | c 20[9] | |
| | All | | | | | | | | d 33[9] | |
| | All | | | | | | | | g 19[9] | |
| | Fatal/Injury | | All | 20(25)[17] | 90[9] | 67[9] | 32[9] | | a 32[9] | |
| | Fatal/Injury | | | | | | | | c 31[9] | |
| | Fatal/Injury | | | | | | | | d 17[9] | |
| | Injury | | | 20[9] | | | | | | |
| | PDO | | | 35[9] | 16[9] | 64[9] | 38[9] | | a 37[9] | |
| | PDO | | | | | | | | c 23[9] | |
| | PDO | | | | | | | | d 38[9] | |
| Convert from two-way to one-way traffic | All | | | 43[9] | | | | | | |
| Implement crossover at work zone | All | | 4-lane divided | 0[7] | | | | | | 6,800 - 38,000 |
| Implement single lane closure at work zone | All | | 4-lane divided | -56[7] | | | | | | 20,000 - 41,500 |
| Improve drainage patterns | All | | | 32[9] | | | | | | |
| | All | | | | | | | | e 40[9] | |
| Install sidewalk | All | | | | | | | | g 74[9] | |
| Reconfigure lanes within existing pavement width (two to three in one direction) | All | | 2-lane | 32[9] | | | 46[9] | | a 46[9] | |
| | All | | 2-lane | | | | | | d 46[9] | |
| | Injury | | 2-lane | 59[9] | | | | | | |

**Table 6 (continued on page 14)**

## Table 6 (continued)
## Sign/Marking/Operational Countermeasures

| Countermeasure(s) | Crash Severity | Area Type | Road Type | All Crashes | Run-off-Road Crashes | Head-on Crashes | Rear-end Crashes | Fixed Object Crashes | Other Crashes | Daily Traffic Volume (vehicles/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| **OPERATIONAL (CONTINUED)** | | | | | | | | | | |
| Reconfigure lanes within existing pavement width (four to five in one direction) | All | Urban | Freeway | **-11**(5)[4] | | | | | | 77,000 - 126,000 |
| | Fatal/Injury | Urban | Freeway | -11(8)[4] | | | | | | 77,000 - 126,000 |
| Reconfigure lanes within existing pavement width (five to six in one direction) | All | Urban | Freeway | **-3**(8)[4] | | | | | | 77,000 - 126,000 |
| | Fatal/Injury | Urban | Freeway | -7(13)[4] | | | | | | 77,000 - 126,000 |
| Remove unwarranted signals | All | | | | | | | | g 17[20] | |

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