RUN-OFF ROAD COLLISIONS

NCHRP Report 500, Vol. 6

Problem Description

• 1999 FARS – 39% fatal crashes were “run-off road”
EXHIBIT III-2
Distribution of Single-Vehicle ROR Fatalities on Two-Lane, Undivided, Noninterchange, Nonjuction Roads by Highway Type (Source: 1999 FARS Data)

EXHIBIT III-3
Distribution of Single-Vehicle ROR Fatalities for Two-Lane, Undivided, Noninterchange, Nonjuction Roads by First Harmful Event (Source: 1999 FARS Data)
EXHIBIT III-4
Distribution of Single-Vehicle ROR Fatalities for Two-Lane, Undivided, Noninterchange, Nonjunction Roads by Most Harmful Event (Source: 1999 FARS Data)

Source: NCHRP Report 500, Vol. 6

EXHIBIT IV-5
Distribution of Single-Vehicle ROR Crashes between Tangent and Curved Sections

Single-Vehicle ROR Crashes on
All Roads

58%
42%

Curves
Tangents

Single-Vehicle ROR Crashes on
Two-Lane Rural Roads

50%
50%

Source: NCHRP Report 500, Vol. 6
OBJECTIVES

• Keep vehicles from encroaching on roadside
• Minimize likelihood of crashing into object or overturning on leaving roadway
• Reduce severity of the crash
Natural Roadside Obstacles

Wild Life
Water Hazards

Engineered (or Non-Engineered) Roadside Obstacles
Utility Pole

Guard Rail
Guard Rail Can be a Hazard

Objective 1

Keep Vehicle from Encroaching
Strategy A
Install shoulder rumble strips

- Grooves are generally 7-in. apart and 0.5 in. deep
- Placed in asphalt or concrete when laid
- Types: milled, rolled, raised
- Rumble strip community of practice

IOWA DOT Shoulder Rumble Strip
Costs of Construction

- **NYDOT**
  - 1990 - $1.88/linear ft.
  - 1998 - $0.15/linear ft.

- **New York Thruway**
  - $.19/linear foot

- **Penn DOT** (Note: PennDOT is experimenting with “bicycle friendly” rumble strip alternatives)
  - $0.25/linear ft.
Strategy B- Rumble strips for roads with narrow or unpaved shoulders

- Most states require wide shoulders to install rumble strips
  - Penn DOT; 4 ft. minimum, 6-8 ft. desirable
- Experimental treatments
  - Milled-in “edge line” rumble strip
  - Modified “standard” rumble strip for narrow shoulders (i.e., 2 ft. paved)
  - Raised/inverted profile thermoplastic marker (edge line)

Source: NCHRP Report 500, Vol. 6
Strategy C
Mid-Lane Rumble Strips

- Experimental on roads with no shoulders or narrow paved shoulders
- Cut in groups of 4 or 5; 0.5-in. deep, spaced about 4-in. apart
- Installed in center of travel lane
- No control problems were found however the motorcycle community is discourage use of these devices as they cause the motorcycles to travel closer to a lane edge

Strategy D
Enhanced Delineation of Sharp Curves

- ROR crash risk increases with degree of curvature
- Warn drivers of hazardous situation;
  - Improved shoulder delineation
    - Chevrons, high-intensity chevrons, large arrow signs, delineators on guardrails
  - Improved curve warning signs (w/ flashing beacons)
  - Non-traditional pavement stripes
    - Transverse stripes before curve of decreasing width and spacing
Shoulder Delineator

- Proven crash-reducing option
- 1966 study of reduction in ROR crashes, 15%
- Vehicle placement on right curves shifted toward centerline, according to 1987 study

Chevron and High-Intensity Chevrons

- Proven crash-reducing option
- Virginia study recommended use of chevrons with
  - spacing 2-3 times MUTCD recommendation
- Fluorescent yellow chevrons produced a 38% reduction in vehicles leaving lane (TTI study)
Pavement Markings with ‘SLOW’ Legend

- 8-ft. high ‘SLOW’ word legend
- Speeds reduced 6% overall; reduced 7% during day and late night
- Pennsylvania study;
  - Little effect on average speed
  - 95th% speed reduced significantly

Pavement Width Narrowing with Striping

- Passenger vehicles exceeding speed limit by more than 10 mph
  - Decreased 20-30%
- Trucks exceeding by 5 mph
  - Decreased even more
Strategy E
Improved Highway Curve Geometry

- ROR and head-on crashes are 1.5 - 4 times more likely on curves than tangents
- ROR crashes account for 57% crashes on 11,000 curves on two-lane roadways
- Flattening curves yields significant crash reductions

<table>
<thead>
<tr>
<th>Original Degree of Curve</th>
<th>New Degree of Curve</th>
<th>Percent Red. in Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>25</td>
<td>15-17</td>
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<td>5</td>
<td>26-49</td>
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<tr>
<td></td>
<td>3</td>
<td>42-69</td>
</tr>
</tbody>
</table>

Source: NCHRP Report 500, Vol. 6

Degree of Curve
= 30 (R=191 ft)

Degree of Curve
= 25 (R=229 ft)

Degree of Curve
= 20 (R=286 ft)

Degree of Curve
= 15 (R=382 ft)

Degree of Curve
= 10 (R=573 ft)
Widening Lanes and Shoulders

Given:
20 ft. roadway (2-10 ft. lanes) with unpaved shoulders

Improvement:
Widen to 22-ft. paved with 8-ft. gravel shoulder

Result:
Curve accidents reduced
5% - lane widening, 1-ft. per side
24% - shoulder widening by 8-ft. per side

EXHIBIT V-11
Percentage Reduction in Total Crashes on Two-Lane Rural Roads Due to Shoulder Widening (Based on Zager et al., 1992)

<table>
<thead>
<tr>
<th>Total Amount of Lane or Shoulder Widening</th>
<th>Lane Widening</th>
<th>Paved Shoulder Widening</th>
<th>Unpaved Shoulder Widening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (ft)</td>
<td>Per Side (ft)</td>
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<td></td>
</tr>
<tr>
<td>0</td>
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</tr>
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<td>12</td>
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<td>23</td>
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</tr>
<tr>
<td>16</td>
<td>8</td>
<td>28</td>
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<td>18</td>
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<td>20</td>
<td>10</td>
<td>33</td>
<td>26</td>
</tr>
</tbody>
</table>

Source: NCHRP Report 500, Vol. 6
Strategy F - Enhanced Pavement Marking at Appropriate Locations

- Higher contrast, wider markings, or raised pavement markers

Wider Pavement Markings

- 8-in. wide markings
  - 8-in. edge line safer than 4-in. edge line
  - 10% decrease vs. 5% decrease (NY study)
- FHWA *Older Driver Manual* recommends 8-in. wide stripes to enhance visibility
Raised Pavement Markers

- NJ projects (53.5 mi. & 126 mi. length, respectively) showed significant night-time accident reduction
- Calculated benefit cost ratios of 19.89 and 15.45, respectively
- Another project of 47.8 mi, significant reduction in night-time accidents; benefit-cost ratio = 25.51
- However, other locations, RMPs not conclusively effective (and in some locations the added delineation seems to be associated with an increase in crashes)

Strategy G
Skid Resistant Pavements

- 1999 FARS data
  - 11% single vehicle fatal ROR crashes occur on wet roads

Source: NCHRP Report 500, Vol. 6
Skid Resistant Pavement Improvements

- Countermeasures
  - Change pavement aggregate
  - Adding overlays
  - Adding texture
- NY Skid Resistance Program
  - Treated 36 sites (1995-97)
  - 50% reduction in wet road accidents
  - 20% reduction in total accidents

Strategy H – Shoulder Treatments

- Countermeasures
  - Shoulder widening
  - Shoulder paving
  - Reduction of pavement edge drop-offs
- Interactive Highway Safety Design Model
  - Shows effectiveness of shoulder widening
  - Other studies conflicting
EXHIBIT V-17
Accident Modification Factor for Paved Shoulder Width (Relative to 6-Font Paved Shoulder) on Two-Lane Rural Highways (Source: Harwood et al., 2000)

EXHIBIT V-18
Accident Modification Factor for Shoulder Type on Two-Lane Rural Highways (Source: Harwood et al., 2000)

<table>
<thead>
<tr>
<th>Shoulder Width (ft)</th>
<th>Paved</th>
<th>Gravel</th>
<th>Composite</th>
<th>Turf</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
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<tr>
<td>2</td>
<td>1.00</td>
<td>1.01</td>
<td>1.02</td>
<td>1.03</td>
</tr>
<tr>
<td>3</td>
<td>1.00</td>
<td>1.01</td>
<td>1.02</td>
<td>1.04</td>
</tr>
<tr>
<td>4</td>
<td>1.00</td>
<td>1.01</td>
<td>1.03</td>
<td>1.05</td>
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<tr>
<td>5</td>
<td>1.00</td>
<td>1.01</td>
<td>1.04</td>
<td>1.08</td>
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<tr>
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<td>1.02</td>
<td>1.06</td>
<td>1.11</td>
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<tr>
<td>10</td>
<td>1.00</td>
<td>1.03</td>
<td>1.07</td>
<td>1.14</td>
</tr>
</tbody>
</table>

Source: NCHRP Report 500, Vol. 6
Pavement Edge Drop-Offs

- Drop-off safety estimate
  - 160 fatalities per year
  - 11,000 injuries per year
  - Safety cost - $1.2-billion
- Tort Liability
  - Millions $ awarded each year
  - One case, $6-million

Not a Typical Dropoff
Typical Drop Off

![Image of typical drop off](image1.jpg)

![Image of typical drop off in real scenario](image2.jpg)
Same Location – 3 Dead

Relative Safety of Various Edge Elevations and Shapes

* These numbers are subjective severity levels.

[Zimmer and Ivey, Texas Transportation Institute, 1982]
Solution to Pavement Edge Drop-off Hazards

• Require 30-35° angle asphalt fillet (a recent FHWA pilot study has determined that the fillet must be compressed to have any long term effectiveness)
• Routinely resurface shoulders

Strategy I – Minimize Likelihood of Overturning or Crashing into Off-Road Object

• Design safety slopes and ditches to prevent rollovers
• Remove/relocate hazardous objects
• Delineate roadside objects
Most Harmful Event for Non-Intersection ROR Crashes

- Overtturn, 41%
- Impact with tree, 29%
- Impact a utility pole, 8%
- Impact with ditch or embankment, 5%
Most Harmful Event for Rural and Urban Interstate Roads

- Overtur, 59%
- Guardrail, 6%
- Concrete traffic barriers, 2%
- Impact with ditch and embankment, 3%

Rollover

- Factors contributing to rollover
  - Side slope
  - Ditch design
  - Nature of soil on slope
  - Design of roadside hardware

EXHIBIT V-10
Percentage of Subsequent Rollovers Related to Various "First Struck" Objects

Source: NCHRP Report 500, Vol. 6
Fatal Rollovers

• Major Problem
  – Embankment and ditch, 31%

• Other first-struck objects
  – Trees, 14%
  – Guardrail, 11%
  – Culverts, 7%
  – Utility poles, 6%
  – Sign posts, 3%

Flatten & Widen Side Slopes

• Rollovers occur on
  – Fore slopes steeper than 3:1
  – Back slopes steeper than 2:1
Slope Next to Highway

Traversable Slope

Non-Traversable Slope

EXHIBIT V-24
Percentage Reduction of Single-Vehicle and Total Crashes Due to Sideslope Flattening on Two-Lane Rural Roads (From Zegeer et al., 1987)

<table>
<thead>
<tr>
<th>Sideslope Before Condition</th>
<th>Sideslope After Condition</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1:4</td>
</tr>
<tr>
<td></td>
<td>SV</td>
</tr>
<tr>
<td>1:2</td>
<td>10</td>
</tr>
<tr>
<td>1:3</td>
<td>8</td>
</tr>
<tr>
<td>1:4</td>
<td>0</td>
</tr>
<tr>
<td>1:5</td>
<td>-</td>
</tr>
<tr>
<td>1:6</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: NCHRP Report 500, Vol. 6
Improve Ditch Sections

• “Cross-section and Roadside design”, US Customary

Ditch Design

- Provides clear zone distance vs
  - Cut or fill slope
  - Design speed
  - Design ADT
  - Horizontal curvature

- NCHRP Project 17-11, Determination of Safe/Cost Effective Roadside Slopes and Associated Clear Distances
  - To improve knowledge on slopes vs clear zone

Clear Zone Concept

Clear Zone based on Number of Vehicles, Anticipated Speeds, and Roadside Slope
Widen Clear Zone

- High speed roadways ~ 30 ft.
- Clear zone excludes:
  - Non-traversable objects
    - Drainage features
  - Objects
    - Trees, rocks, roadside hardware
- Not cost beneficial to purchase small increments of ROW (~5-10 ft.) to eliminate obstacles
  - Due to high cost of relocation and right-of-way

EXHIBIT V-25
Percent Reductions in “Related Accidents” Due to Increasing the Roadside Clear Recovery Distance on Two-Lane Rural Roads*

<table>
<thead>
<tr>
<th>Amount of Increased Roadside Recovery Distance, meters (feet)</th>
<th>Percent Reduction in Related Accident Types (i.e., ROR+head-on+sideswipe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 (5)</td>
<td>13%</td>
</tr>
<tr>
<td>2.4 (8)</td>
<td>21</td>
</tr>
<tr>
<td>3.1 (10)</td>
<td>25</td>
</tr>
<tr>
<td>3.7 (12)</td>
<td>29</td>
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<td>4.6 (15)</td>
<td>35</td>
</tr>
<tr>
<td>6.2 (20)</td>
<td>44</td>
</tr>
</tbody>
</table>

*Note that “related accidents” would be the total of ROR, head-on, and sideswipe crashes.

Source: NCHRP Report 500, Vol. 6
Improve Roadside Hardware and Natural Objects

- Relocate objects outside clear zone, e.g., utility poles
- Shield or replace “hard” objects with breakaway devices
  - e.g., crash cushions or breakaway luminary supports

Breakaway Objects?
Cable Rail Crash

Strategy J
Reduce Severity of Crash

• Improve design of roadside hardware
• Improve design and application of barrier and attenuation
• NCHRP 350 defines criteria
Roadside Design & Barrier Resources

- Roadside Design Guide, AASHTO, 2002
- FHWA website;

Delineation of Roadside Objects

- An experimental treatment
- Low cost delineation to make roadside objects at night visible
- Pennsylvania research
  - At high ROR utility pole and tree-related crashes
  - Use 4-in. round of reflective tape

Note: This is an experimental strategy and early indications are that the delineation may act as an “Attractor” and drivers may drive towards the object rather than avoid it.
QUESTIONS?