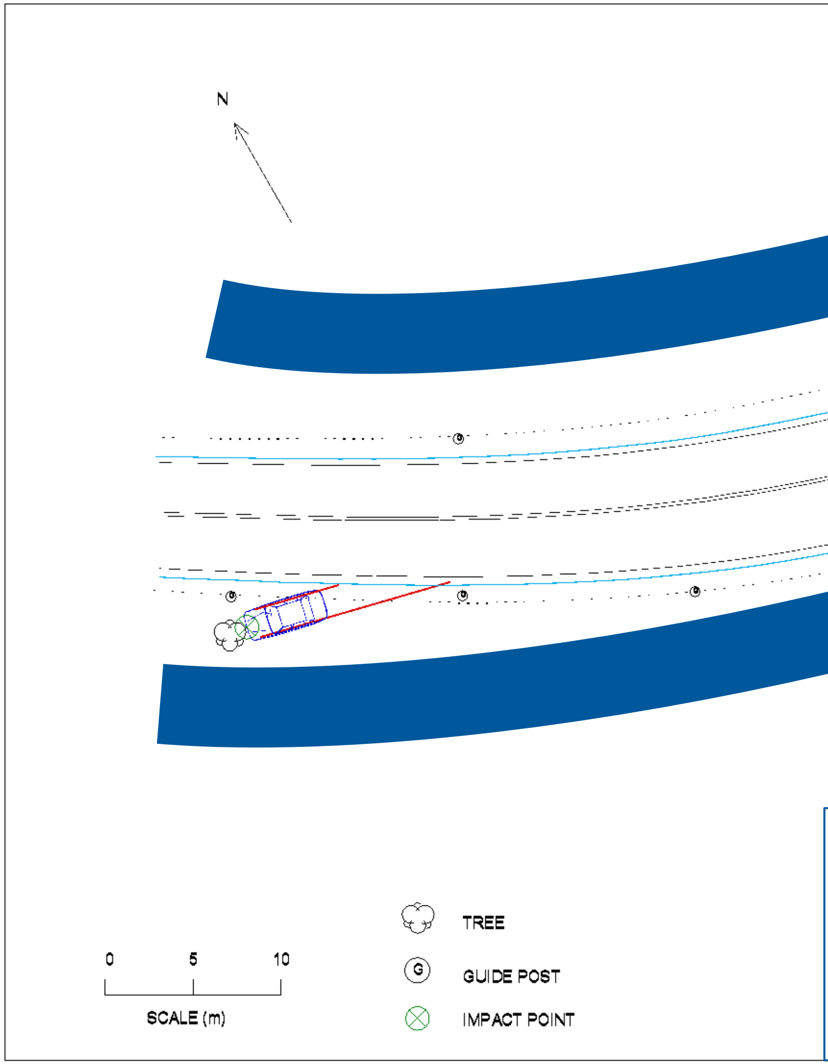
Jeremy Woolley and Sam Doecke

Some implications from the in-depth study and simulation modelling of road departure crashes on bends on rural roads

Clear Zones



Ideally – up to 10.5m (14m)
In practice – < 10.5m
f(design speed, ADT, batters)

Clear Zone Correction for Curves

- Crash histories indicate a need
- A specific site investigation shows a definitive crash potential that could be significantly reduced by increasing the clear zone width, and
- Such increases are cost-effective.

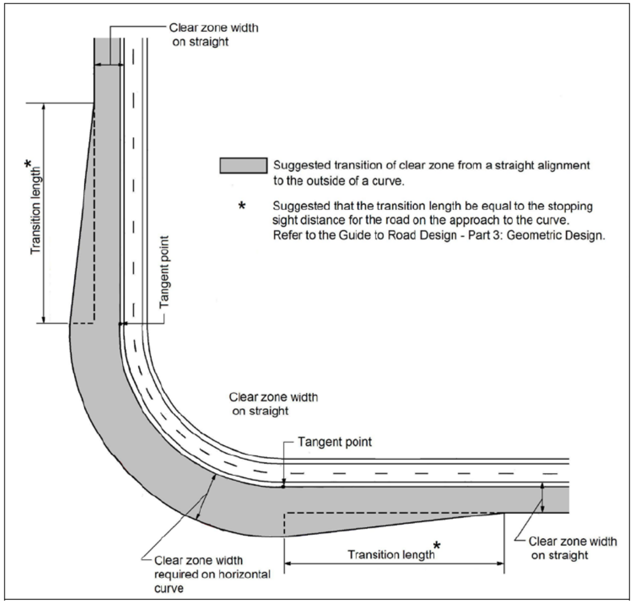


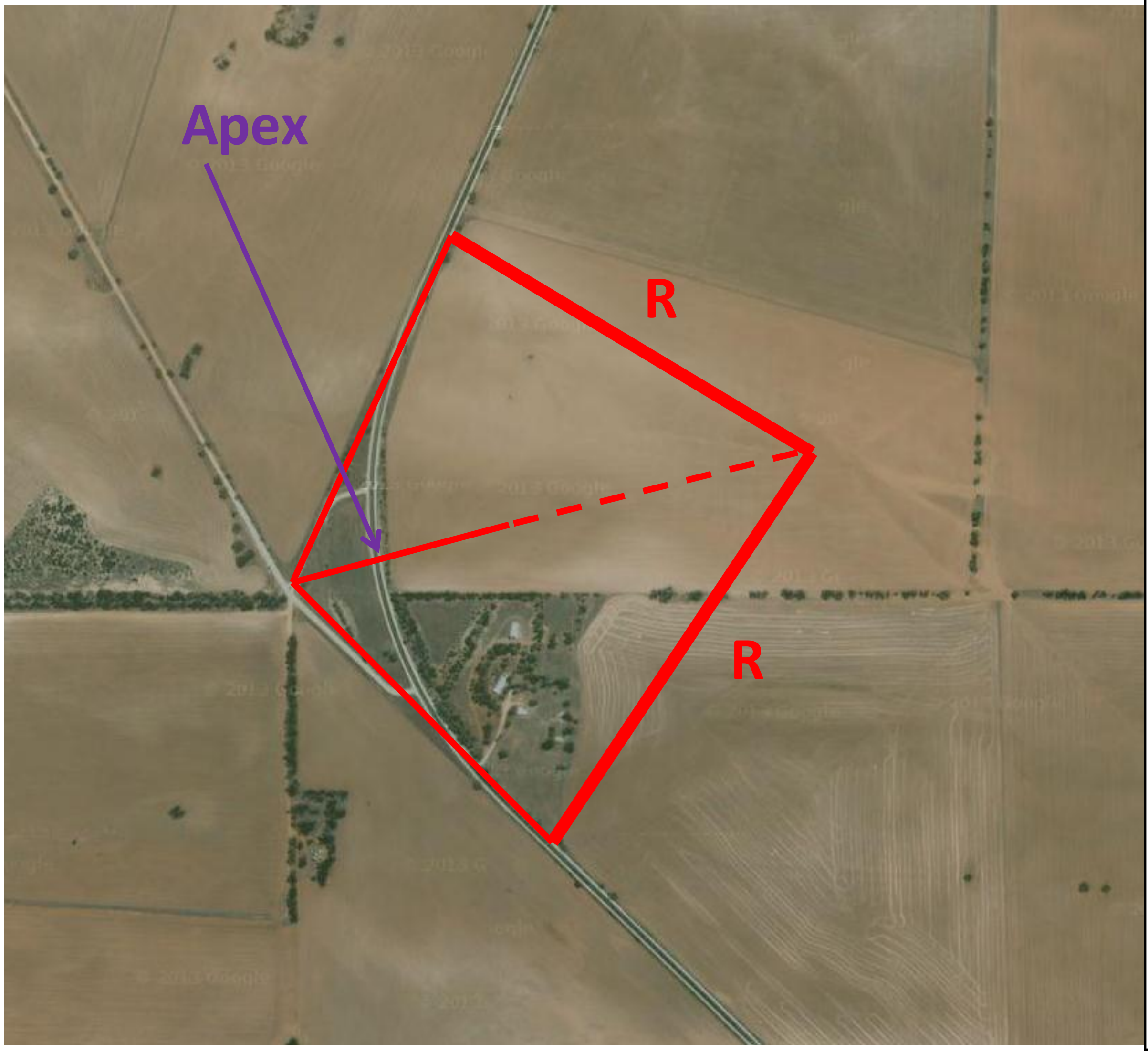
Figure 4.5: Clear zone transition on approach to horizontal curves

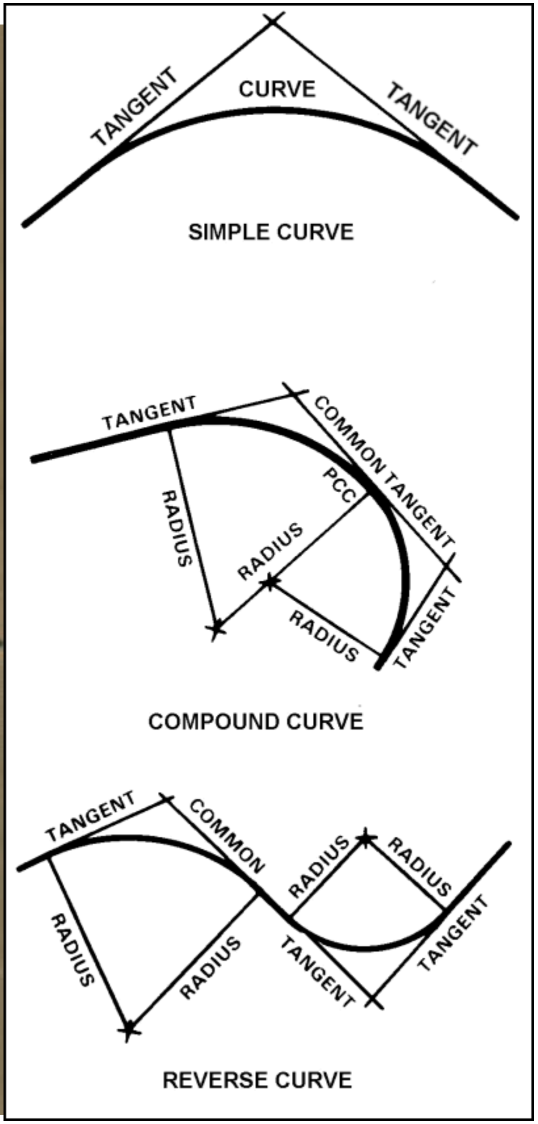
Table 4.2: Curve correction factors

Radius (m)	Design speed (km/h)					
	60	70	80	90	100	110
900	1.1	1.1	1.1	1.2	1.2	1.2
700	1.1	1.1	1.2	1.2	1.2	1.3
600	1.1	1.2	1.2	1.2	1.3	1.4
500	1.1	1.2	1.2	1.3	1.3	1.4
450	1.2	1.2	1.3	1.3	1.4	1.5
400	1.2	1.2	1.3	1.3	1.4	–
350	1.2	1.2	1.3	1.4	1.5	–
300	1.2	1.3	1.4	1.5	1.5	–
250	1.3	1.3	1.4	1.5	–	–
200	1.3	1.4	1.5	–	–	–
150	1.4	1.5	–	–	–	–
100	1.5	–	–	–	–	–

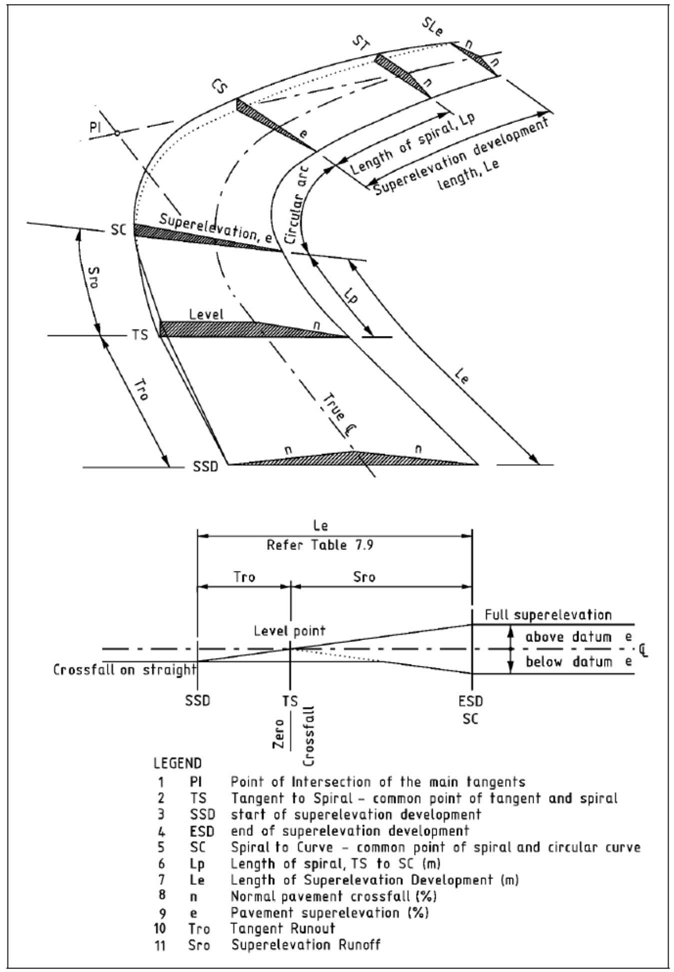
Source: AASHTO (2006).

Some terminology





Superelevation



ource: Austroads (2003).

Figure 7.8: Typical superelevation development profile on two lane roads (tangent to transition curve to circular curve

Background

- The practice of using clear zones in lieu of barrier protection needs to be challenged
  - 10-20% of errant vehicles will exceed the 10.5m clear zone
  - Even if ≥10.5m is achieved, surface often contains trip hazards
  - this is exacerbated on bends (due to superelevation etc)

- Previous simulation modelling work at CASR
  - Departures on straights
  - Influence of wide medians and centreline barriers
  - Interplay between clear zones and barriers from a Safe Systems perspective
  - Only the shallow angle drift off departures are catered for

Crashes associated with curves on rural roads

- Curves are over-represented in rural road crashes
- 2001 to 2005 (Tziotis et al 2005):
  - 27% of all injury crashes
  - 52% of road departure crashes (run off road)
- Issue for young drivers (Clark et al 2010)

- Many factors associated with crash rates:
  - Radius
  - Super-elevation
  - Grade
  - Transitions
  - Signs and delineation

CASR In-depth crash database

- Several different studies in rural areas
- Criterion of ambulance call out / transport to hospital
- Bias towards daytime crashes during business hours

Crash severity	Number	Percentage
PDO	4	6.3%
Doctor	3	4.7%
Treated	20	31.3%
Admitted	18	28.1%
Fatal	19	29.7%
Total	64	100.0%

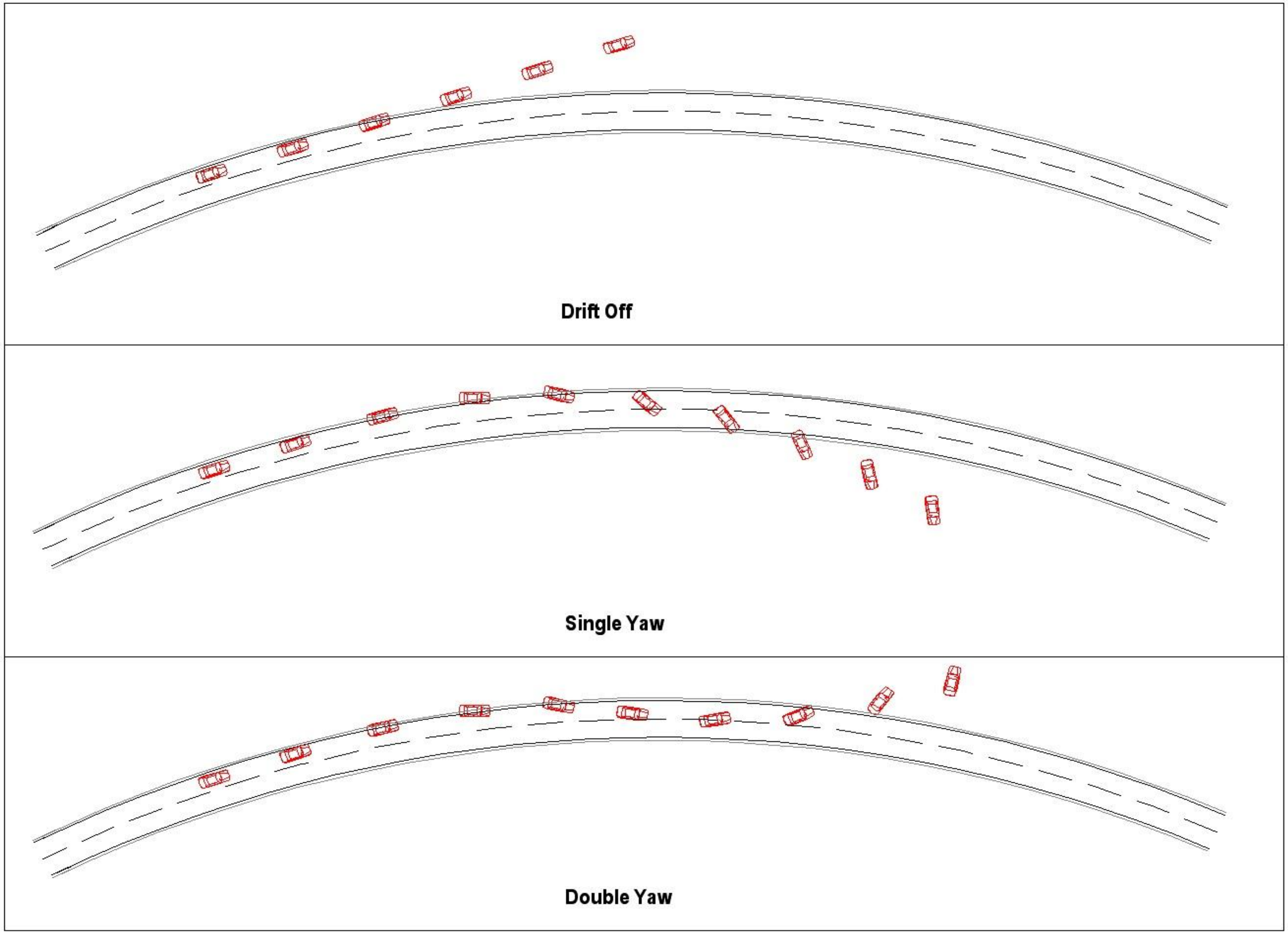
Characteristics of the sample

Speed zone (km/h)	Number	Percentage
80	7	10.9%
100	44	68.8%
110	13	20.3%
Total	64	100.0%

Rollover	Number	Percentage
No	37	57.8%
Yes	27	42.2%
Total	64	100.0%

Lighting	Number	Percentage
Day	49	76.6%
Night	15	23.4%
Total	64	100.0%

Road Departure Types



Departure Characteristics

Departure direction		Curve radius 0-199	200-399	400+	Total
Left	Left bend	6	1	2	9
	Right bend	15	7	4	26
Right	Left bend	5	2	1	8
	Right bend	12	6	3	21
Total		38	16	10	64

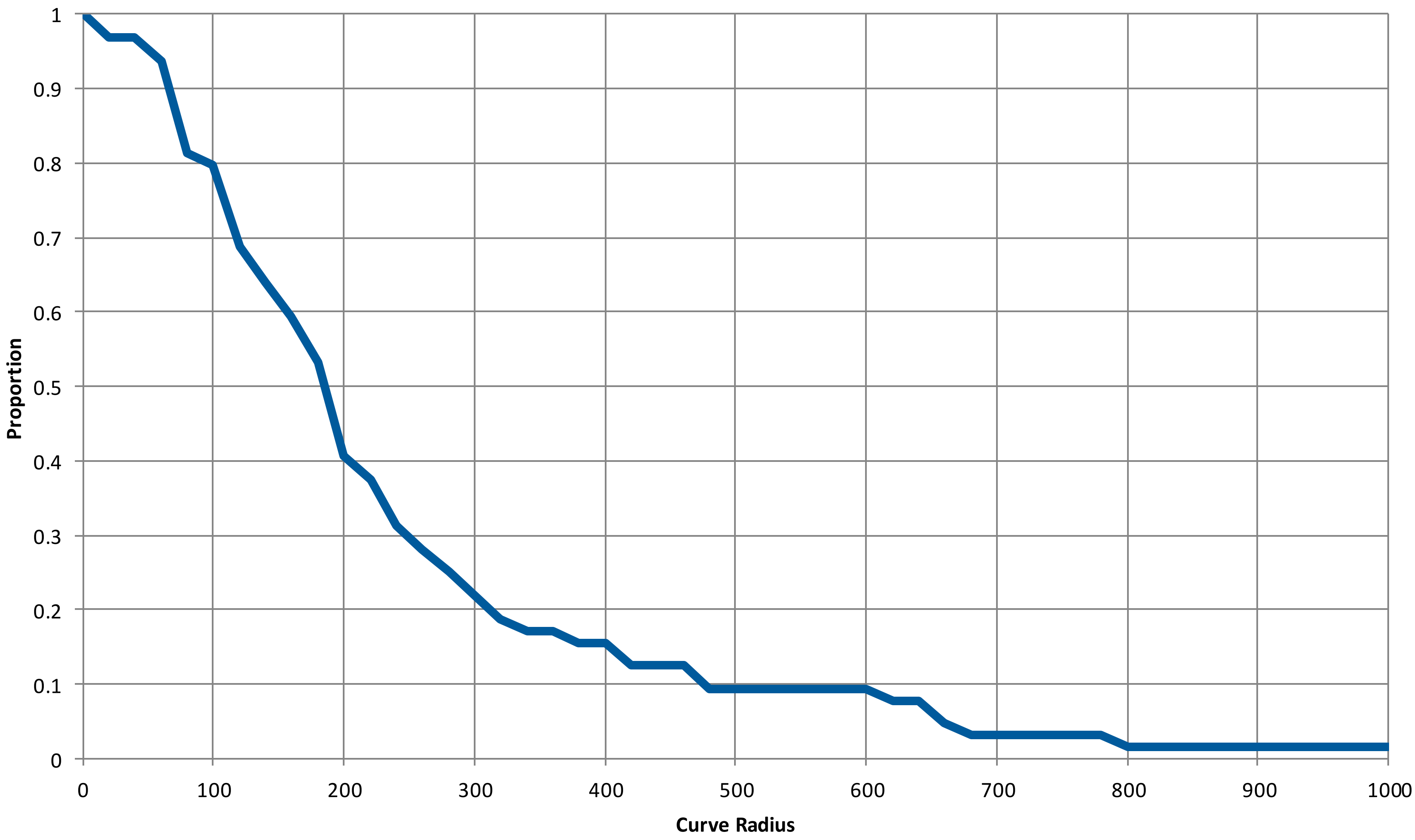
Departure type		Curve radius 0-199	200-399	400+	Total
Left Bend	Drift off	3	1	1	5
	Single yaw	5	1	2	8
	Double yaw	3	0	0	3
Right Bend	Drift off	9	2	3	14
	Single yaw	11	6	3	20
	Double yaw	6	5	1	12
Total		37	15	10	62*

*2 cases involved more than two yawing movements but were not included here

Initiation of departure and actual point of departure relative to apex

	Departure initiation				
Departure	Before curve	Before apex	After apex	Unknown	Total
Before apex	1	6	0	0	7
After apex	1	8	13	2	24
After bend	0	5	26	0	31
Unknown	0	0	0	2	2
Total	2	19	39	4	64

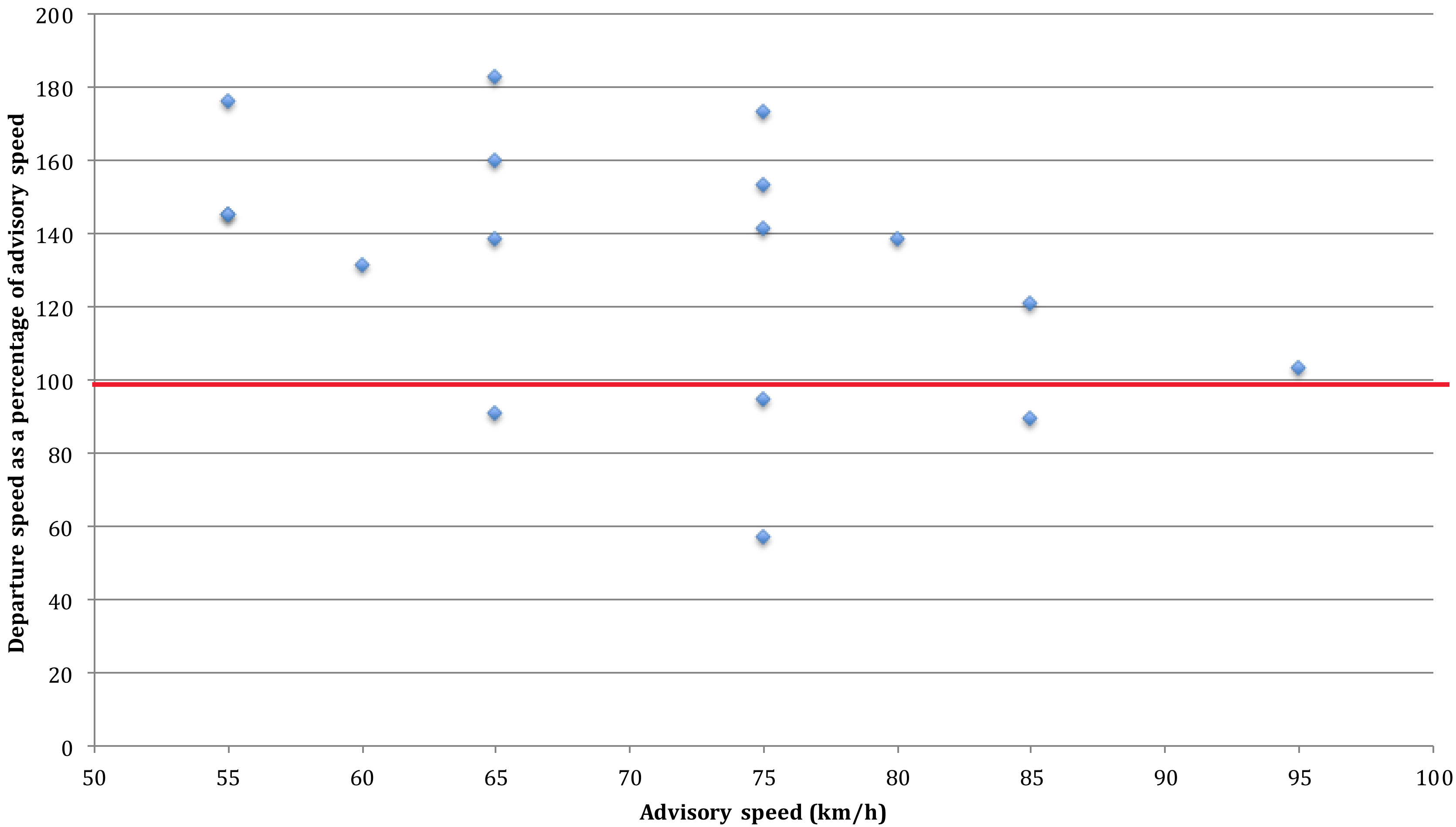
Cumulative distribution of curve radius for road departure crashes on curves (n=64)



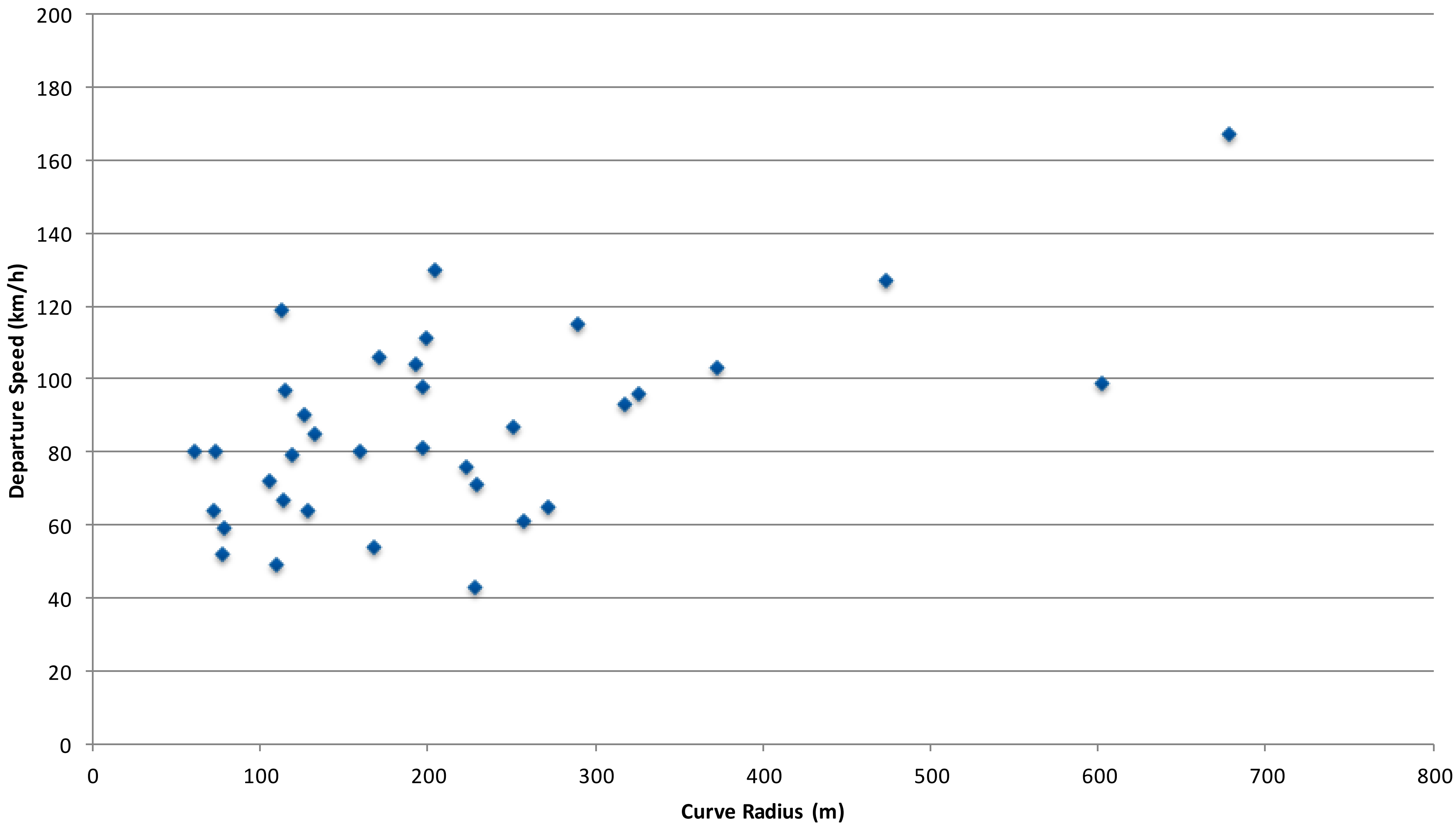
Run off road crashes on curves by advisory speed and curve radius

	Curve radius			
Advisory speed (km/h)	0-199	200-399	400+	Total
25	2	0	0	2
45	2	0	0	2
55	7	0	0	7
60	1	0	0	1
65	7	0	0	7
70	1	0	0	1
75	1	4	1	6
80	2	0	0	2
85	0	3	1	4
95	1	0	0	1
Curve Advisory Sign	1	2	0	3
None	13	7	8	28
Total	38	16	10	64

Departure Speed vs Advisory Speed (n=16)



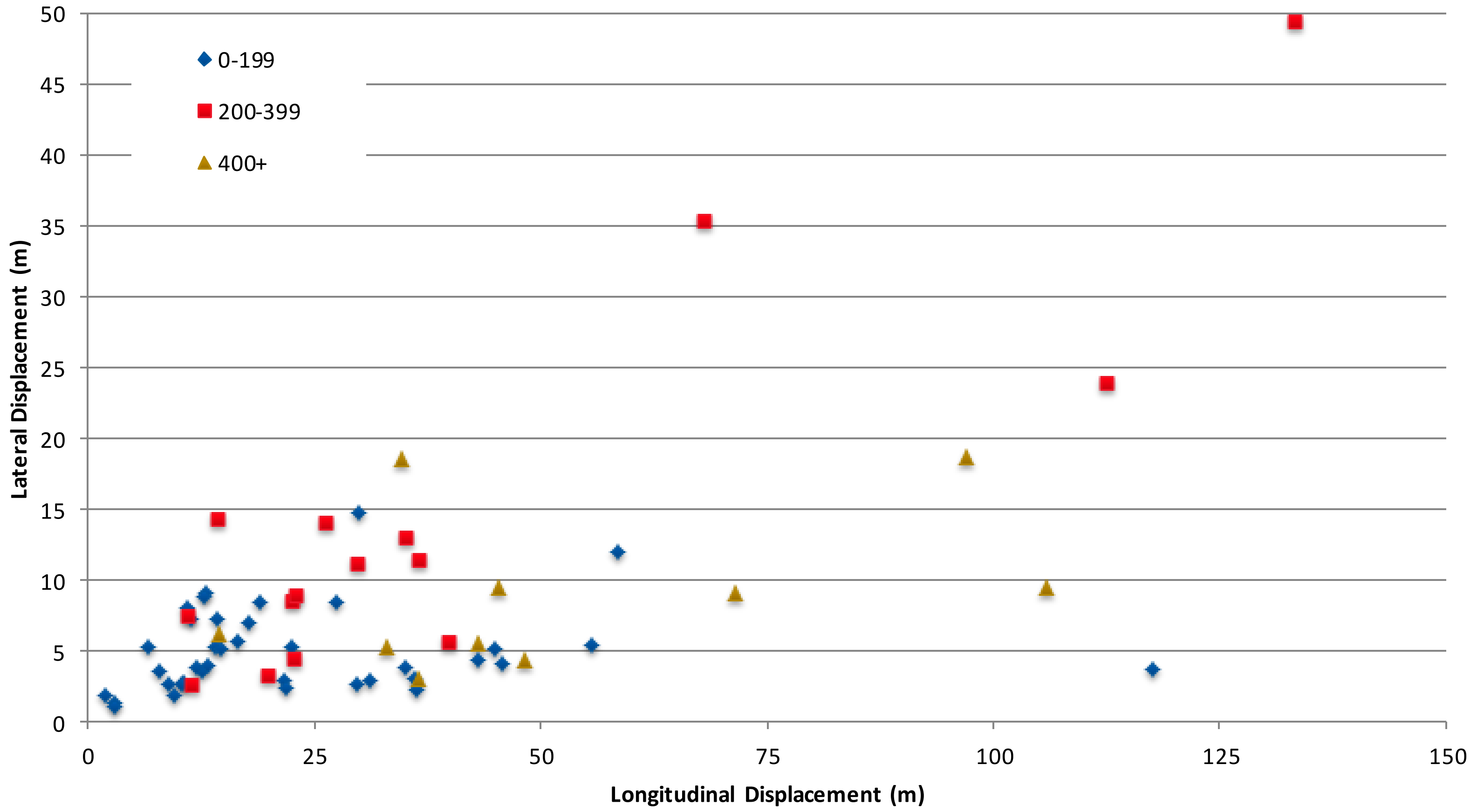
Departure Speed by Curve Radius



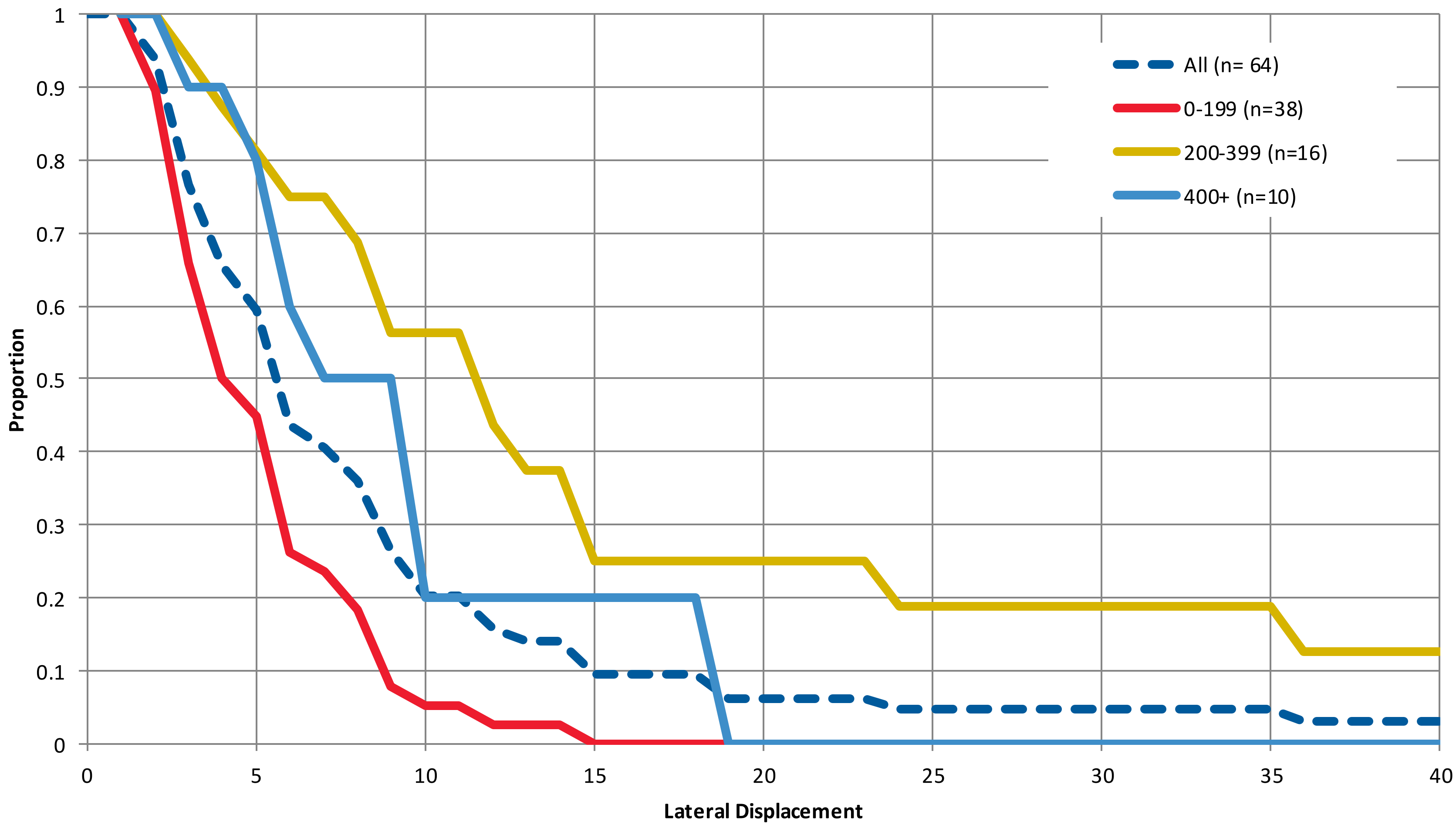
Friction demand if vehicles had to negotiate the bend at their chosen entry speed (proxy was the estimated departure speed)

Friction demand	Number	Percentage
0-0.19	7	20.0%
0.2-0.39	16	45.7%
0.4-0.59	7	20.0%
0.6-0.79	3	8.6%
0.8-0.99	2	5.7%
Total	35	100.0%

Longitudinal and lateral displacement by curve radius (an outlier removed for clarity)



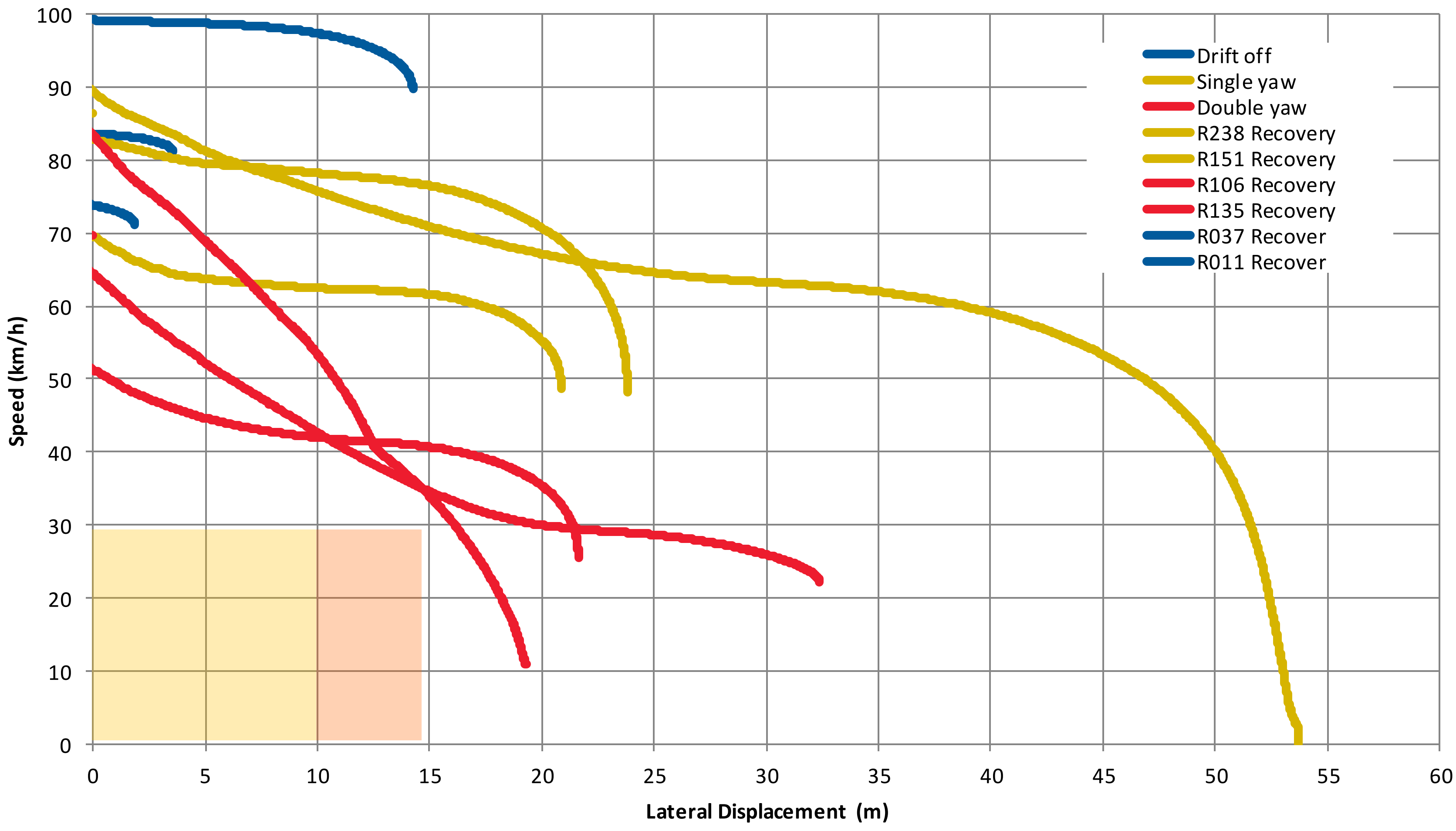
Cumulative distributions of lateral displacements by curve radius category



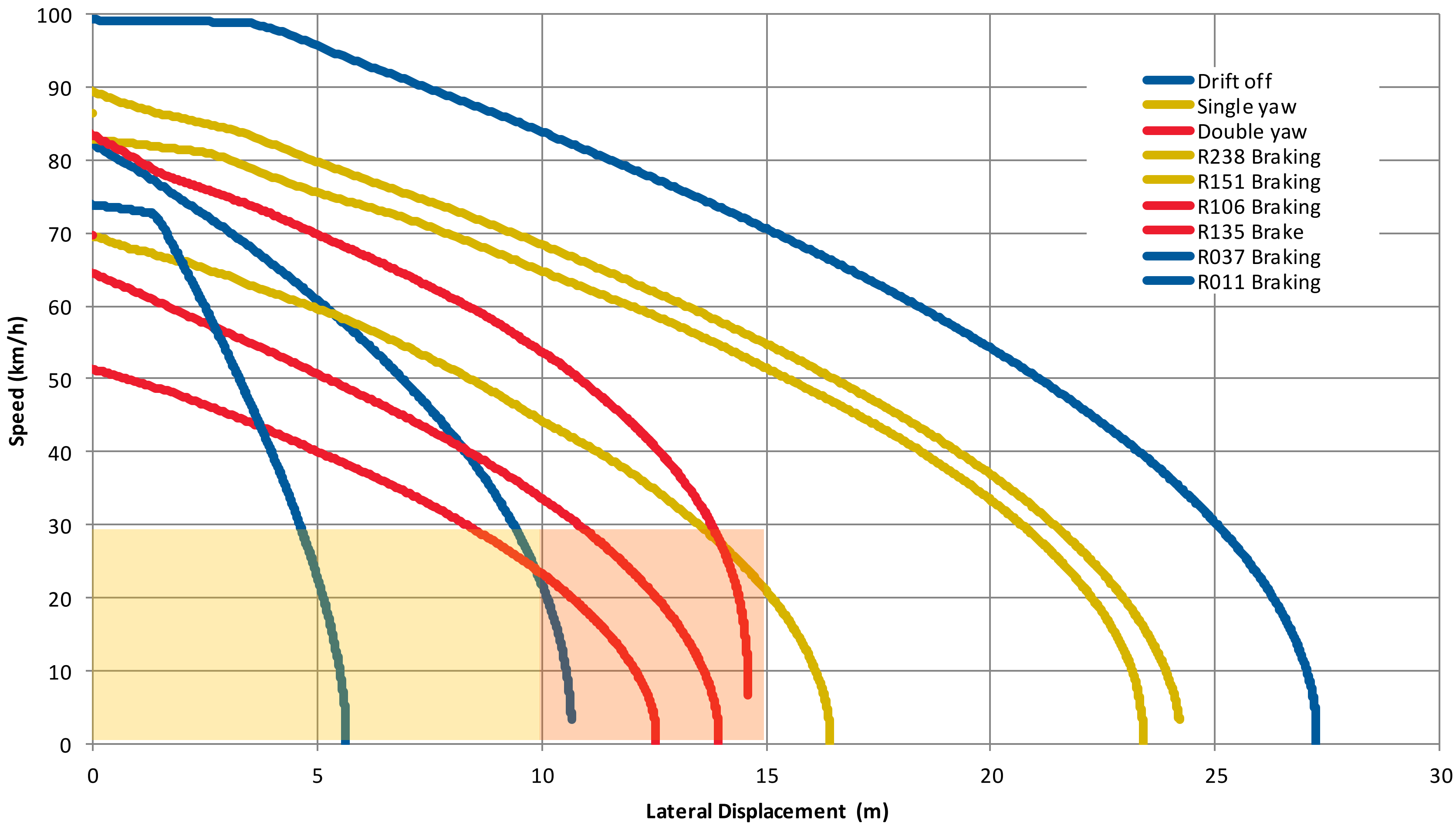
Simulated Cases

Case	Type	Bend direction	Radius (metres)	Departure angle (degrees)	Lateral displacement (metres)	Speed Zone (km/h)	Rollover	Severity
R011	Drift off	Left	44	1	2.3	100	No	Fatal
R037	Drift off	Right	107	16	3.9	100	No	Admitted
R202	Drift off	Right	466	5	5.3	110	No	Admitted
C054	Single yaw	Right	61	13	2.8	100	No	Treated
R151	Single yaw	Left	74	16	3.6	80	No	Treated
R238	Single yaw	Right	373	19	4.5	100	No	Admitted
C031	Double yaw	Right	318	16	11.2	100	Yes	Admitted
R106	Double yaw	Right	133	17	2.9	100	No	Fatal
R135	Double yaw	Left	73	25	9.1	100	Yes	Admitted

Lateral Displacement – Steering input only

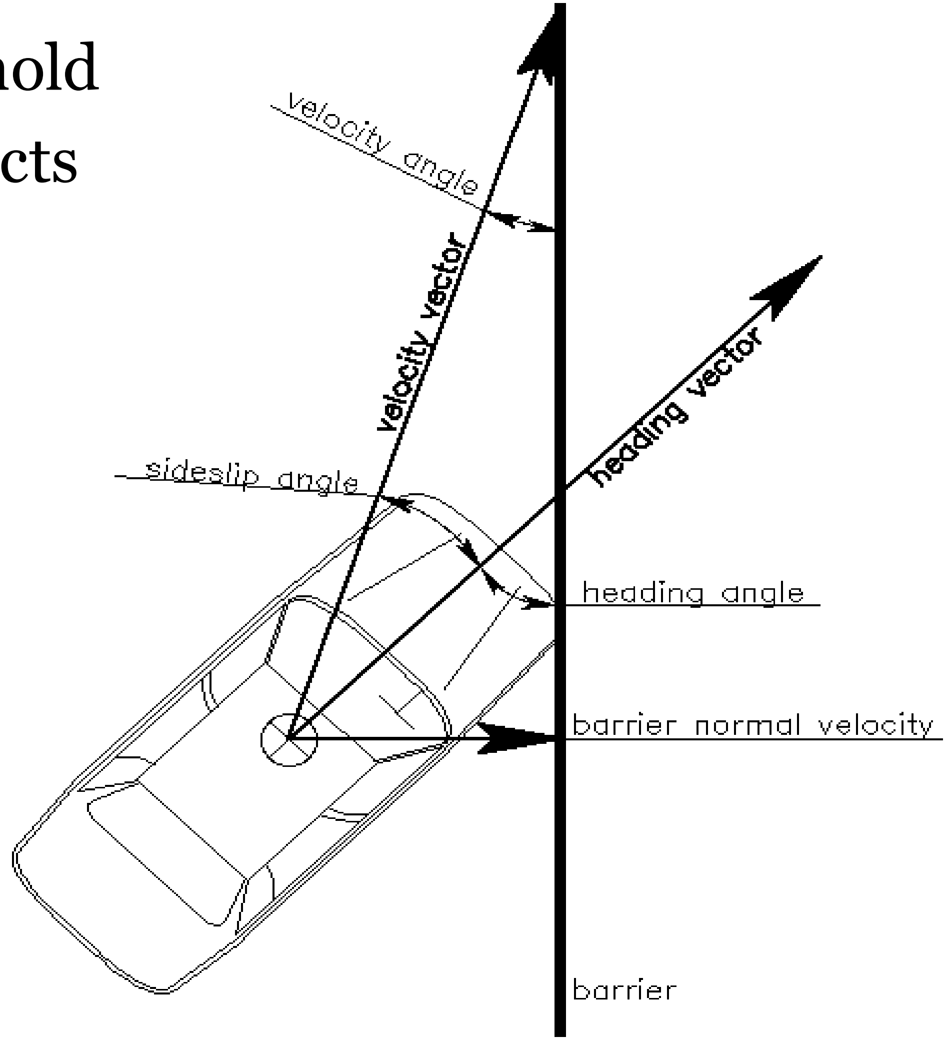


Lateral displacement – Braking only

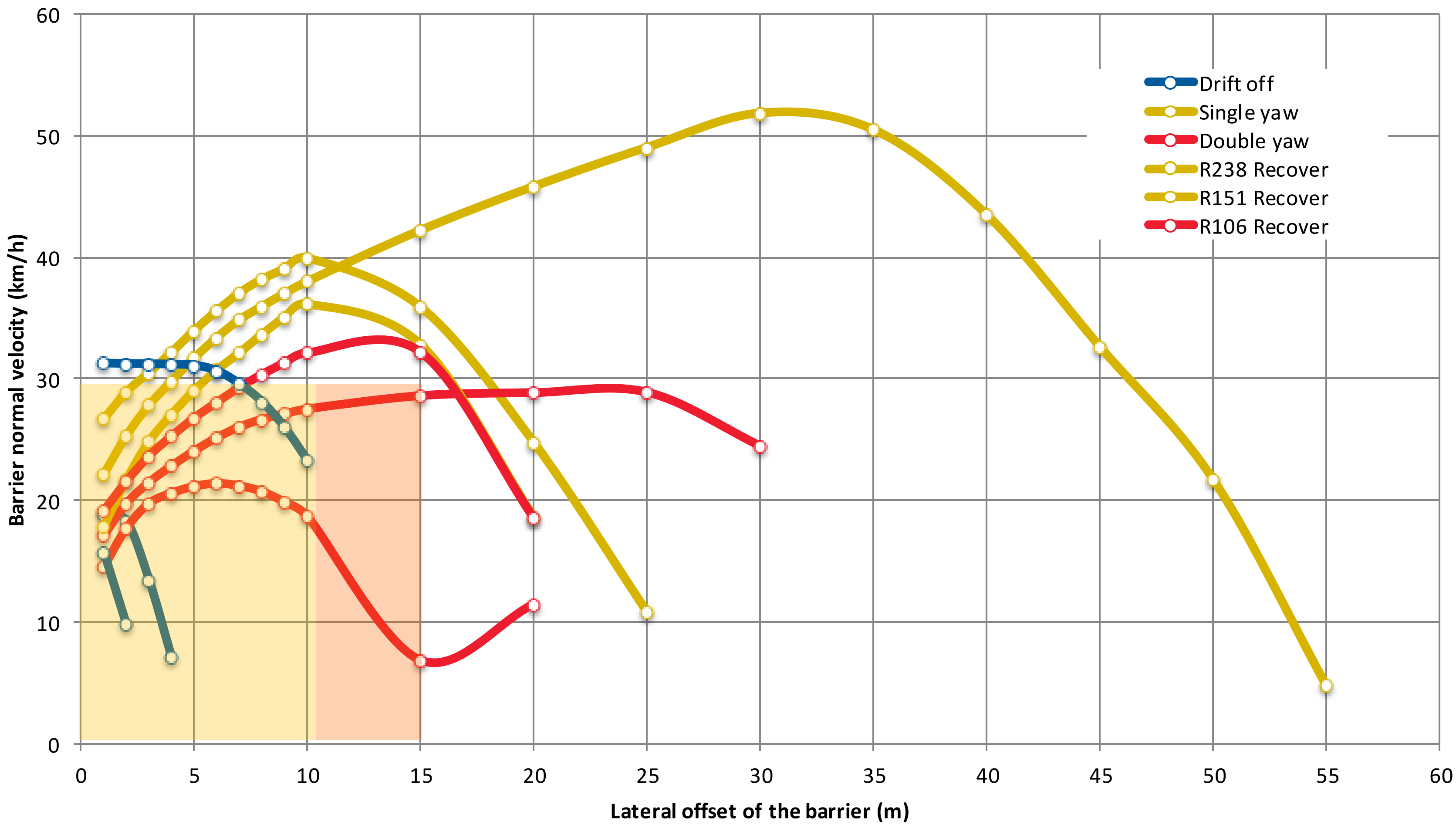


Barrier Normal Velocity

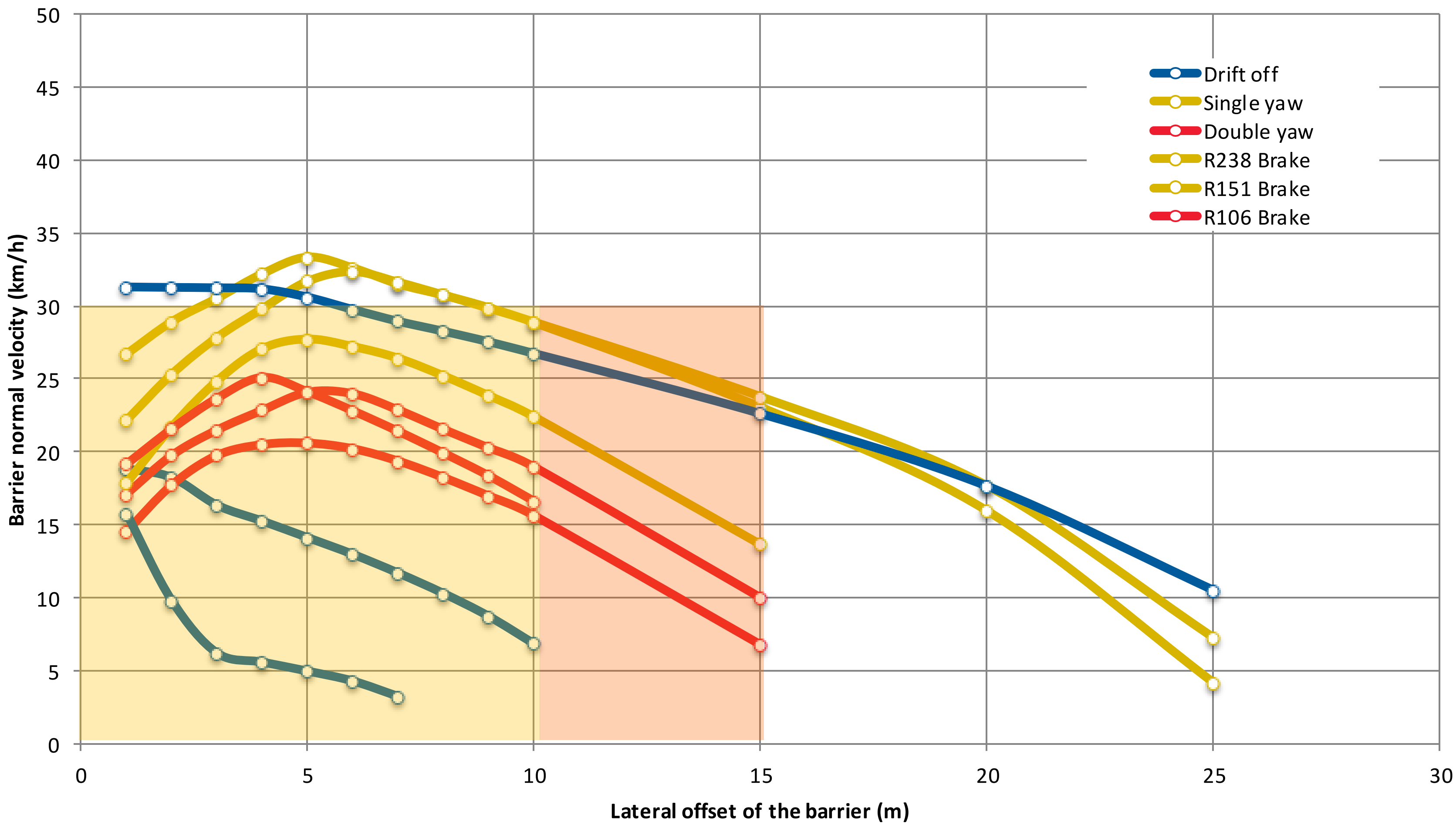
- Proxy for injury threshold
- 30 km/h for side impacts



Barrier normal velocity relative to the lateral offset of the barrier - steering input only



Barrier normal velocity relative to the lateral offset of the barrier - braking input only



Conclusions

- 10m clear zones on curves assist with drift off departures
- Yawing departures not well catered for
- Better off having barriers as close as practicable to edge of road
- Rollovers are a major issue
- Majority of departures beyond apex of curve
- Excessive speed (in terms of exceeding friction demand) did not seem to be a dominant factor in the sample of crashes
- Protection on inside of curves also necessary

Implications

- Providing a clear zone in lieu of barrier protection is not recommended
- Better off having narrower clear zones and using barriers
- Barrier protection needed on inside of curves as well
- Barrier protection length needs consideration on the exit tangents and beyond

Limitations

- Barrier performance under varying impact configurations
- Unsure of proportion of road departure crashes that involve yawing or drift off
- Assumption of level terrain from edge of road
- Representativeness of sample
- Ideally would look at horizontal curve sub categories in more detail as well (simple, reverse, compound, spiral)

Ongoing Work

- Rollover and tripping mechanisms in clear zones
- What level of imperfections can be tolerated in a clear zone?
  - Terrain
  - Cross fall and slopes
  - Hinge points and drop offs

Acknowledgements and disclaimer

- This project was funded the South Australian Department for Planning, Transport and Infrastructure

- The Centre for Automotive Safety Research receives supporting funding from the South Australian Department for Planning, Transport and Infrastructure and the Motor Accident Commission

- The views expressed in this report are those of the presenter and do not necessarily represent those of the University of Adelaide or the funding organisations

- For further information go to:

www.casr.adelaide.edu.au

Acknowledgements and Disclaimer

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Government of South Australia

Department of Planning, Transport and Infrastructure

MAC

Motor Accident Commission

Table 4.1: Clear zone distances from edge of through travelled way

Design speed (km/h)	Design ADT	Clear zone width (m)					
		Fill batter			Cut batter		
		6:1 to flat	4:1 to 5:1	3:1 and steeper(2)	6:1 to flat	4:1 to 5:1	3:1 and steeper(2)
≤ 60	< 750	3.0	3.0	(2)	3.0	3.0	3.0
	750 – 1500	3.5	4.5	(2)	3.5	3.5	3.5
	1501 – 6000	4.5	5.0	(2)	4.5	4.5	4.5
	> 6000	5.0	5.5	(2)	5.0	5.0	5.0
70 – 80	< 750	3.5	4.5	(2)	3.5	3.0	3.0
	750 – 1500	5.0	6.0	(2)	5.0	4.5	3.5
	1501 – 6000	5.5	8.0	(2)	5.5	5.0	4.5
	> 6000	6.5	8.5	(2)	6.5	6.0	5.0
90	< 750	4.5	5.5	(2)	3.5	3.5	3.0
	750 – 1500	5.5	7.5	(2)	5.5	5.0	3.5
	1501 – 6000	6.5	9.0	(2)	6.5	5.5	5.0
	> 6000	7.5	10.0(1)	(2)	7.5	6.5	5.5
100	< 750	5.5	7.5	(2)	5.0	4.5	3.5
	750 – 1500	7.5	10.0(1)	(2)	6.5	5.5	4.5
	1501 – 6000	9.0	12.0(1)	(2)	8.0	6.5	5.5
	> 6000	10.0(1)	13.5(1)	(2)	8.5	8.0	6.5
110	< 750	6.0	8.0	(2)	5.0	5.0	3.5
	750 – 1500	8.0	11.0(1)	(2)	6.5	6.0	5.0
	1501 – 6000	10.0(1)	13.0(1)	(2)	8.5	7.5	6.0
	> 6000	10.5(1)	14.0(1)	(2)	9.0	9.0	7.5

1. Where a site specific investigation indicates a high probability of continuing crashes, or such occurrences are indicated by crash history, the designer may provide clear zone distances greater than the clear zone shown in Table 4.1. A jurisdiction may limit clear zones to 9 m for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.

2. Since recovery is less likely on the unshielded, traversable 3:1 slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of the slope. Determination of the recovery area at the toe of the slope should take into consideration available road reservation, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the travelled lane and the beginning of the 3:1 slope should influence the recovery area provided at the toe of the slope. While the application may be limited by several factors, the fill slope parameters which may enter into determining a maximum desirable recovery area are illustrated in Figure 4.4.

Notes:

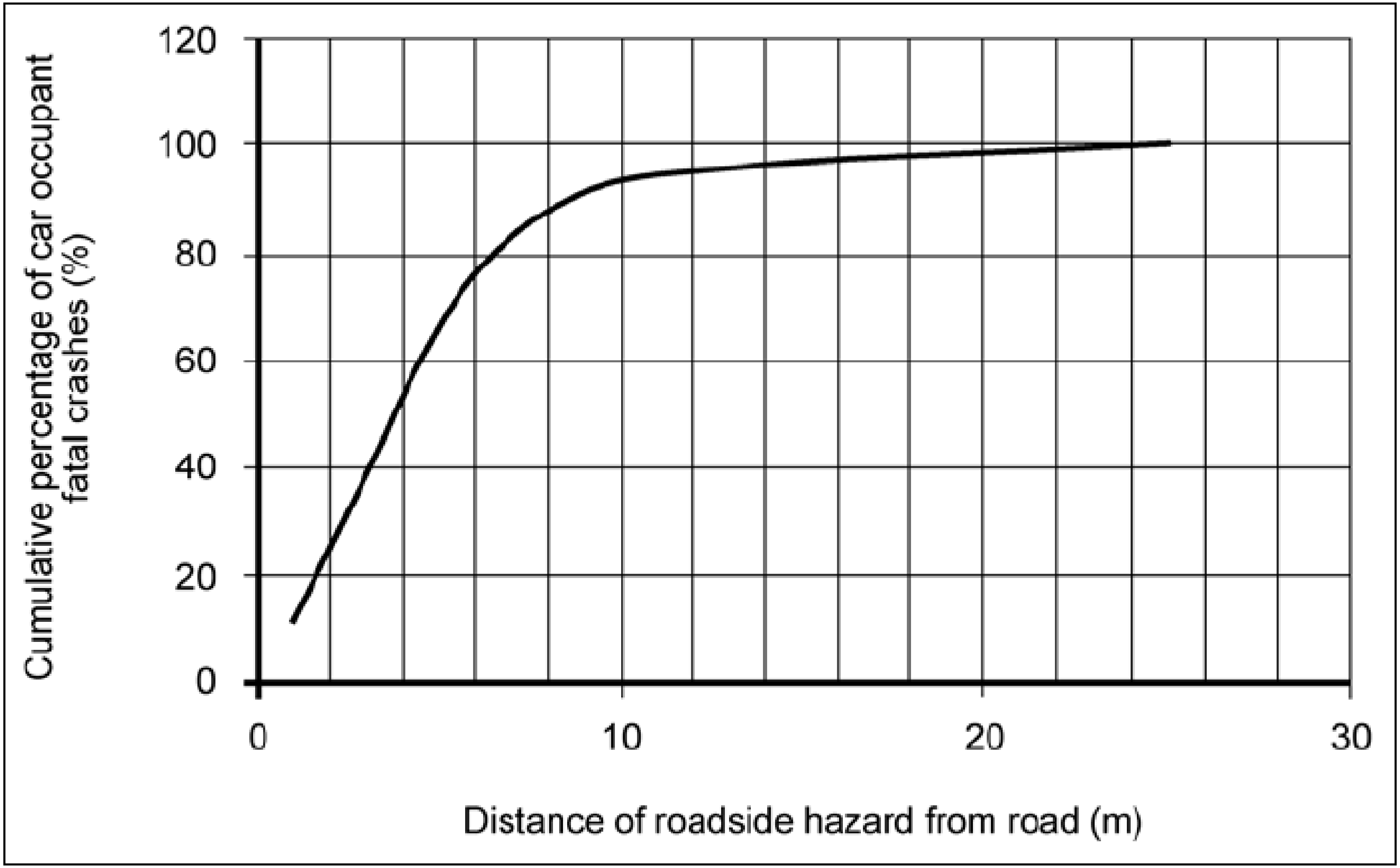
The design ADT in the table is the average daily traffic volume in both directions and in all lanes, other than for divided roads where it is the total traffic in all lanes in one direction.

Where the road is curved the values in Table 4.1 should be adjusted by the curve correction factors in Table 4.2.

The RTA New South Wales uses a similar approach based on a hazard corridor and with curve adjustments included rather than ADT (Appendix C). For the same situation the RTA method results in greater clear zones than those shown in Table 4.1.

Source: Adapted from AASHTO (2006).

Kloeden and McLean 1999



Departure Speeds vs Design Speeds