Managing Run-off-Road Collisions: Engineering Treatments with AMFs

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Abstract

Run-off-road collisions occur when a vehicle leaves the roadway and the driver is unable to safely recover the travel lane.

There are three key objectives for roadway and roadside design that can be addressed to reduce the number of run-off-road collisions. The first objective of roadway design is to keep the vehicle in the travel lane. The second engineering objective is to assist drivers that encroach onto the roadside to regain control of the vehicle, and return safely to the correct travel lane without hitting a roadside object or feature, or overturning. In addition, the vehicle's recovery must be controlled, so that the driver does not over-correct and cross into the opposing travel lane or median of a divided highway. The third engineering objective is to reduce the severity of run-off-road collisions if the first two objectives were not met.

A variety of treatments can be considered to address these three objectives. In deciding which treatment(s) to implement, the expected safety benefit can be estimated using Accident Modification Factors.

This paper expands on the objectives to manage run-off-road collisions, and focuses on six engineering treatments that can be implemented to reduce the frequency and severity of run-off-road collisions; specifically: flatten horizontal curves, improve curve superelevation, add shoulder rumble strips, add centreline rumble strips, change shoulder width and/or type, and install/upgrade guiderail. Each of these treatments is accompanied by the best estimate of Accident Modification Factor(s) available to date based on work currently underway to develop a Highway Safety Manual for the Transportation Research Board.

Run-off-road collisions

Run-off-road collisions are one of three collision types generally expected on road segments (sideswipe and rear-end are also common collision types on road segments). Run-off-road collisions occur when a vehicle leaves the roadway, encroaches onto the shoulder and beyond, and the driver is unable to safely recover the travel lane (Exhibit 1). The first harmful event of a run-off-road collision occurs off of the roadway.

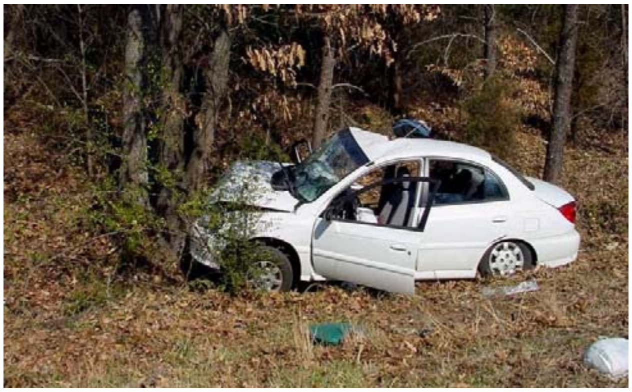

Exhibit 1: A run-off-road collision

Run-off-road collisions can be caused by a variety of contributing factors, including speed, driver workload, evasive manoeuvres, and driver inattention (1).While run-off-road collisions generally occur on the right side of the road, they can also occur in the median of a divided roadway, or if the vehicle crosses the centreline or median and does not strike a vehicle in the opposing lane, the run-off-road collision may occur on the left side of the roadway.

The Organization for Economic Co-operation and Development (OECD) has identified rural road safety as a road safety concern among its member countries. The OECD published "Safety Strategies for Rural Roads" (1999), which showed that fatal collisions on rural roads are gradually increasing among member countries. The majority of rural fatal collisions (approximately 80%) are single-vehicle collisions, particularly run-off-road occurrences (at least 35% of fatal rural road collisions), head-on collisions (almost 25% of fatal rural road collisions) and collisions at intersections (approximately 20% fatal rural road collisions).

Based on Transport Canada's national Traffic Accident Injury Data (TRAID) file, from 1995 to 1999, an average of 35.2% of all rural traffic fatalities were the result of single-vehicle collisions, and an average of 44.4% of rural injured drivers were the result of single-vehicle collisions. The majority of single-vehicle collisions that resulted in fatal and serious injuries were the result of non-collision events such as running off the road, overturning, skidding or sliding (69.6% of fatalities and 75.8% of serious injuries). Further, of drivers that died or were seriously injured in single-vehicle collisions, close to half (47.2%, 39.6% respectively) of the collisions occurred on sections of road that were curved, either level or with a grade (2).

It is possible to reduce the severity and frequency of run-off-road collisions through roadway and roadside design. The frequency of run-off-road collisions can be managed by roadway characteristics that facilitate maintaining the lane or recovering of the lane. The severity of these collisions can be managed by roadside design that is "forgiving"; that is, roadsides that are clear of obstacles which might be unavoidable for a driver who has left the roadway.

<u>Three objectives to reduce run-off-road collisions</u>

There are three key objectives for roadway and roadside design to reduce the number of run-off-road collisions. They are, in order of consideration:

1. To reduce the occurrence of run-off-road collisions by keeping vehicles in the travel lane;
2. To assist drivers who encroach onto the roadside to regain control of the vehicle, and return safely to the correct travel lane without hitting a roadside object or feature or overturning. In addition, the vehicle's recovery must be controlled, so that the driver does not over-correct and cross into the opposing travel lane or median of a divided highway; and,
3. To minimize the severity of run-off-road collisions if the first two objectives were not met.

A variety of treatments can be considered to address these three objectives, with a focus on their implementation and impact on run-off-road collisions. Design elements can be grouped by the three objectives to provide a hierarchy for consideration if a run-off-road collision pattern is identified at a given location. The following are some examples of the elements that apply to each of the three objectives; this list is not meant to be exhaustive:

Objective	Related design elements
Keep vehicle in the travel lane	Horizontal curve design Lane width Raised pavement markers Rumble strips Signage
Assist recovery of the lane	Clear zone Shoulder design Roadside design
Reduce severity of collision	Sideslope Install guiderails Roadside natural objects

In deciding which treatment(s) to implement, it is useful to know the expected safety benefit, which is best estimated using Accident Modification Factors.

The following sections describe a selection of the design elements that have proven to be effective in the treatment of run-off-road collisions, grouped by the three objectives for managing run-off-road collisions. Each of these treatments is accompanied by the best estimate of Accident Modification Factors or Functions (AMFs) available to date based on work currently underway to develop Parts I and II of a Highway Safety Manual for the Transportation Research Board (as part of NCHRP Project 17-27). The Highway Safety Manual is scheduled for publication in 2008.

Additional information on strategies that may be proven, tried, or experimental, but may not have AMFs, can be found in NCHRP Report 500 Volume 6 “A Guide for Addressing Run-Off-Road Collisions” (3).

Objective 1: Keep vehicle in the travel lane

The primary objective of roadway design is to keep the vehicle in the travel lane. Roadway design elements affect the ability of vehicles to stay within the travel lane. The following trends in run-off-road collisions at curves have been documented (4):

- Run-off-road to the right on left curves are the most frequent run-off-road collision type
- Run-off-road to the outside of curves increases with degree of curvature

Therefore, focusing first on run-off-road collisions at horizontal curves, two potential treatments with AMFs are outlined below. This is followed by a discussion of using rumble strips to alert drivers that they are leaving the travel lane.

Horizontal curve design

A combination of internal and external horizontal curve characteristics can contribute to the occurrence of collisions on a curve. The radius or degree of curve, superelevation, and the presence of spiral cures are examples of internal features. Density of curves upstream, length of connecting tangent road sections, and sight distance are examples of external features (5).

External features can influence the driver's expectation of the curve ahead. Vehicle operations and driver behaviour are also contributing factors, as with any collision type.

The detailed design of horizontal curves includes many elements. Once a curved road segment has been built, there are few treatments that can be used to increase the safety of the curve, and most of these are expensive. Two treatments for existing horizontal curves with proven effectiveness are flattening the horizontal curve and improving the superelevation of the curve.

Flatten the horizontal curve
This treatment can be relatively expensive, require additional right-of-way and substantial construction costs. However, studies have shown that three elements play key roles in the safety of horizontal curves. Increasing the radius of a curve, increasing the length of the curved section, and providing a spiral transition are all beneficial to safety. The following AMF combines these three internal curve elements, and can be applied to total collisions on the curved roadway segment. It is valid for two-lane rural roads only (6).

$$AMF = \frac{1.55L_C + \frac{80.2}{R} - 0.012S}{1.55L_C}$$

Where:
L_C = length of horizontal curve (miles); does not include spiral curve length
R = radius of curvature (ft)
S = 1 if a spiral transition is present; 0 if spiral transition is not present

Improve curve superelevation
This treatment is less expensive than flattening the curve, but is applicable only to those curves whose superelevation has deteriorated over time. Correcting a superelevation that is deficient in comparison to the AASHTO Policy on Geometric Design has shown to reduce collisions on horizontal curves. These AMFs apply to total collisions on the curved roadway segment. They are valid for two-lane rural roads only (6).

Superelevation Deficiency (SED)	**AMF**
< 0.01	1.00
0.01 < SED < 0.02	1.00 + 6(SED – 0.01)
> 0.02	1.06 + 3(SED – 0.02)

<u>Rumble strips</u>
Another method for keeping vehicles in the travel lane is to alert drowsy or inattentive drivers that they are leaving the travel lane. When vehicles tires travel over rumble strips, a low rumbling sound is produced along with vehicle vibration. Shoulder rumble strips are generally applied on the edgeline or to the right of the edgeline (Exhibit 2). Centreline rumble strips are generally applied directly on the centreline (Exhibit 3). The Transportation Association of Canada provides comprehensive guidelines for the implementation of shoulder and centreline rumble strips (7, 8).

Rumble strips are a relatively low cost measure than can be readily implemented. Noise is a concern, and rumble strips should not be placed within 200m of residences.

Add shoulder rumble strips
Providing shoulder rumble strips on rural and urban freeways has a positive effect on reducing single vehicle run-off-road collisions. These AMFs apply to freeways only (9). AMFs have not been developed for rural two-lane roads.

Freeway type	Collision type	AMF
Rural and urban freeway	All single-vehicle run-off-road	0.82
	Injury single-vehicle run-off-road	0.87
Rural freeway	All single-vehicle run-off-road	0.79
	Injury single-vehicle run-off-road	0.93

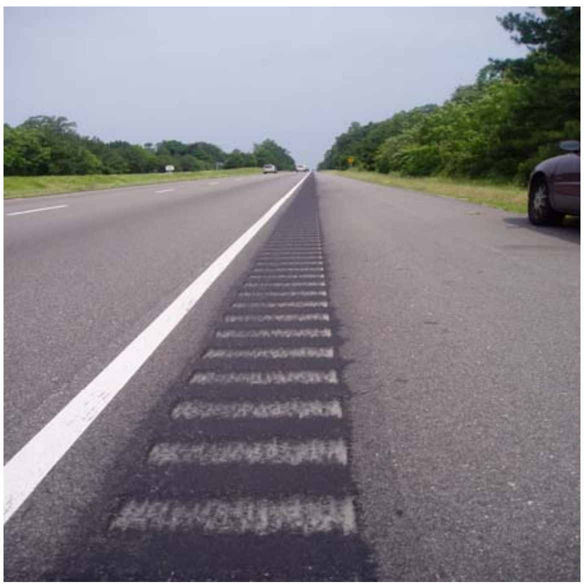

Exhibit 2: Shoulder rumble strips

Exhibit 3: Centreline rumble strips

Add centreline rumble strips
The target collision type for centreline rumble strips is head-on or opposite-direction sideswipe collisions. However, one could infer that if an opposing vehicle was not present, a head-on collision could become a run-off-road to the left collision. The following AMFs are applicable to rural two-lane highways. The average length of the treatment was 3.2 km (2 mi), and traffic volumes ranged from 5,000 to 22,000 vpd (10). A wide range of roadway geometry was included in the study sample, including curved and tangent sections with and without vertical grades. Centreline rumble strip designs varied in the study sample, including types (milled-in, rolled-in, formed, raised thermo-plastic) and patterns (continuous, intermittent).

Collision type	Severity	AMF
All types	All severities	0.86
	Injury	0.85
Head-on / opposite-direction sideswipe	All severities	0.79
	Injury	0.75

Objective 2: Assist recovery of the lane

The secondary objective of roadway design is to keep the vehicle in the travel lane. Roadway design elements affect the ability of vehicles to stay within the travel lane, and some potential treatments with AMFs are outlined below.

Change shoulder width and/or type

Changing the shoulder width and type can be a relatively low cost measure, and can be cost-effectively implemented with other measures such as rumble strips or curve improvements.

Widening the shoulder provides more recovery area for drivers to regain control of their vehicle and safely recover the travel lane. However, widening shoulders may also increase the number of voluntary stops along the roadway, or allow undesired passing if the shoulder is 3m or wider. Higher travel speeds may also result from wider shoulders, although the relationship is not accurately defined (11).

Improving the shoulder type (e.g., from gravel to paved) provides a more stable surface for drivers to regain control of their vehicle and safely recover the travel lane.

The following AMF applies to total collisions on two-lane rural roadways; the AMF is not applicable to urban roadways. If shoulder widths or types are different for the two directions of travel, the AMF should be determined for each direction and then averaged to obtain an AMF for the roadway (12).

$$AMF = (AMF_{WRA} AMF_{TRA} - 1.0) P_{RA} + 1.0$$

Where:
AMF = Accident Modification Factor for total collisions
AMF_{WRA} = Accident Modification Factor for related collisions based on shoulder width
= Accident Modification Factor for the after-improvement condition divided by the AMF for the before condition, determined from the following table:

Shoulder width m (ft)	Average Daily Traffic (ADT)		
	≤ 400	400 to 2000	≥ 2000
0 (0)	1.10	$1.1+2.5x10^{-4}$(ADT-400)	1.50
0.6 (2)	1.07	$1.07+1.43x10^{-4}$(ADT-400)	1.30
1.2 (4)	1.02	$1.02+8.125x10^{-5}$(ADT-400)	1.15
1.8 (6)	1.00	1.00	1.00
2.4 (8)	0.98	$0.98+6.875x10^{-5}$(ADT-400)	0.87

AMF_{TRA} = Accident Modification Factor for related collisions based on shoulder type; related collisions include single-vehicle run-off-road and multiple-vehicle opposing-direction and same-direction sideswipe collisions
AMF_{TRA} = Accident Modification Factor for the after-improvement condition divided by the AMF for the before condition; determined from the following table:

	Shoulder width m (ft)							
Shoulder type	**0 (0)**	**0.3 (1)**	**0.6 (2)**	**0.9 (3)**	**1.2 (4)**	**1.8 (6)**	**2.4 (8)**	**3.0 (10)**
Paved	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Gravel	1.00	1.00	1.01	1.01	1.01	1.02	1.02	1.03
Composite	1.00	1.01	1.02	1.02	1.03	1.04	1.06	1.07
Turf	1.00	1.01	1.03	1.04	1.05	1.08	1.11	1.14

P_{RA} = proportion of total collisions constituted by related collisions; estimated to be 0.35 if unknown

Objective 3: Minimize severity of run-off-road collisions

The third objective of roadway design is to reduce the severity of run-off-road collisions if the first two objectives were not met, and a run-off-road collision occurs. Roadside design elements are the focus of this objective, and the AASHTO Roadside Design Guide (2002) provides comprehensive guidelines for the range of roadside elements.

Install guiderail

Any object (hardware or natural object) located on the roadside has the potential to be struck by an errant vehicle. A traversable "clear zone" is free of roadside hardware and rigid natural objects (e.g., trees), protects objects that cannot be removed (e.g., guiderails), or makes objects that cannot be removed less severe to the striking vehicle (e.g., breakaway signs). The AASHTO Roadside Design Guide (2002) provides values for clear zone distances based on design speed, design AADT, and sideslope steepness. If it is not feasible to remove or relocate objects, one alternative is to shield unforgiving objects with a guiderail.

The following AMF applies to run-off-road collisions. The treatment studied was guiderails installed along an embankment (13).

Run-off-road collision severity	**AMF**
Fatal + Injury	0.56
Injury	0.53

Summary

Run-off-road collisions are one of three collision types generally expected on road segments (sideswipe and rear-end are also common collision types on road segments). There are three key objectives for roadway and roadside design that can be addressed to reduce the number of run-off-road collisions: keep the vehicle in the travel lane, assist drivers that encroach onto the roadside to regain control of the vehicle, and reduce the severity of run-off-road collisions if the first two objectives were not met.

By focusing on these three objectives, the frequency and severity of run-off-road collisions may be reduced. A variety of treatments can be considered to address these three objectives. Six engineering treatments are discussed in this paper, along with reliable Accident Modification Factors that can be used to determine which treatments to implement.

Managing run-off-road collisions will assist in the achievement of Canada's Road Safety Vision 2010, particularly the goal to reduce fatalities and serious injuries that occur in rural areas by 40%.

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