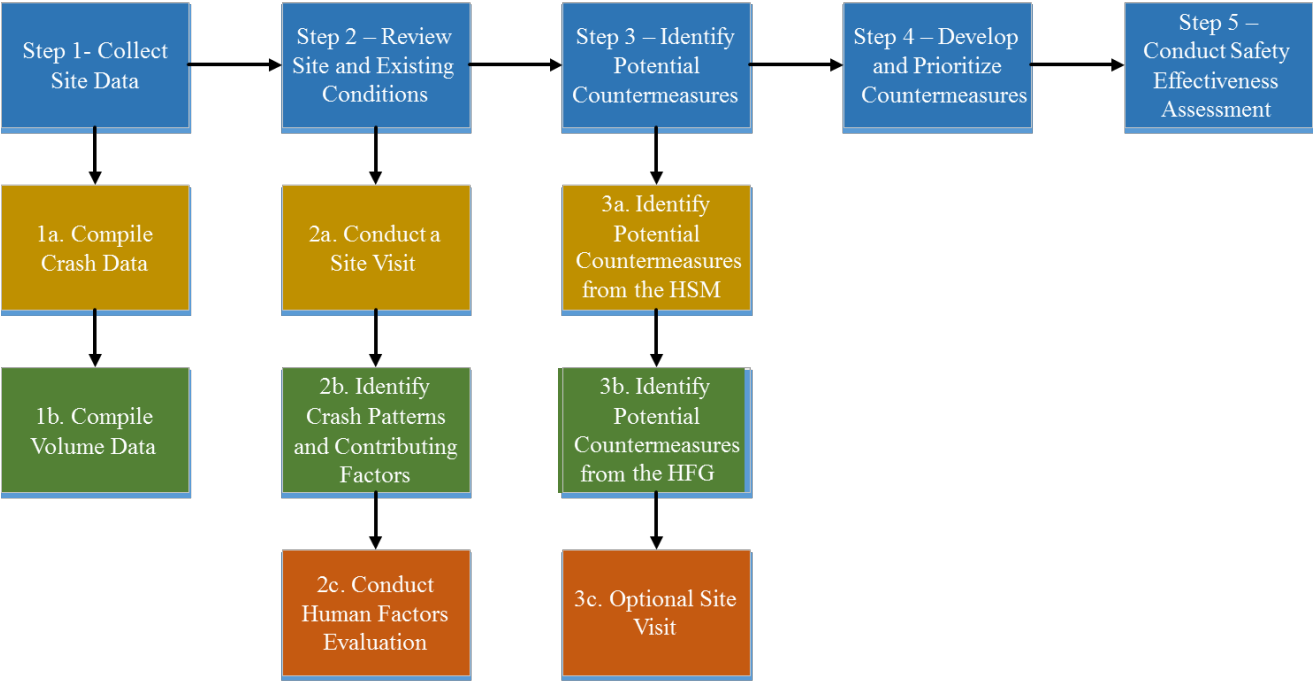


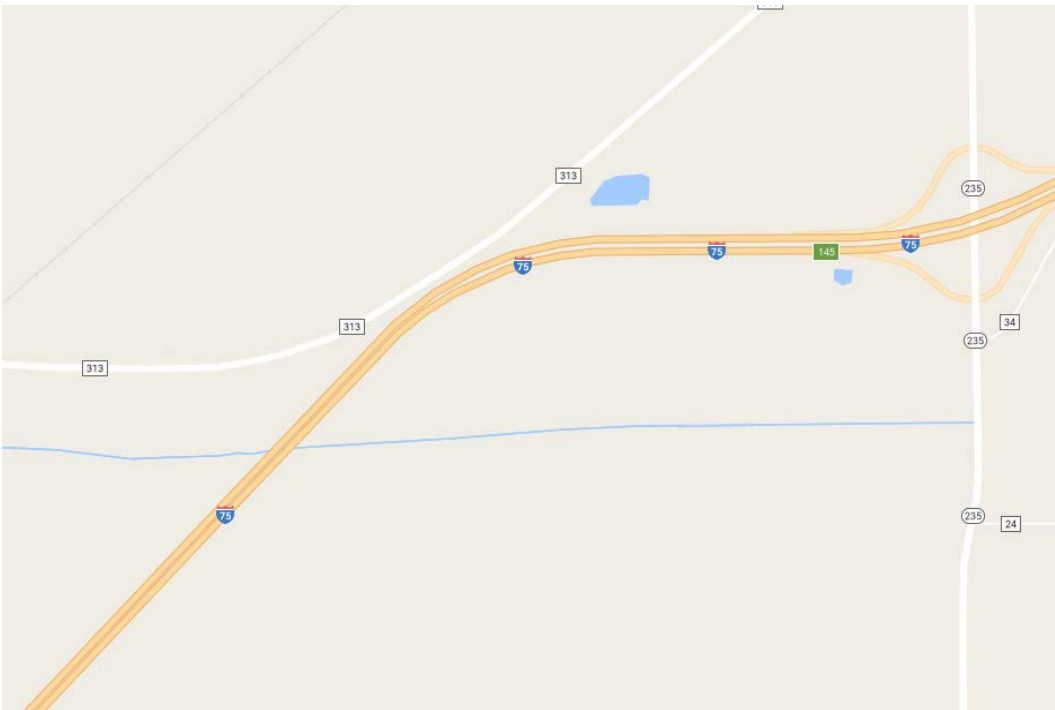
# Safety Center Webinar – HANDOUT- Sample Problems from the HSM/HFG Primer



## Example 3.2 – Rural Multilane Highways – Joint Use of the HSM and the HFG

### Step 1 Collect Site Data

**Problem Statement:** A local community college is planning to open a satellite campus in a more rural section of a neighboring county. The campus is expected to increase traffic volume along I-75 at the current exit (just north of milepost 145) by 7,000 vehicles per day by 2020 (3 years from the study). In anticipation of the added traffic, the State DOT is evaluating the current safety of the highway south of the exit for the proposed campus. There is a large radius sweeping horizontal curve leading to/from the existing exit that will serve the campus. The DOT is interested in implementing infrastructure improvements along the 2.4-mile segment and wants to evaluate the impacts of adding lighting to the corridor as well as increasing the shoulder width to 10 feet, both of which are currently planned projects along the corridor. Additionally, the corridor is scheduled for pavement replacement in 2019 as a part of the DOT's pavement management process. Any additional countermeasures, which can be shown to have a high potential to reduce crashes along the corridor, will be implemented at that time.



**Figure 1. Interstate 75 south of County Road 235**

Site Characteristics:

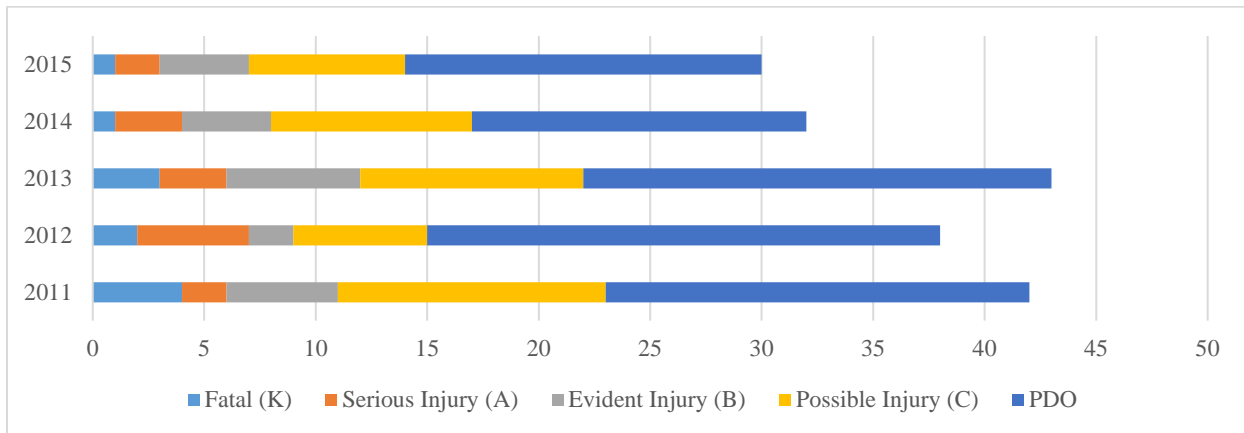
- Rural Principal Arterial
- 12-foot lanes
- Four-foot paved shoulder on both sides
- No lighting
- No median or roadside barriers
- Roadside rating of 1, open clear road sides, shallow roadside slopes
- 75 MPH posted speed limit
- Two-inch drop off between traveled way and shoulders
- 40-foot grass median
- Shoulder rumble strips to the left and the right of travel lanes in either direction
- No access points within 2.4-mile study segment
- No grade or vertical curvature
- Horizontal curve radius ~1,700 feet

Crash Data:

**Table 1. Number of crashes by year and crash severity**

| Crash Year   | Fatal (K) | Serious Injury (A) | Evident Injury (B) | Possible Injury (C) | PDO       | Total      |
|--------------|-----------|--------------------|--------------------|---------------------|-----------|------------|
| 2011         | 4         | 2                  | 5                  | 12                  | 19        | 42         |
| 2012         | 2         | 5                  | 2                  | 6                   | 23        | 38         |
| 2013         | 3         | 3                  | 6                  | 10                  | 21        | 43         |
| 2014         | 1         | 3                  | 4                  | 9                   | 15        | 32         |
| 2015         | 1         | 2                  | 4                  | 7                   | 16        | 30         |
| <b>Total</b> | <b>11</b> | <b>15</b>          | <b>21</b>          | <b>44</b>           | <b>94</b> | <b>185</b> |

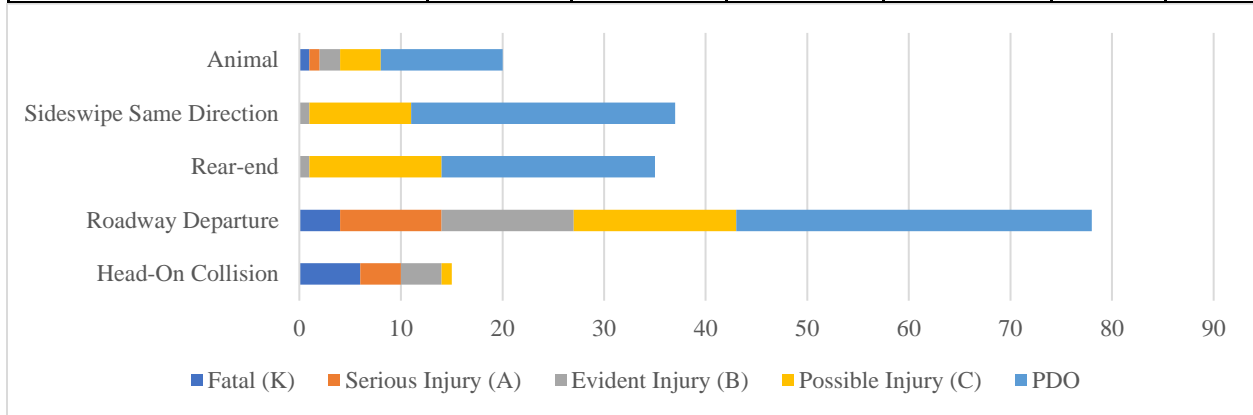
**Step 2b. Identify Crash Patterns and Trends**



**Figure 2. Number of crashes by year and crash severity**

**Table 2. Number of crashes by collision type and crash severity**

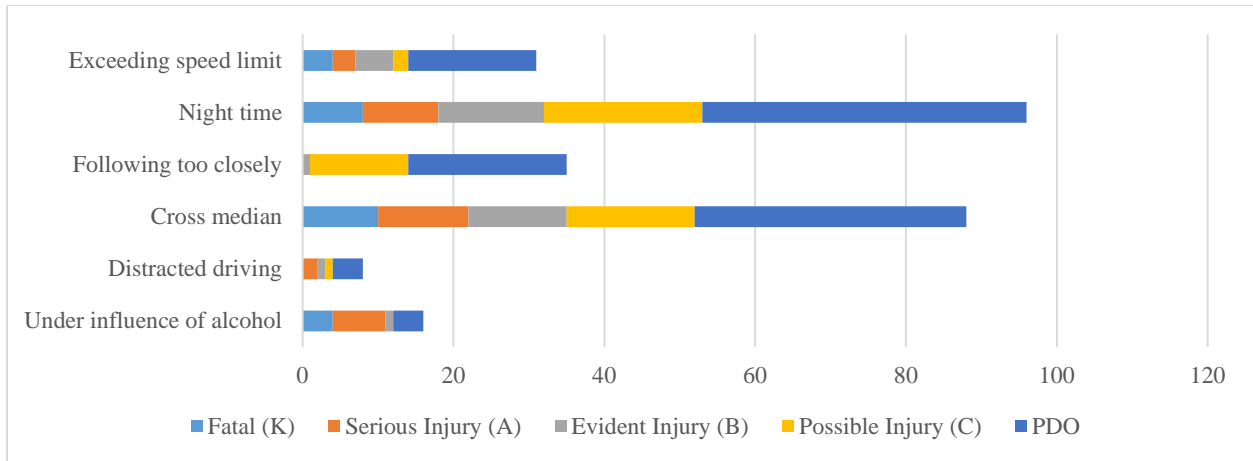
| Collision Type           | Fatal (K) | Serious Injury (A) | Evident Injury (B) | Possible Injury (C) | PDO       | Total      |
|--------------------------|-----------|--------------------|--------------------|---------------------|-----------|------------|
| Head-On Collision        | 6         | 4                  | 4                  | 1                   | 0         | 15         |
| Roadway Departure        | 4         | 10                 | 13                 | 16                  | 35        | 78         |
| Rear-end                 | 0         | 0                  | 1                  | 13                  | 21        | 35         |
| Sideswipe Same Direction | 0         | 0                  | 1                  | 10                  | 26        | 37         |
| Animal                   | 1         | 1                  | 2                  | 4                   | 12        | 20         |
| <b>Total</b>             | <b>11</b> | <b>15</b>          | <b>21</b>          | <b>44</b>           | <b>94</b> | <b>185</b> |



**Figure 3. Number of crashes by collision type and crash severity**

**Table 3. Number of crashes by contributing factor and crash severity**

| Contributing Factors       | Fatal (K) | Serious Injury (A) | Evident Injury (B) | Possible Injury (C) | PDO        | Total      |
|----------------------------|-----------|--------------------|--------------------|---------------------|------------|------------|
| Under influence of alcohol | 4         | 7                  | 1                  | 0                   | 4          | 16         |
| Distracted driving         | 0         | 2                  | 1                  | 1                   | 4          | 8          |
| Cross median               | 10        | 12                 | 13                 | 17                  | 36         | 88         |
| Following too closely      | 0         | 0                  | 1                  | 13                  | 21         | 35         |
| Night time                 | 8         | 10                 | 14                 | 21                  | 43         | 96         |
| Exceeding speed limit      | 4         | 3                  | 5                  | 2                   | 17         | 31         |
| <b>Total</b>               | <b>26</b> | <b>34</b>          | <b>35</b>          | <b>54</b>           | <b>125</b> | <b>274</b> |



**Figure 20. Number of crashes by collision type and crash severity**

### Step 2c Conduct Human Factors Evaluation

**Objective:** review the relevant data from previous steps, and identify the individual road user, vehicle, and environment factors - and any possible interactions - that could contribute to driver or road user confusion, misperceptions, high workload, distraction, or other problems and errors.

| Road User   | Vehicle                                 | Environment  | Interactions | Relevant Sections in the HFG |
|---|---|--|--------------|------------------------------|
| Speeding behaviors<br><br>Impairments due to alcohol or distraction<br><br>Future increase in younger drivers | Possible glare from on-coming headlamps | No barriers or cables on center median<br><br>No lighting<br><br>High posted speed limit (75 MPH)<br><br>Increased future traffic volumes due to college expansion |              |                              |

| Road User  | Vehicle  | Environment   | Interactions  | Relevant Sections in the HFG |
|--|--|---|---|------------------------------|
| <p>Speeding behaviors</p> <p>Impairments due to alcohol or distraction</p> <p>Future increase in younger drivers</p> | <p>Possible glare from on-coming headlamps</p> | <p>No barriers or cables on center median</p> <p>No lighting</p> <p>High posted speed limit (75 MPH)</p> <p>Increased future traffic volumes due to college expansion</p> | <p>Lack of barriers or cables across median combined with high speeds contributes to crashes and injuries due to road departures.</p> <p>Lack of lighting interacts with high speeds to decrease visibility of lane edges and increase perception-reaction time and likely contributes to road departures at night</p> <p>Speed limits may be too high for conditions, especially with a future influx of younger drivers</p> <p>Speculative, but headlamp glare could also be contributing to nighttime road departure incidents</p> |                              |

**Step 3a. Identify Potential Countermeasures from the HSM**

| <b>Worksheet 1A -- General Information and Input Data for Rural Multilane Roadway Segments</b>                 |  |                             |                        |
|--|--|-----------------------------|------------------------|
| <b>General Information</b>   |  | <b>Location Information</b> |                        |
| Analyst  | ARM                                    | Roadway                     | SR 75                  |
| Agency or Company  | CS                                     | Roadway Section             | MP 251.4 to MP 252.8   |
| Date Performed   | 05/17/17                               | Jurisdiction                | OH                     |
|  |  | Analysis Year               | 2020                   |
| <b>Input Data</b>  |  | <b>Base Conditions</b>      | <b>Site Conditions</b> |
| Roadway type (divided / undivided)   |  | Undivided                   | Divided                |
| Length of segment, L (mi)  |  | --                          | 2.4                    |
| AADT (veh/day)   | AADT <sub>MAX</sub> = 89,300 (veh/day) | --                          | 57,000                 |
| Lane width (ft)  |  | 12                          | 12                     |
| Shoulder width (ft) - right shoulder width for divided [if differ for directions of travel, use average width] |  | 8                           | 4                      |
| Shoulder type - right shoulder type for divided  |  | Paved                       | Paved                  |
| Median width (ft) - for divided only   |  | 30                          | 40                     |
| Side Slopes - for undivided only   |  | 1:7 or flatter              | Not Applicable         |
| Lighting (present/not present)   |  | Not Present                 | Not Present            |
| Auto speed enforcement (present/not present)   |  | Not Present                 | Not Present            |
| Calibration Factor, Cr   |  | 1.00                        | 1.05                   |

Example 3.2- Proposed Conditions

| Worksheet 1A -- General Information and Input Data for Rural Multilane Roadway Segments                        |  |                      |                      |
|--|--|----------------------|----------------------|
| General Information  |  | Location Information |                      |
| Analyst  | ARM                                    | Roadway              | SR 75                |
| Agency or Company  | CS                                     | Roadway Section      | MP 251.4 to MP 252.8 |
| Date Performed   | 05/17/17                               | Jurisdiction         | OH                   |
|  |  | Analysis Year        | 2020                 |
| Input Data   |  | Base Conditions      | Site Conditions      |
| Roadway type (divided / undivided)   |  | Undivided            | Divided              |
| Length of segment, L (mi)  |  | --                   | 2.4                  |
| AADT (veh/day)   | AADT <sub>MAX</sub> = 89,300 (veh/day) | --                   | 64,000               |
| Lane width (ft)  |  | 12                   | 12                   |
| Shoulder width (ft) - right shoulder width for divided [if differ for directions of travel, use average width] |  | 8                    | 10                   |
| Shoulder type - right shoulder type for divided  |  | Paved                | Paved                |
| Median width (ft) - for divided only   |  | 30                   | 40                   |
| Side Slopes - for undivided only   |  | 1:7 or flatter       | Not Applicable       |
| Lighting (present/not present)   |  | Not Present          | Present              |
| Auto speed enforcement (present/not present)   |  | Not Present          | Not Present          |
| Calibration Factor, Cr   |  | 1.00                 | 1.05                 |



**Table 4. Existing conditions Worksheet 1E results**

| <b>Worksheet 1E -- Summary Results for Rural Multilane Roadway Segments</b> |   |                                    |                                     |
|---|---|------------------------------------|-------------------------------------|
| (1)   | (2)   | (3)                                | (4)                                 |
| <b>Crash severity level</b>   | <b>Predicted average crash frequency (crashes/year)</b> | <b>Roadway segment length (mi)</b> | <b>Crash rate (crashes/mi/year)</b> |
|   | (7) from Worksheet 1C (a) or (b)                        |                                    | (2)/(3)                             |
| Total   | 31.9  | 2.4                                | 13.3                                |
| Fatal and Injury (FI)   | 14.2  | 2.4                                | 5.9                                 |
| Fatal and Injury (FI <sup>a</sup> )   | 7.9   | 2.4                                | 3.3                                 |
| Property Damage Only (PDO)  | 17.7  | 2.4                                | 7.4                                 |

NOTE: Using the KABCO scale, these include only KAB crashes. Crashes with severity level C (possible injury) are not included.

**Table 5. Proposed conditions Worksheet 1E results**

| <b>Worksheet 1E -- Summary Results for Rural Multilane Roadway Segments</b> |   |                                    |                                     |
|---|---|------------------------------------|-------------------------------------|
| (1)   | (2)   | (3)                                | (4)                                 |
| <b>Crash severity level</b>   | <b>Predicted average crash frequency (crashes/year)</b> | <b>Roadway segment length (mi)</b> | <b>Crash rate (crashes/mi/year)</b> |
|   | (7) from Worksheet 1C (a) or (b)                        |                                    | (2)/(3)                             |
| Total   | 32.9  | 2.4                                | 13.7                                |
| Fatal and Injury (FI)   | 14.5  | 2.4                                | 6.0                                 |
| Fatal and Injury <sup>a</sup> (FI <sup>a</sup> )                            | 8.0   | 2.4                                | 3.3                                 |
| Property Damage Only (PDO)  | 18.4  | 2.4                                | 7.7                                 |

NOTE: Using the KABCO scale, these include only KAB crashes. Crashes with severity level C (possible injury) are not included.

**Table 6. Countermeasures and safety effects for selected potential projects**

| CMF  | CMF Crash Type   | Applicable Site Crashes | CMF                   | Standard Error | CMF   |       | Estimated Crash Impacts |     |
|--|--|-------------------------|-----------------------|----------------|-------|-------|-------------------------|-----|
|  |  |                         |                       |                | High  | Low   | High                    | Low |
| <b>Cross Median</b>                              |  |                         |                       |                |       |       |                         |     |
| Cable Median Barrier                             | All cross median injury crashes (K,A,B,C)              | 52                      | <a href="#">0.71</a>  | 0.08           | 0.87  | 0.55  | 45                      | 29  |
| Steel Median Barrier                             | All cross median injury crashes (K,A,B,C)              | 52                      | <a href="#">0.65</a>  | 0.10           | 0.85  | 0.45  | 44                      | 23  |
| <b>Nighttime</b>                                 |  |                         |                       |                |       |       |                         |     |
| Provide Lighting                                 | Nighttime injury crashes (K,A,B,C)                     | 53                      | <a href="#">0.72</a>  | 0.07           | 0.86  | 0.58  | 46                      | 31  |
| <b>Roadway Departure</b>                         |  |                         |                       |                |       |       |                         |     |
| Install Safety edge                              | All roadway departure crashes                          | 78                      | <a href="#">0.909</a> | 0.087          | 1.083 | 0.735 | 84                      | 57  |
| Increase Shoulder Width from 4ft to 12 ft.       | Roadway Departure and Head-On Injury Crashes (K,A,B,C) | 58                      | <a href="#">0.992</a> | 0.10           | 1.192 | 0.792 | 62                      | 41  |
| <b>Combined Treatment Countermeasures</b>        |  |                         |                       |                |       |       |                         |     |
| Cable Median Barrier and Increase Shoulder Width | All cross median, Injury Crashes (K,A,B,C)             | 52                      | .70                   | .06            | 0.824 | 0.584 | 43                      | 30  |

### Step 3b. Identify Potential Countermeasures from the HFG

Generate a list of keywords that can be used to characterize the nature and causes of the crashes, conflicts, and related safety outcomes-especially those seen in the *Interactions* column of the HFIM. For this example, useful keywords would seem to be: medians, younger drivers, lighting, rural driving, speeding and speeding behaviors, and impaired driving (alcohol, distraction). We then search the Table of Contents and the Index in the HFG for these (and closely related) keywords to identify Chapters, Guidelines, and Tutorials that seem most relevant to the HFIM interactions and underlying safety issues. The .pdf version of the HFG can also be manually searched for each keyword to identify potentially useful HFG contents. We can also use Appendix B of this primer document to quickly identify Chapters and Guidelines of particular interest. Relevant Chapters, Guidelines, and Tutorials are then listed in the rightmost column of the HFIM.

An initial review of the HFG using these keywords yields the following Chapters/Guidelines as *potentially* relevant to this example:

- **Chapter 6: Curves (Horizontal Alignment)**
  - 6-10 Countermeasures to Improve Pavement Delineation
  - 6-12 Signs on Horizontal Curves
- **Chapter 8: Tangent Sections and Roadside (Cross Section)**
  - 8-4 Overview of Driver Alertness on Long Tangent Sections
- **Chapter 17: Speed Perception, Speed Choice, and Speed Control**
  - 17-10 Speeding Countermeasures: Setting Appropriate Speed Limits
  - 17-12 Speeding Countermeasures: Communicating Appropriate Speed Limits
- **Chapter 20: Markings**
  - 20-8 Post-mounted Delineators
- **Chapter 21: Lighting**
  - 21-2: Countermeasures for Mitigating Headlamp Glare
  - 21-4 Nighttime Driving

| Road User  | Vehicle  | Environment   | Interactions  | Relevant Sections in the HFG   |
|--|--|---|---|--|
| <p>Speeding behaviors</p> <p>Impairments due to alcohol or distraction</p> <p>Future increase in younger drivers</p> | <p>Possible glare from on-coming headlamps</p> | <p>No barriers or cables on center median</p> <p>No lighting</p> <p>High posted speed limit (75 MPH)</p> <p>Increased future traffic volumes due to college expansion</p> | <p>Lack of barriers or cables across median combined with high speeds contributes to crashes and injuries due to road departures.</p> <p>Lack of lighting interacts with high speeds to decrease visibility of lane edges and increase perception-reaction time and likely contributes to road departures at night</p> <p>Speed limits may be too high for conditions, especially with a future influx of younger drivers</p> <p>Speculative, but headlamp glare could also be contributing to nighttime road departure incidents</p> | <p>Chapter 6:<br/>Curves<br/>(Horizontal Alignment)</p> <ul style="list-style-type: none"> <li>o 6-10</li> <li>o 6-12</li> </ul> <p>Chapter 8:<br/>Tangent Sections and Roadside</p> <ul style="list-style-type: none"> <li>o 8-4</li> </ul> <p>Chapter 17:<br/>Speed Perception, Speed Choice, and Speed Control</p> <ul style="list-style-type: none"> <li>o 17-10, 17-12</li> </ul> <p>Chapter 20:<br/>Markings</p> <ul style="list-style-type: none"> <li>o 20-8</li> </ul> <p>Chapter 21:<br/>Lighting</p> <ul style="list-style-type: none"> <li>o 21-2, 21-4</li> </ul> |

| HFG Section  | Summary of Important Road User Issues and Countermeasures  |
|--|--|
| 6-10 Countermeasures to Improve Pavement Delineation                   | This guideline describes how pavement markings can help driver performance. Though its focus is on curve driving, it provides useful guidance for this site. It includes guidance on edge and center lines, raised reflective pavement markers, and markers on signs.  |
| 6-12 Signs on Horizontal Curves  | This guideline provides information on the advance placement and spacing for chevrons for curve warning signs. Designers and planners can use this information to notify the driver of the upcoming curve so that the driver can change the speed or path of the vehicle—or both.  |
| 8-4 Overview of Driver Alertness on Long Tangent Sections              | Fatigue can reduce both vigilance and driver performance; fatigue is clearly a causal factor in some of the crashes at this site. This guideline explains how to break the monotony, such as adding visual complexity, or provide countermeasures, such as shoulder rumble strips and/or median barriers.  |
| 17-10 Speeding Countermeasures: Setting Appropriate Speed Limits       | This guideline discusses how to set an appropriate speed limit accounting for the unique traffic, design, and environmental aspects of a roadway. It includes standard conditions, variable speed limits, and heavy truck traffic. The PSL at this site may be too high, and a review to determine if speed is appropriately set may be helpful.   |
| 17-12 Speeding Countermeasures: Communicating Appropriate Speed Limits | This guideline discusses best practices for communicating posted speed limits to drivers and explains when to use approaches such as redundant signs, active speed warning, and in-pavement measures. There may be specific locations within this roadway segment where such countermeasures could be helpful.   |
| 20-8 Post-mounted Delineators  | Post-mounted delineators are a series of retroreflective marking devices above the pavement surface that are used to communicate the roadway alignment to drivers. They are useful when the alignment might be confusing or unexpected. Although it is unclear if the alignment is confusing at this site, their use could be considered. This guideline provides recommendations for delineator use, including spacing. |
| 21-2 Countermeasures for Mitigating Headlamp Glare                     | This guideline discusses approaches to reducing glare from other vehicles' headlamps. Glare occurs when the intensity of a light source is greater than the adaptation level to the surrounding view. Given the lack of lighting and the general roadway geometry, it is possible that glare from on-coming headlamps is contributing to crashes and that countermeasures to reduce such glare could be utilized.        |
| 21-4 Nighttime Driving   | This guideline lists the respective benefits and suggested conditions for using seven treatments for improving visibility at night, ranging from continuous lighting to advance warning signs. Visibility at night on this roadway site be limited by the lack of ambient light, the reach of headlamps, and the inability of drivers to detect roadway edges.   |

## Step 4: Develop and Prioritize Countermeasures

### Summary and Discussion of Solutions Provided by the HSM and HFG for the ‘Rural Multilane’ Example

| Potential Countermeasure or Solution                            | Source             | Discussion   |
|---|--------------------|--|
| Install highway lighting  | HSM                | The HSM indicates high confidence in this solution   |
| Install cable median barrier                                    | HSM & HFG, 8-4     | This is an obvious solution and is well-supported by the HSM analysis. This is an ‘either or’ solution with respect to the steel median (below); only one of these solutions should be selected.   |
| Install steel median barrier                                    | HSM & HFG, 8-4     | This is an obvious solution and is well-supported by the HSM analysis. This is an ‘either or’ solution with respect to the cable median (above); only one of these solutions should be selected.   |
| Widen shoulders   | HSM                | Only feasible during a repaving project; also, the safety benefits are uncertain.  |
| Install cable median barrier and Widen shoulders                | HSM & HFG, 8-4     | This combined treatment solution would represent a situation where the cable median barriers are being installed during a repaving project. This scenario encompasses the benefits of the cable median barrier installation along with the opportunity for widening shoulders. |
| Install safety edge   | HSM                | While feasible, the safety benefits of this solution are uncertain. However, the HFG (6-10) suggests a similar solution and may provide useful information.  |
| Consider markings to improve delineation                        | HFG, 6-10          | A number of solutions are presented in this guideline; it also provides additional detail on edge lines that may compliment the HSM recommendation for safety edges.   |
| Consider other countermeasures to address run off road crashes. | HFG, 6-12, 8-4     | Other countermeasures – in addition to the median barriers noted above, could be considered (such as curve warning signs)  |
| Set and communicate speed limits to improve safety              | HFG, 17-10 & 17-12 | The posted speed limit should be evaluated, and countermeasures for effectively communicating the speed limit to drivers considered for implementation   |
| Add post-mounted Delineators                                    | HFG, 20-8          | If drivers are unclear about the roadway alignment, post-mounted delineators may help them maintain safe lane positions.   |
| Countermeasures to improve nighttime driving.                   | HFG, 21-2 & 21-4   | To improve visibility at night and reduce nighttime crashes, a range of countermeasures (e.g., glare screens, advance warning signs, additional lighting) could be implemented.  |