



Road departures and head-on collisions



# Loss of control



# Clear zones and medians provide no guarantee



# What types of crashes occur?

Most rural road crashes involve road departure





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- Continues to be dominated by single vehicle crashes
- Crashes on curves are over-represented



Source: CASR



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Source: CASR



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- Bulk of serious injury crashes involve a driver loosing control and rolling over or crashing with a roadside hazard
- Head-on crashes are also a substantial problem and many result from a loss of control scenario where there happens to be another vehicle coming the other way



Source: CASR

# Vehicle Improvements 1959 vs 2009



# Impact Energy

60 km/h versus 100 km/h



# Crashworthiness

Side pole impact 29 km/h



# Crashworthiness

High speed pole impact

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# The Gap

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Rural road crashes lead to more fatalities and serious injuries

Single vehicle departures can lead to:

- Frontal collisions with roadside hazards
- Side collisions with roadside hazards
- Head-on collisions with other vehicles



**ANCAP**  
Crash testing for safety

Side pole impact

29 km/h

Offset frontal

64 km/h

# ANCAP Crash test speeds in Australia

Offset frontal      64 km/h

Side impact      50 km/h

Side pole impact      29 km/h

Pedestrian      40 km/h



**ANCAP**  
Crash testing for safety



# New vehicle technologies

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## Electronic stability control (ESC):

Evidence has shown reduction in frequency of single vehicle injury crashes:

- Reduction in injury crashes by 32% to 45%
- Reduction in fatal crashes by 56% to 69%



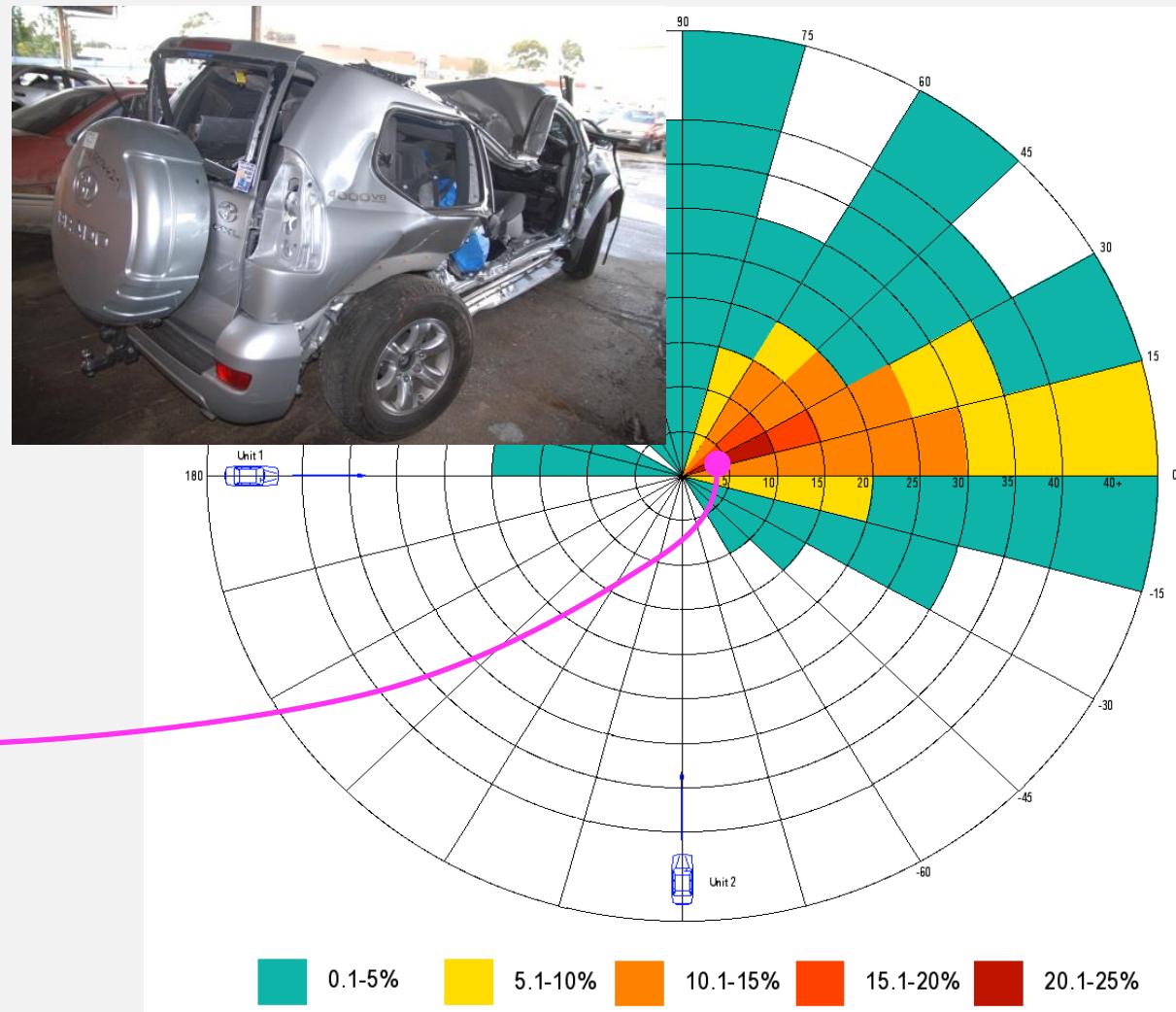
# Consequences vs Likelihood?

Intersection crashes are also a significant problem

- Very high speeds and unfavourable impact angles
- Generally unforgiving roadside at intersections – poles, trees, drainage headwalls etc.



Source: CASR



Source: Doecke et al (2013)

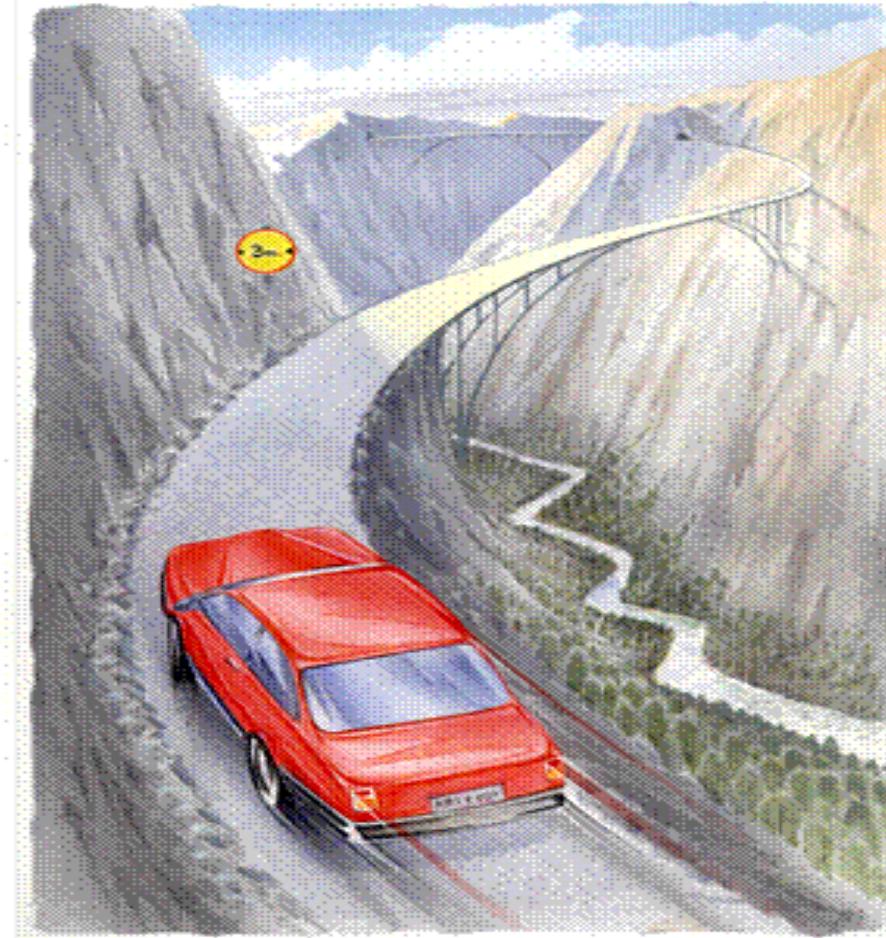
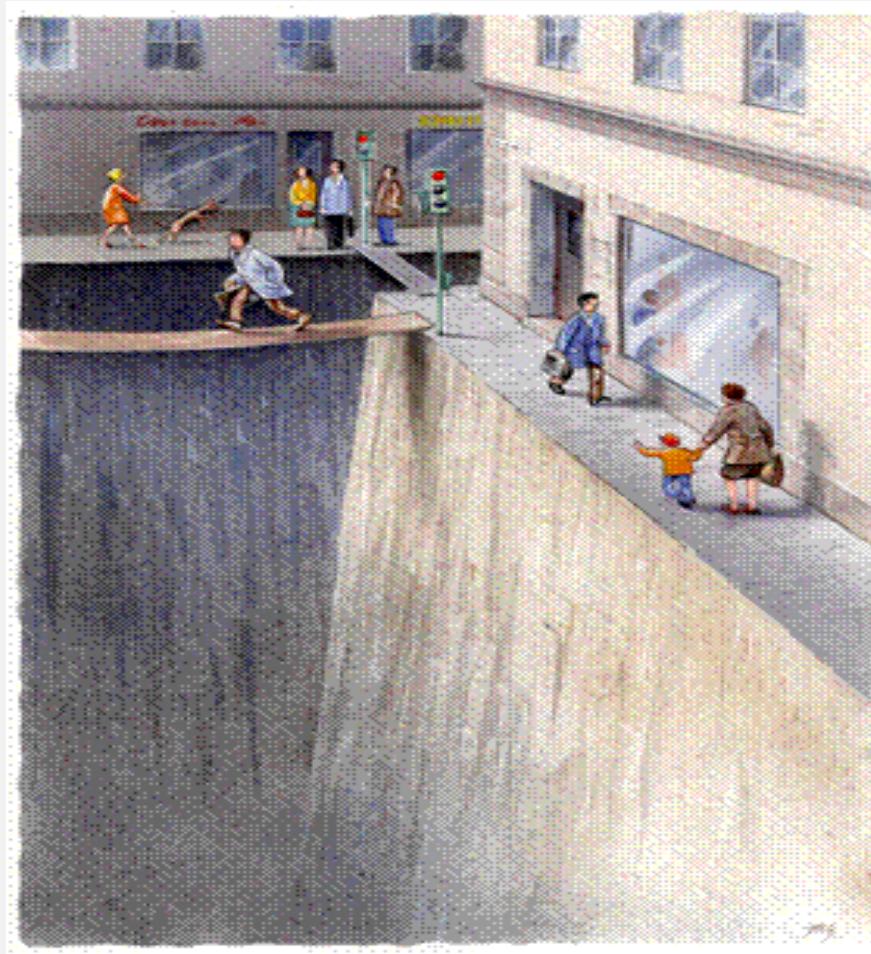
# Current design philosophy

We have unrealistically high expectations of road users

- Keep the vehicle in the travel lane at all times
  - Never become distracted
  - Regardless of journey length or the road conditions or skill level
- 
- **100% performance**
  - **100% of the time**



# Road environment in terms of energy transfer



*Slide courtesy of Claes Tingvall*

# Taxonomy of errors on rural roads

## Austroads (2014) study into user errors on rural roads

- A small number of error types account for most crashes on rural roads
- Most common error was overcorrection after straying onto the unsealed shoulder

Error	Frequency
Overcorrection after straying onto unsealed shoulder	8
Failed to give way	5
Fell asleep	4
Lane excursion	4
Loss of traction/overcorrection on unsealed surface	3
Drove off road	2
Change into occupied lane	1
Evasive manoeuvre (animal on road)	1
Fail to give way to approaching traffic	1
Failed to stop	1
Failed to appreciate stationary vehicle	1
Failure to monitor speed of other traffic	1
Left sealed surface	1
None - vehicle component failure	1
Overcorrection after straying into opposing lane	1
Pnaic braking	1
Rolled vehicle	1
Simultaneous overtaking	1

(Based on Austroads 2014)

# Taxonomy of errors on rural roads

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## Austroads (2014) study into user errors on rural roads

- A small number of treatments applied in the appropriate locations would have protected a large number of drivers who made errors
- Sealed shoulders, roadside and centreline flexible barriers would be particularly effective

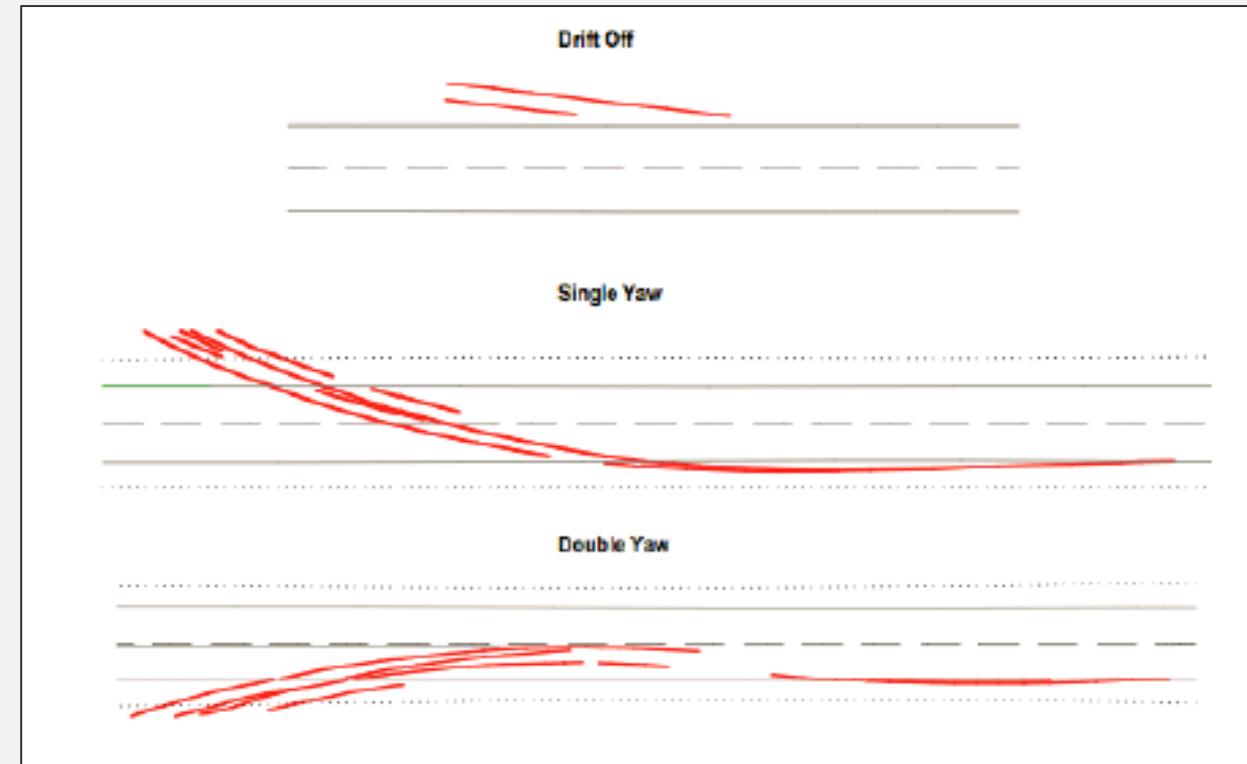
Infrastructure countermeasure	Frequency
Roadside barrier	11
Sealed shoulder	11
Centre line WRSB	9
Divided road	7
Clear zone	6
Roundabout	4
Heavy vehicle lanes	3
Sealed surface	2
Fence road reserve	1
Geometry changes	1
Overtaking provision	1
Restricted access	1
Slip lane geometry	1

(Based on Austroads 2014)

# Road Departure Scenarios

## Departure types of straights

- Clear zones best serve very low angle or “drift off” departures where driver is most likely to successfully recover
- Single yaw and double yaw often lead to vehicle rotation and large lateral displacements
- These often result in hazards being struck in a side impact configuration
- Head on collisions can also result

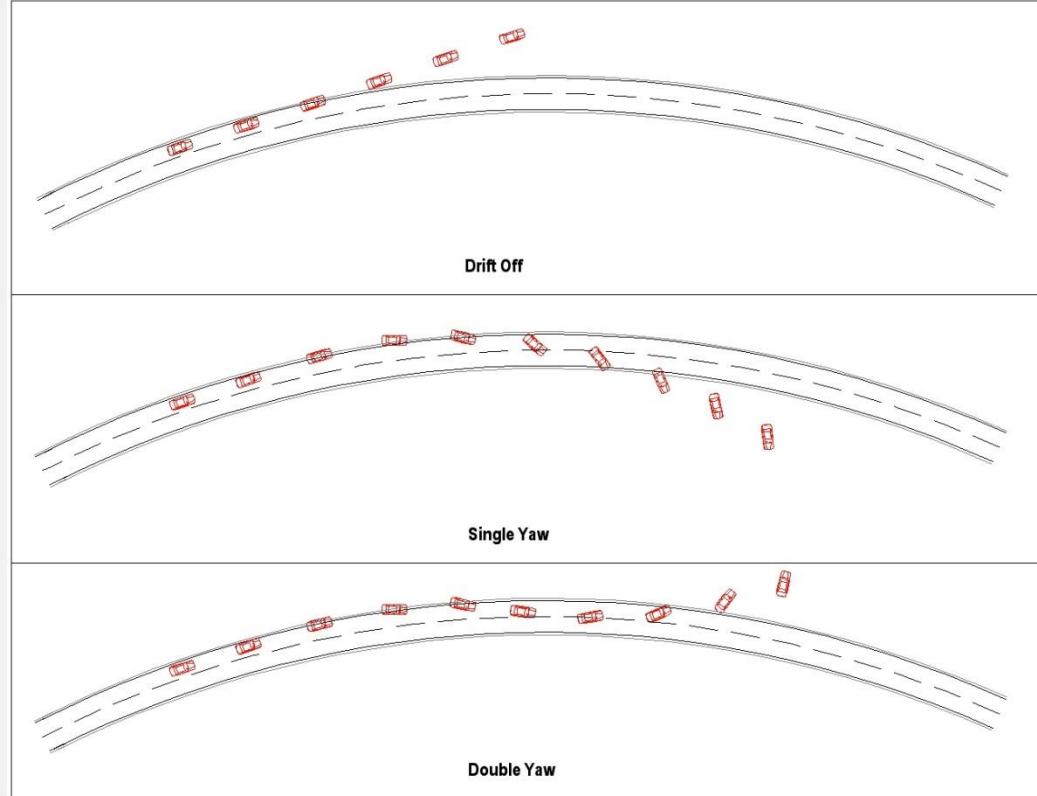


*Most common types of road departure (Doecke and Woolley 2011)*

# Road Departure Scenarios

## Departure types on curves

- Drift off (understeer) is only one scenario
- Single yaw can lead to vehicles on inside of curve and head on collisions
- Double yaw can lead to head on collisions and departures beyond the vertex of the curve

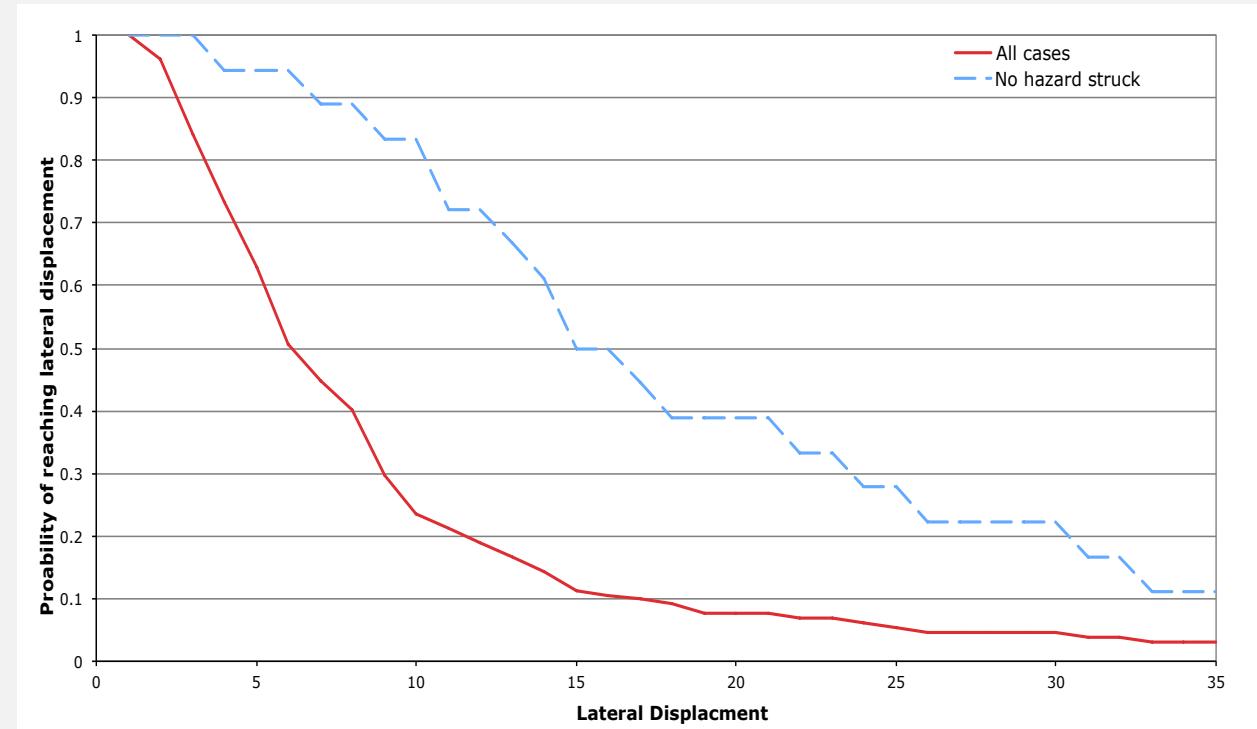


*Most common types of road departure (Doecke and Woolley 2012)*

# Lateral Displacements

## Lateral displacement

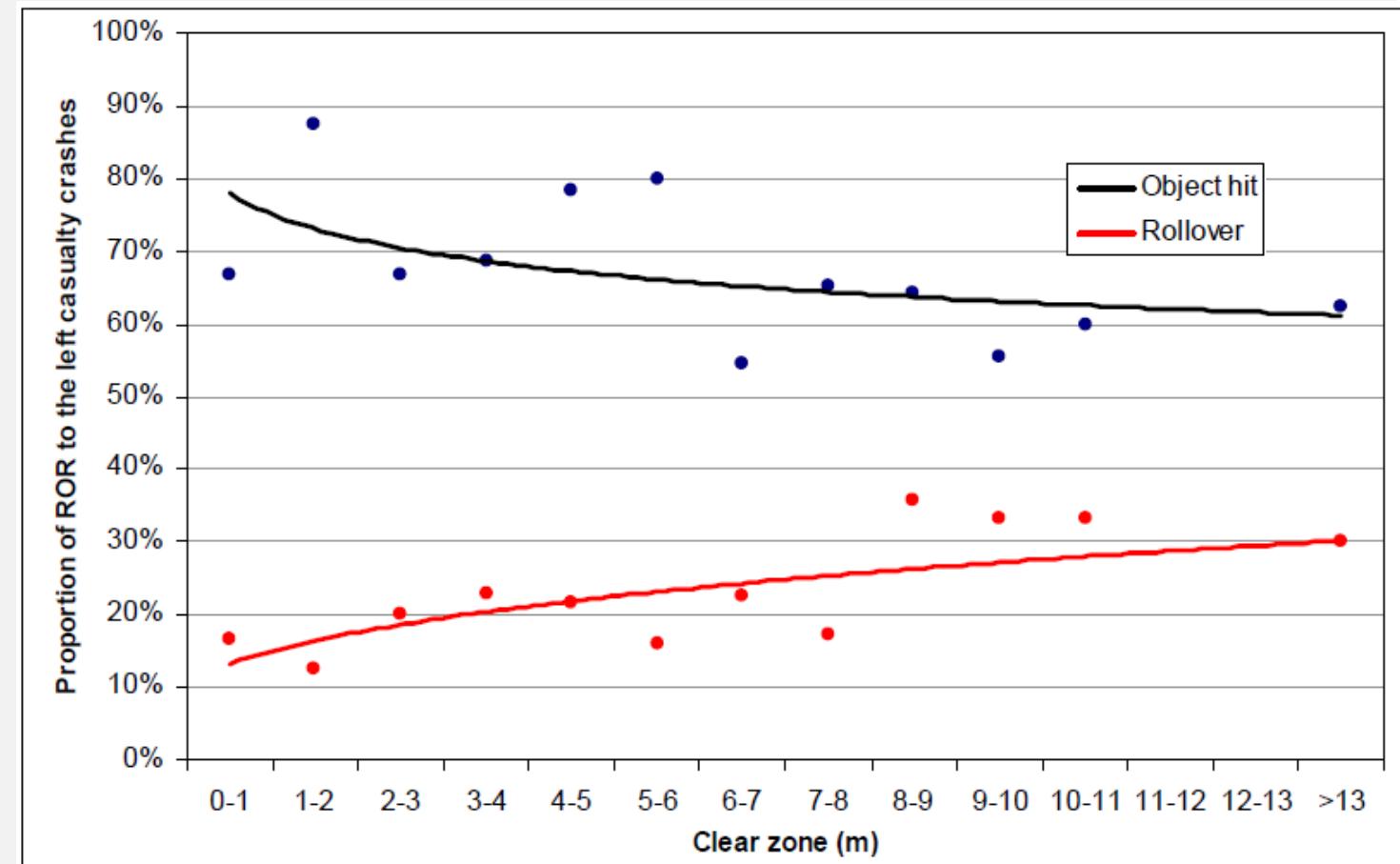
- High proportion of road departures have very large lateral displacement
- 50% of crashes where no hazard struck have lateral displacement over 15m
- Crashes where no hazard is struck have much larger lateral displacement than where a hazard is struck



*Lateral displacement of vehicles after road departure (Doecke and Woolley 2011)*

# Lateral Displacements – Clear Zones?

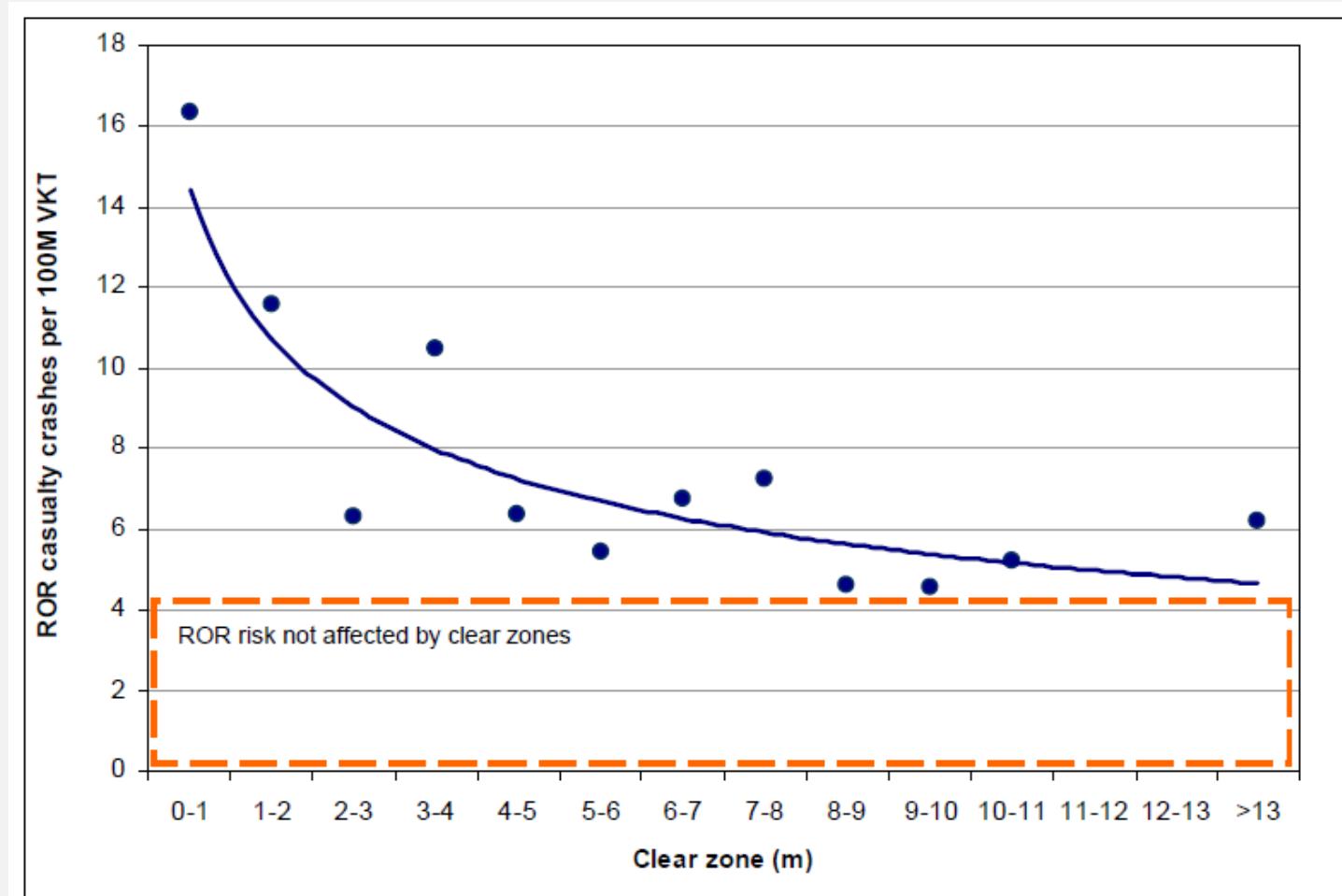
- Hazards beyond the clear zone – risk
- Hazard-free roadsides – not a safe place
- Rollovers – head and neck injuries



Proportions of Object hit and Rollover run-off-road crashes vs. clear zone (Austroads 2011)

# Lateral Displacements – Clear Zones?

- Hazards beyond the clear zone – risk
- Hazard-free roadsides – not a safe place
- Rollovers – head and neck injuries
- Wider clear zones do not deliver Safe System:
  - high residual risk
  - supporting solution at best

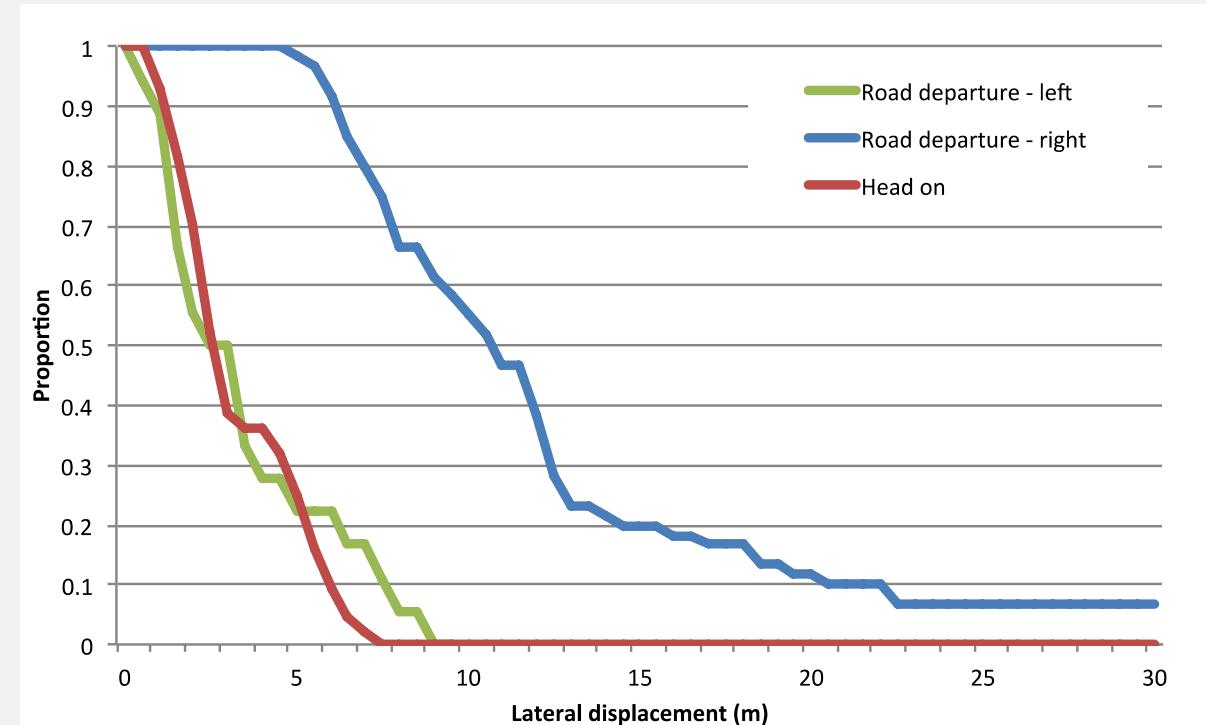


Run-off-road crash rate vs. available clear zone (Austroads 2011)

# Centreline Incursions

## Lateral displacement

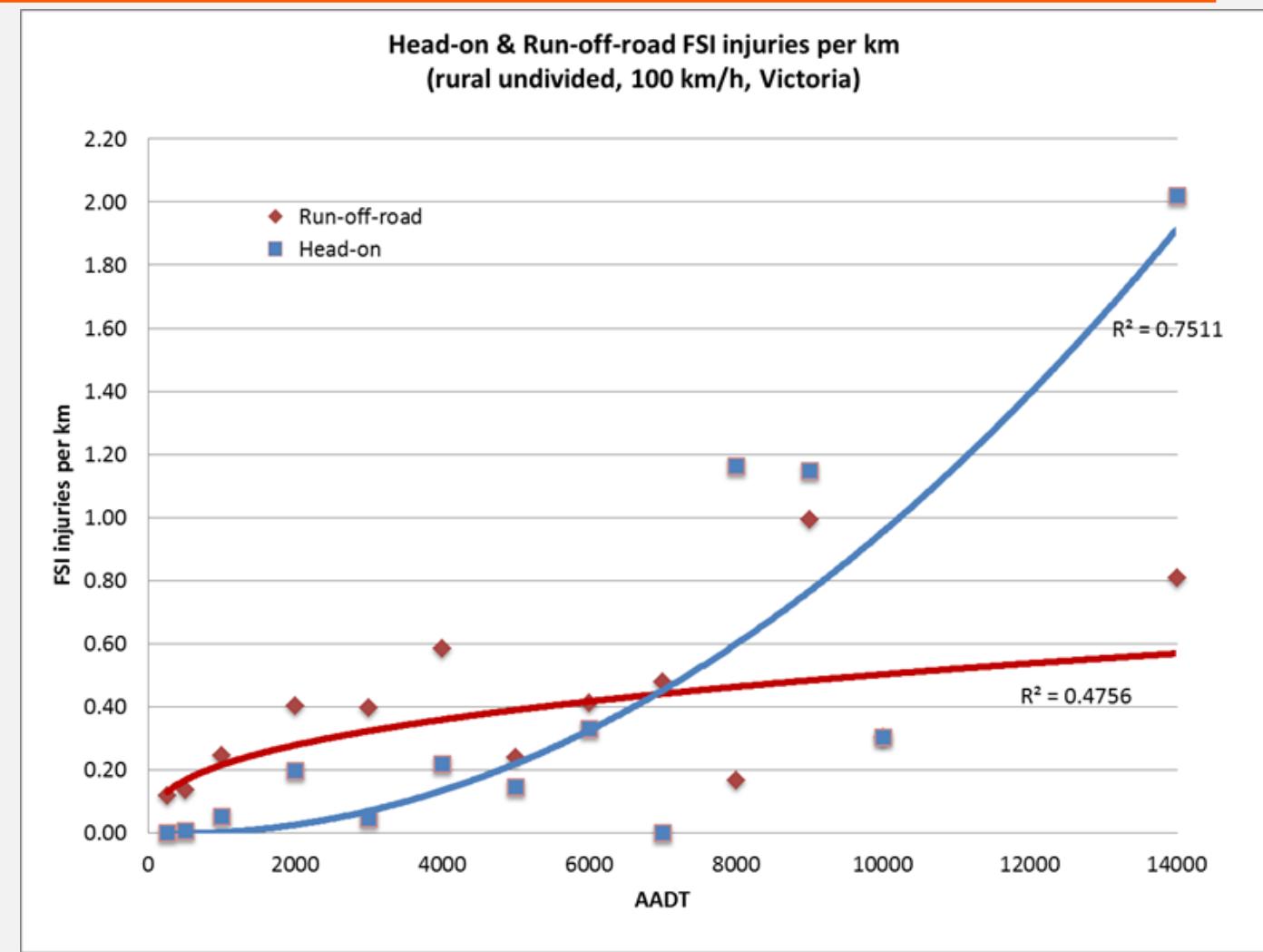
- High proportion of road departures involve crossing the centreline
- Centreline barriers could prevent road departures to left that include a centreline incursion in the yawing departure scenarios



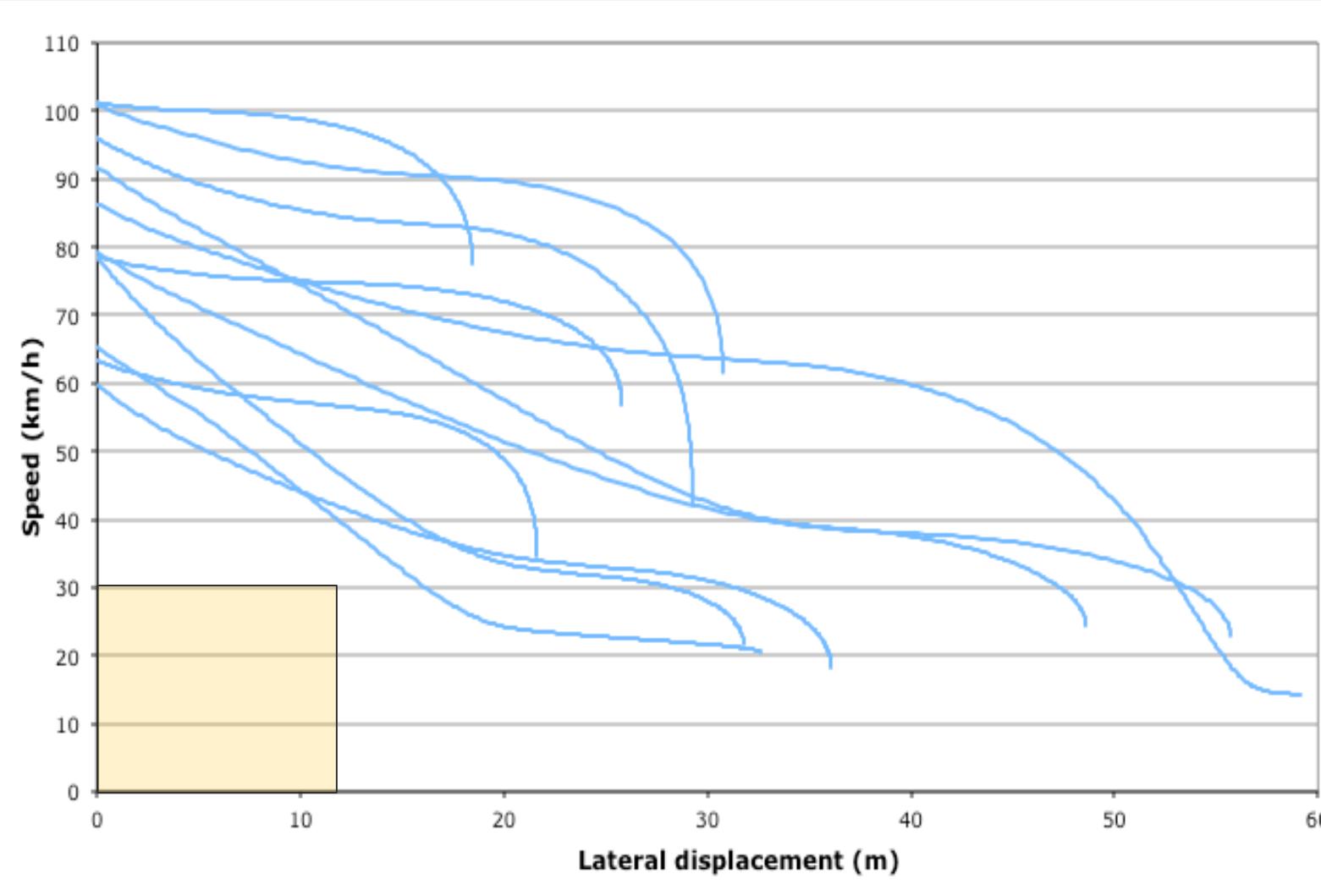
*Lateral displacement over centreline, disaggregated by crash type  
(Doecke and Woolley 2013)*

# Run-off-roads and head-ons

- Many run-off-road events to the right become head-on crashes
- Just needs a vehicle in opposite direction
- Higher risk at higher AADT
- Centreline barrier vs. two side barriers
- Agency policy / standards needed

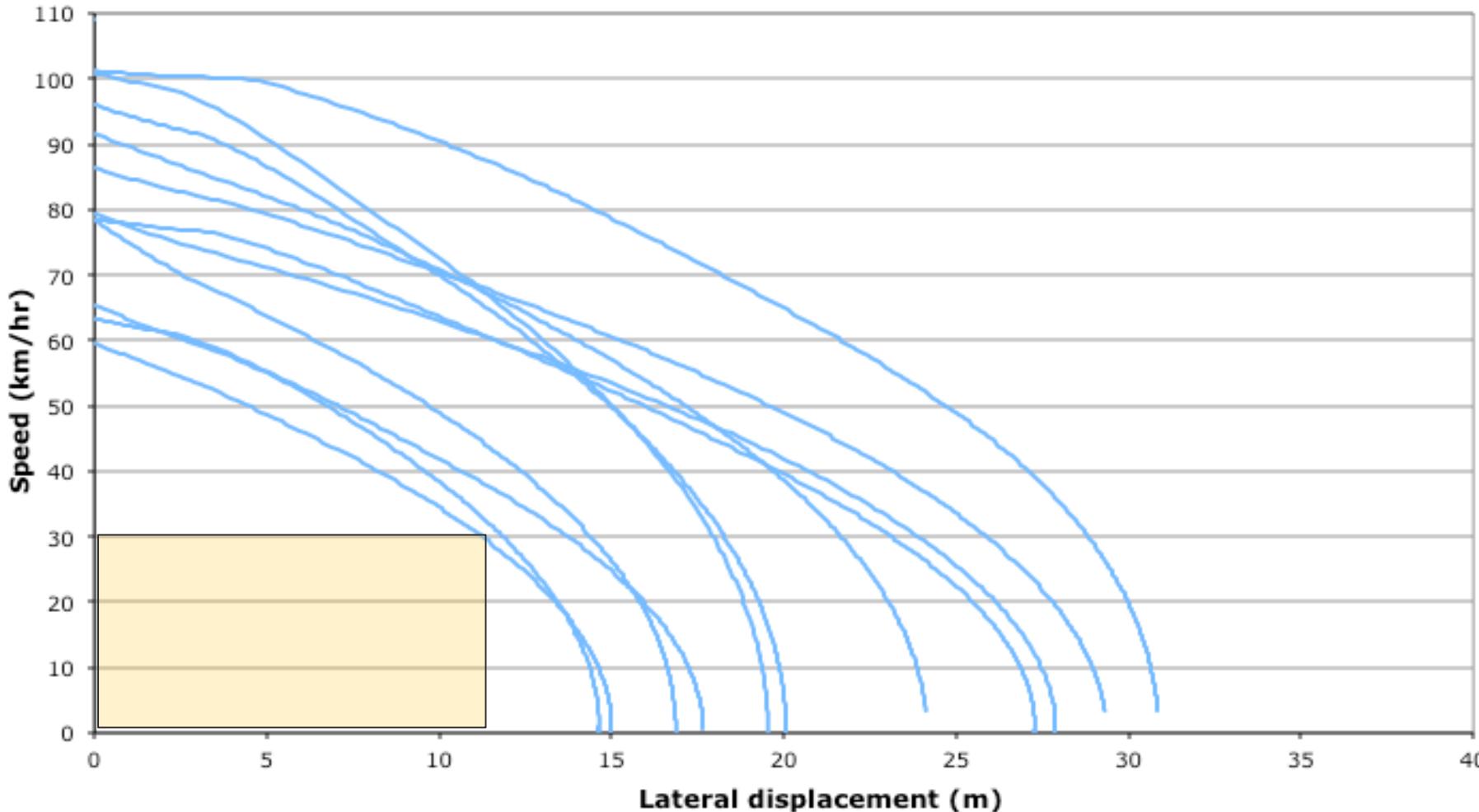


# Reconstructed Departures



*Lateral displacement of simulated vehicle loss of control with attempted recovery (Doecke and Woolley 2011)*

# Reconstructed Departures

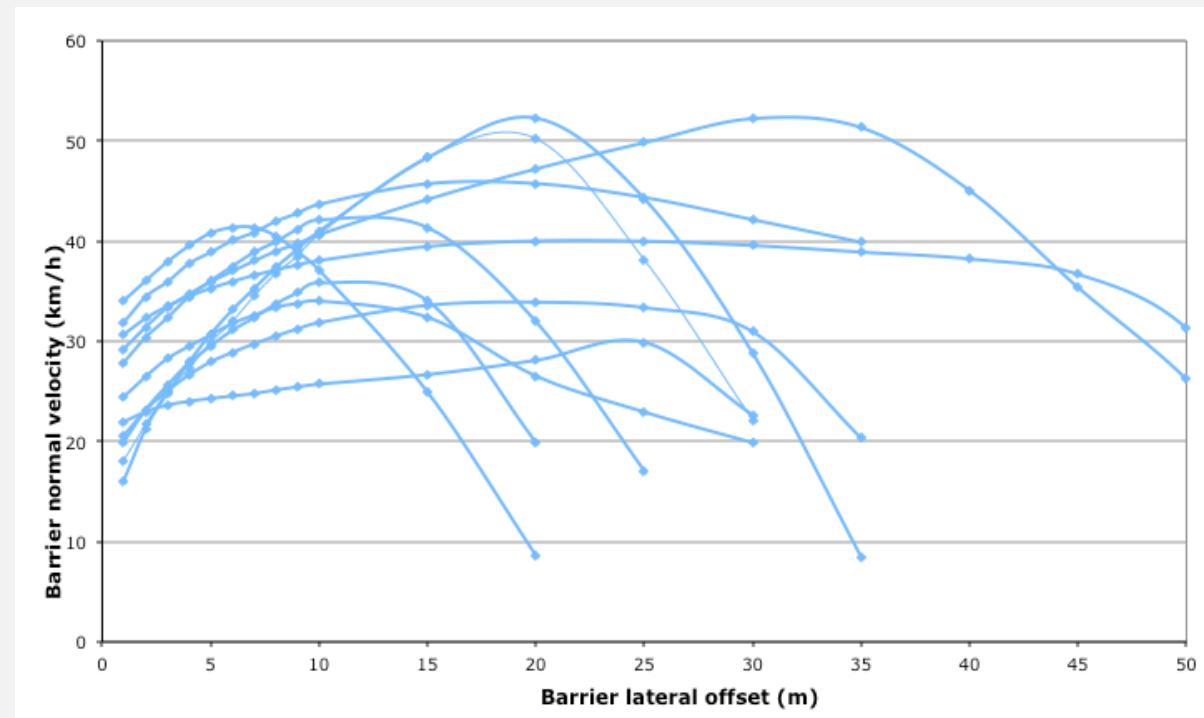


*Lateral displacement of  
simulated vehicle loss of control  
with emergency braking  
(Doecke and Woolley 2011)*

# Crash Barriers

## Barrier lateral offset

- Simulations suggest lowest barrier normal velocity (speed perpendicular to barrier) and hence impact force lower when barrier closer to roadside
- Suggests barriers should be placed as close as practicable to traffic lane



*Normal velocity versus barrier lateral offset  
(Doecke and Woolley 2011)*

# Treatment Hierarchy

## Single Vehicle Crashes

- Flexible barriers are the closest to Safe System performance currently available
- Run off areas can assist but need to be well engineered and maintained
- Very low speed environments best option but often not publically acceptable along rural arterial routes

Hierarchy	Treatment	Influence (E = exposure L = likelihood S = severity)
Safe System options ('primary' or 'transformational' treatments)	<ul style="list-style-type: none"> <li>• Flexible roadside and median barriers (or equally/better performing future equivalent)</li> <li>• Very high quality compacted roadside surface, very gentle to flat side slopes and exceptionally wide run-off areas</li> <li>• Very low speed environment/speed limit.</li> </ul>	S S L, S
Supporting treatments which move towards better Safe System alignment (compatible with future implementation of Safe System options)	<ul style="list-style-type: none"> <li>• Wide run-off areas, with well-maintained shallow drainage and gentle side slopes</li> <li>• Wide sealed shoulders with audio-tactile edgeline</li> <li>• Lower speed limit.</li> </ul>	S L L, S
Supporting treatments (does not affect future implementation of Safe System options)	<ul style="list-style-type: none"> <li>• Non-flexible safety barrier</li> <li>• Consistent design along the route (i.e. no out-of-context curves)</li> <li>• Consistent delineation for route</li> <li>• Skid resistance improvement</li> <li>• Improved superelevation</li> <li>• Audio-tactile centreline</li> <li>• Audio-tactile edgeline</li> <li>• Vehicle activated signs.</li> </ul>	S L L L L L L L
Other considerations	<ul style="list-style-type: none"> <li>• Speed enforcement</li> <li>• Rest area provision</li> <li>• Lane marking compatible with in-vehicle lane-keeping technology.</li> </ul>	L, S L L

Sourced from Austroads (2016)

# Treatment Hierarchy

## Head on crashes

- Primary treatments eliminate the risk of head on crashes
- Eliminating exposure (one way traffic) is the best option but often not practical
- Flexible median barriers are the closest to Safe System performance currently available

Hierarchy	Treatment	Influence (E = exposure L = likelihood S = severity)
Safe System options ('primary' or 'transformational' treatments)	<ul style="list-style-type: none"> <li>• One-way traffic</li> <li>• Flexible median barrier</li> <li>• Very wide median</li> <li>• Very low speed environment/speed limit.</li> </ul>	L S S L, S
Supporting treatments (compatible with future implementation of Safe System options)	<ul style="list-style-type: none"> <li>• Wide median</li> <li>• Painted median/wide centrelines.</li> </ul>	L L
Supporting treatments (does not affect future implementation of Safe System options)	<ul style="list-style-type: none"> <li>• Non-flexible barrier provision</li> <li>• Lower speed environment/speed limit</li> <li>• Ban overtaking</li> <li>• Skid resistance improvement</li> <li>• Audio-tactile centreline</li> <li>• Audio-tactile edgeline</li> <li>• Roadside barriers</li> <li>• Consistent design along the route (i.e. no out-of-context curves)</li> <li>• Consistent delineation for route</li> <li>• Overtaking lanes</li> <li>• Improved superelevation.</li> </ul>	S L, S L L L L S L L L L L L
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Sourced from Austroads (2016)

# Crash Barriers and Harm Minimisation



Flexible

Semi-rigid

Rigid



# What do we know?

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**To maximise safety, we need to rethink the use of clearzones and barriers**

- Rural road crashes dominated by single vehicle lane departures and head-on collisions
- Low angle “drift off” scenarios are thought to represent around 80% of departures

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- Clearzones cannot deliver Safe System outcomes in isolation → rollovers → incursions, even when very wide
- Some clearzone is better than none at all → most benefit in first few metres (drift off scenario)

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- Some clearzone is better than none at all → most benefit in first few metres (drift off scenario)
- Continuous lengths of barrier better performing than clearzones → flexible barrier near Safe System outcomes
- Issues around maintenance, access, wide loads and cost of road widening for centreline barriers
- New terminology for clearzones such as “run out area” to emphasise the need to safely manage departures

# What do we know?

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**To maximise safety, we need to rethink the use of clearzones and barriers**

- Unlikely that lower order rural roads will receive investment that will allow continuous lengths of flexible barrier
- Need to rely on benefits achievable with run out areas in combination with other measures such as speed management and vehicle technologies

# What do we know?

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- Unlikely that lower order rural roads will receive investment that will allow continuous lengths of flexible barrier
- Need to rely on benefits achievable with run out areas in combination with other measures such as speed management and vehicle technologies
- Barrier protection of hazards in the traditional sense should still be pursued where continuous lengths cannot be achieved
- Wide centrelines, sealed shoulders, ATLMs → promising but cannot deliver Safe System outcomes in isolation
  - Should be regarded as supporting treatments
  - Wide centrelines allow opportunity to retrofit centreline barriers

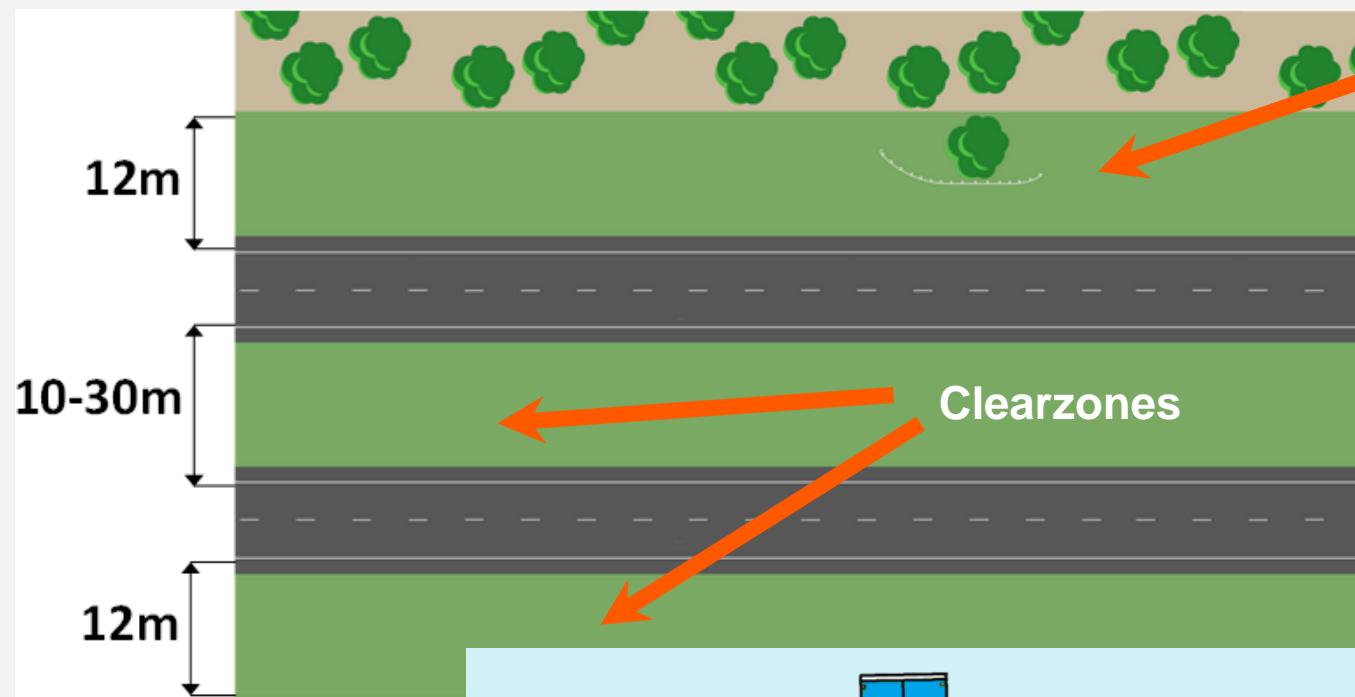
# Knowledge gaps that we can address

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- The performance of barriers under a wide range of circumstances beyond current testing conditions
- The optimum roadside barrier offset and performance implications of large offsets
- The optimal combination of various treatment types (e.g. centreline barrier in preference to roadside barrier? If sealed shoulders are required if barrier is present?)
- Further research and monitoring of motorcycle collisions with barriers in Australian and New Zealand context if they become more prevalent
  - Swedish experience suggests positive safety effect on 2+1 roads

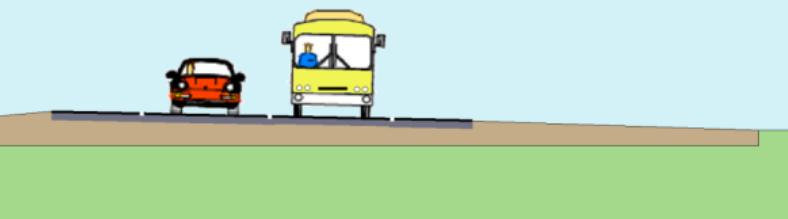
# High standard rural roads

## Traditional Treatment



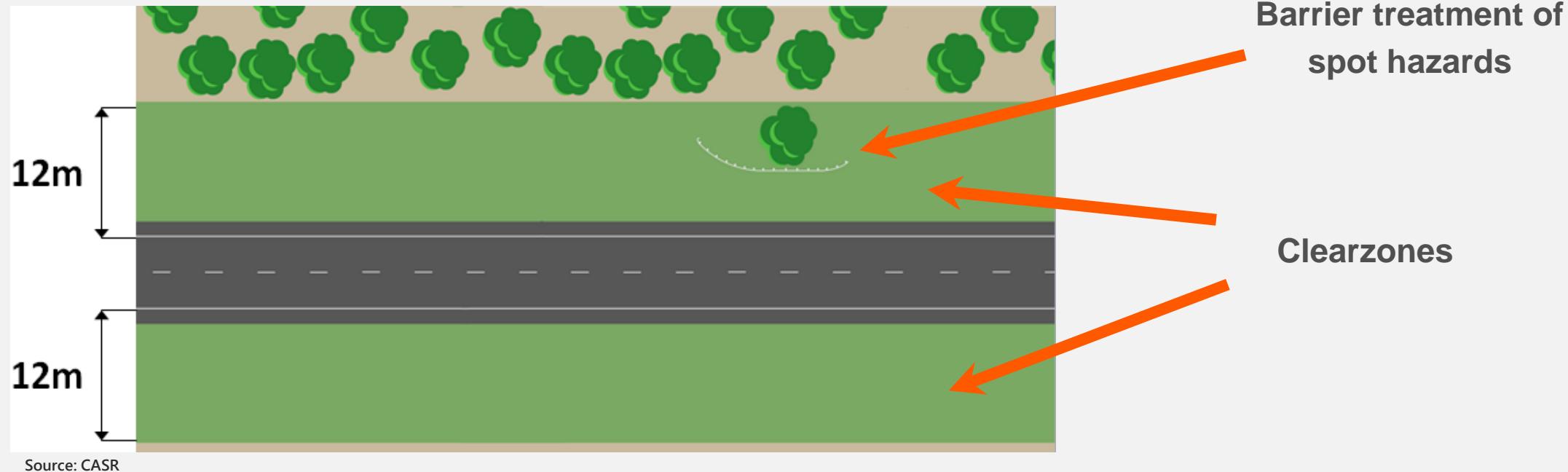
Source: CASR

## Barrier treatment of spot hazards



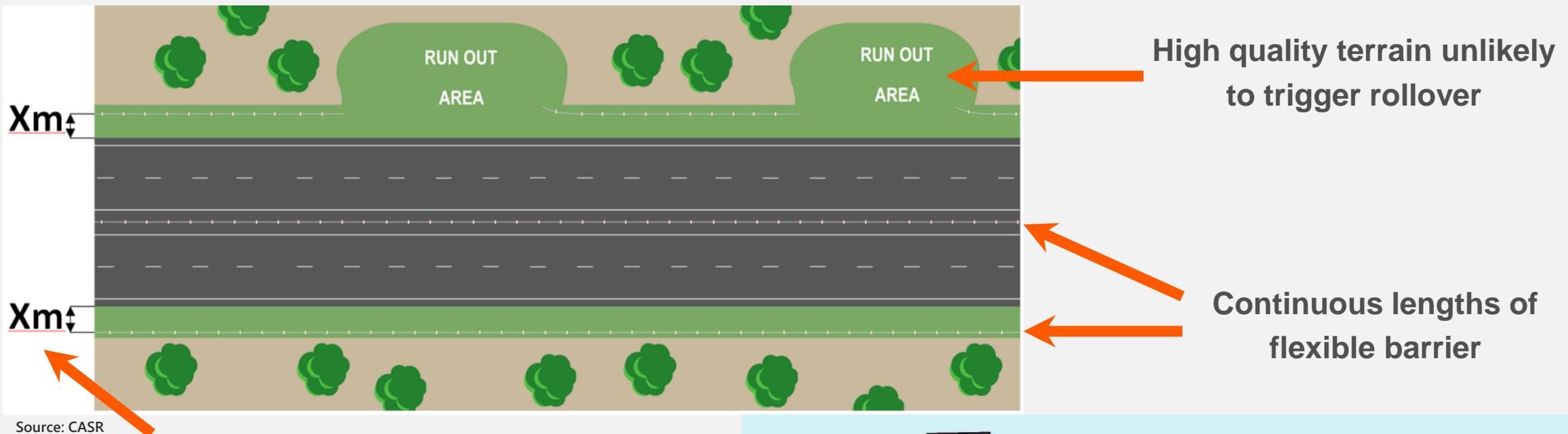
# Rural arterials

## Traditional approach



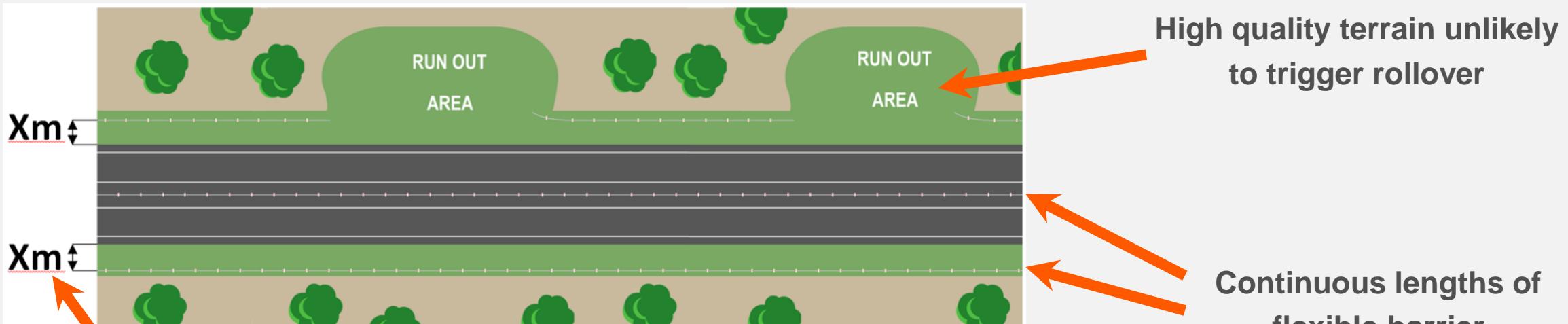
# Safe Systems Approach

## High standard rural roadway – proposed treatment



# Safe Systems Approach

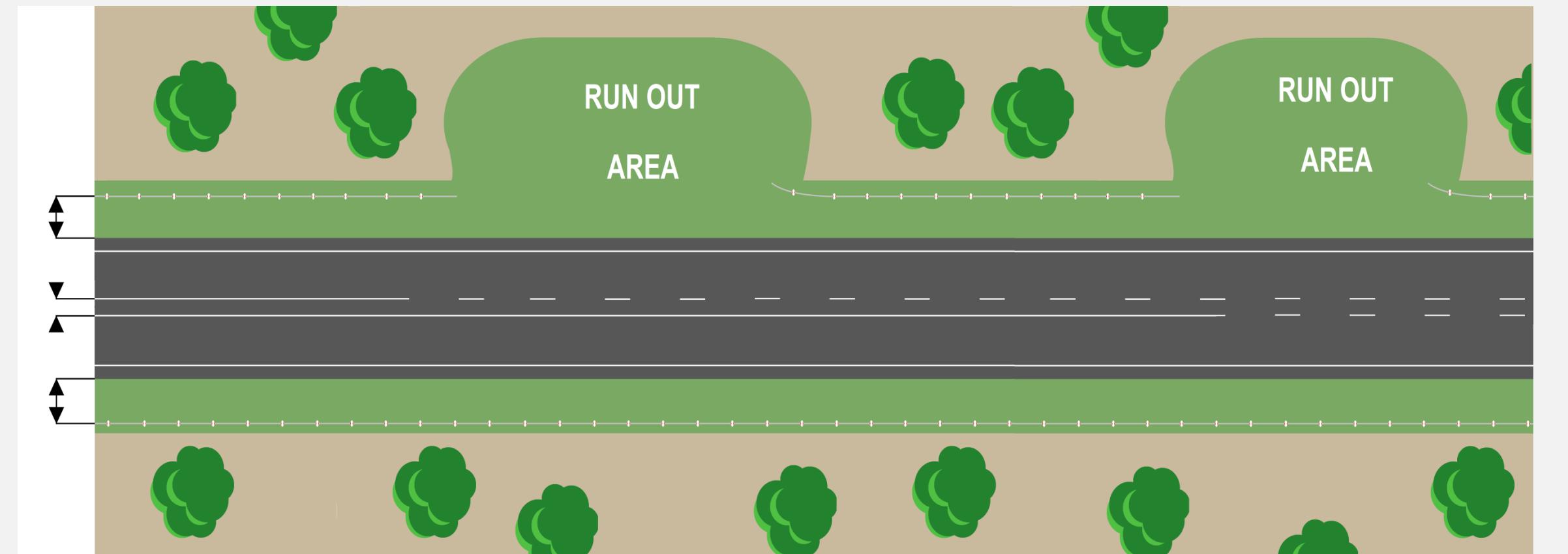
## Rural Arterials - Proposed Approach



Barrier offset may be required for practical reasons

# Supplementary Approach

## Rural Arterials - Proposed Approach



# Key evidence – barriers

Evidence	Reference
Less severe outcomes when impacting a barrier rather than a roadside hazard	Martin et al (1997) Montella and Pernetti (2010)
Rigid barriers more likely to result in rollovers and severe outcomes when compared to other barrier types	Martin and Quincy (2001) Montella and Pernetti (2010)
Impacts with end terminals are particularly hazardous	Martin et al (1997) Montella and Pernetti (2010)
Flexible barriers closest to Safe System performance compared to other barrier types	Austroads (2009, 2010, 2013)
Providing barriers as close as possible to road edge likely to result in less severe outcomes	Doecke and Woolley (2011)
Centreline barriers likely to reduce incidence of run-off-road crashes – many involve double-yaw movements over centreline	Doecke and Woolley (2011)
Recommendation for the use of flexible barriers and continuous barrier lengths	Austroads (2014) Jamieson et al (2013) Martin et al (1997)

# Key evidence - clearzones

Evidence	Reference
Clearzones cater well for drift off scenarios	Doecke and Woolley (2011)
Clearzone width of 10m is insufficient to allow safe impact speeds – most errant vehicles travel beyond 10m	Doecke and Woolley (2011)
Diminishing returns with clearzone width	Jurewicz and Pyta (2010)
Application of a clearzone must take into account hazards beyond it	Jamieson et al (2013)
Medians wider than 15m still at risk of cross-median crashes	Corben et al (2003)

# Innovative road design

## 2+1 and 2+2 roadways

Evidence	Reference
Substantial reductions in fatalities and serious injuries	Bergh and Carlsson (2001) Carlsson (2009) Crowther and Squires (2010)
Same crash frequency but with lower severity	Bergh and Carlsson (2001) Carlsson (2009)
Increased traffic efficiency	Carlsson (2009)
Benefits for motorcycles	Carlsson (2009)



YouTube: <https://www.youtube.com/watch?v=aVx2sG03Pn8>

# Innovative road design

## Centreline barriers

Evidence	Reference
Reduction of Fatal and serious injury crashes	Anderson (2010) Marsh and Pilgrim (2010) NZMOT – Waikato Expy
Elimination of head on crashes	NZMOT – Waikato Expy
Small reduction in speed and lateral movement away from centreline barrier	Lim and Phillips (2011)
High rate of flexible barrier strikes	Anderson (2010)



# Innovative road design

## Flexible barriers on divided roads

Evidence	Reference
Near elimination of median incursions and cross median road departures	Ray et al (2009)
44-83% reduction in fatal median crashes	FHWA (2006) Washington State DoT (2009)
64% reduction in severe injury median crashes	Washington State DoT (2009)
89% reduction in casualty cross median crashes	FHWA (2006)



Source: CASR

# Innovative road design

## Flexible roadside barriers

Evidence	Reference
83-87% reduction in severe head-on and road departure crashes where applied on a continuous basis	Candappa et al (2011)
42% reduction in all severe injury crashes when applied on non-continuous basis in conjunction with median barriers	
Greater reduction in run-off-road FSI crashes compared to semi-rigid and rigid barriers	Chow and Meulieners (2015)
Extremely low risk of severe injury in single vehicle run-off-road crash into flexible barrier – lower than run-off-road crashes with no roadside object hit	Austroads (2013)

# Innovative road design

## Wide centrelines

Evidence	Reference	
75% reduction in over centreline crashes and fatalities	Bobberman (2016) Whittaker (2012)	
Improved safety for all wide centrelines above 0.5m width	Levett et al (2009)	
Reduced speeds and centreline crossovers	Connell et al (2011)	
Positive public reception	Bishop et al (2013)	

*Levett et al. (2009)*

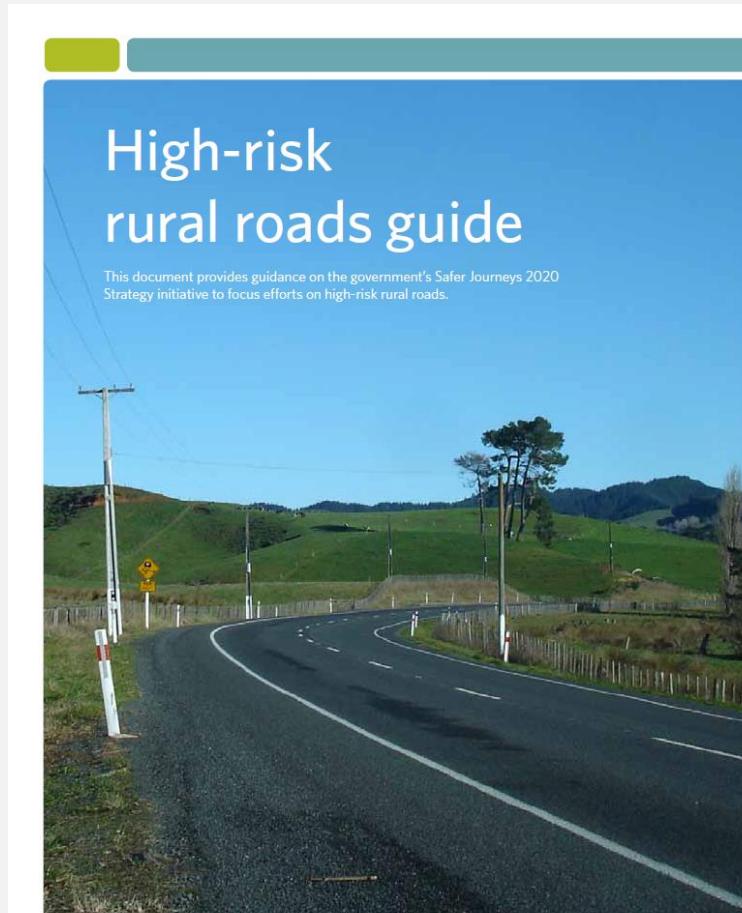
# Approaches to risk management

Creatively prioritise Road Departure and Head On treatments at route and corridor level:

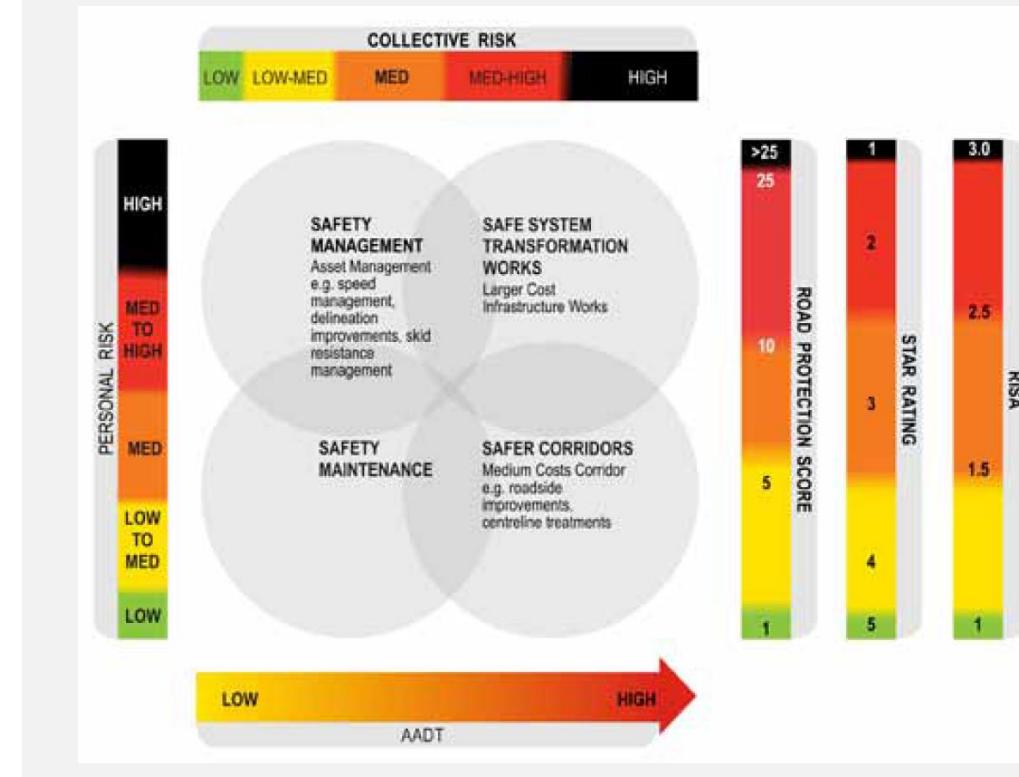
- Systemic and mass-action treatments vs black length only
- Balancing BCRs vs. continuity of treatment
- Future proofing solutions (i.e. supporting but open to extension to primary)
- Using asset management and operational/freight solutions to support Safe System objectives



# NZ High Risk Rural Roads Guide



New Zealand Government



# In Summary

## Take home messages

- We need to manage inevitable road departures and reconsider our reliance on clear zones
- Continuous lengths of barriers can produce the best safety outcomes
- Centreline barrier is a highly effective Safe System treatment on rural roads and eliminates depart right and head on collisions and also depart left collisions involving yawing



Sources: CASR, Levett et al (2009)

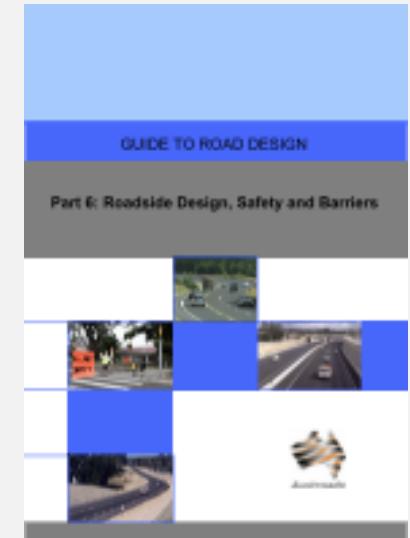
# A note on the Austroads Guides

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## Guide to Road Design Part 6

- Currently under review
- New design approach to minimise Road Departure FSI's
- Wide clear zones now a supporting treatment with evidence based approach to establish their benefit



**Thank you**

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