ROAD GEOMETRY AND DRIVERS SPEED CHOICE

Presented to: IPENZ Transportation Group Technical Conf 2007

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Date: 10 October session L2

Background

- **CAS 2001 to 2005**
  - 21,101 rural injury crashes
  - 45% (9,636) lost control/head-on curve related injury crashes
- **Speed**
  - Single biggest contributory factor
  - Identified in 37%
- ***So why do drivers make inappropriate speed choices and/or lose control on curves?***

How Do Drivers Know What is Appropriate

- *Generally, drivers make fewer errors at geometric features that conform with their expectations than at features that violate their a priori and/or ad hoc expectancies.*

- *If a road is consistent in design, then the road should not violate the expectations of motorists or inhibit the ability of motorists to control their vehicle safely*.

- *Consistent roadway design should ensure that "most drivers would be able to operate safely at their desired speed along the entire alignment.*

Woodridge et al 1999

Previous Studies

- **Jackett (1992)**
  - Strong Positive Relationship Between
  - Curve related crashes (loss of control/head-on)/1,000,000 veh.
  - Difference between Ball Bank Curve Speed and Approach Speed

- **Koorey and Tate (1997)**

$$ASRGDAS = -\left(\frac{107.95}{H}\right) + \sqrt{\left(\frac{107.95}{H}\right)^2 + \left[\frac{127{,}000}{H}\right]\left[0.3 + \frac{X}{100}\right]}$$

where

ASRGDAS = RGDAS Advisory Speed (km/h)

X = % Crossfall (sign relative to curvature)

H =Absolute Curvature (rad/km) = (1000/Radius in metres)

Objectives

- **To Investigate:**
  - *What influences drivers speed choice on a particular curve?*
  - *What will be the likely impact of differences between a driver's expectation of a safe travel speed and the "safe negotiation speed"?*
- **Will Allow**
  - *The benefits of other treatments*
  - *Impact of modifying drivers' speed choices.*

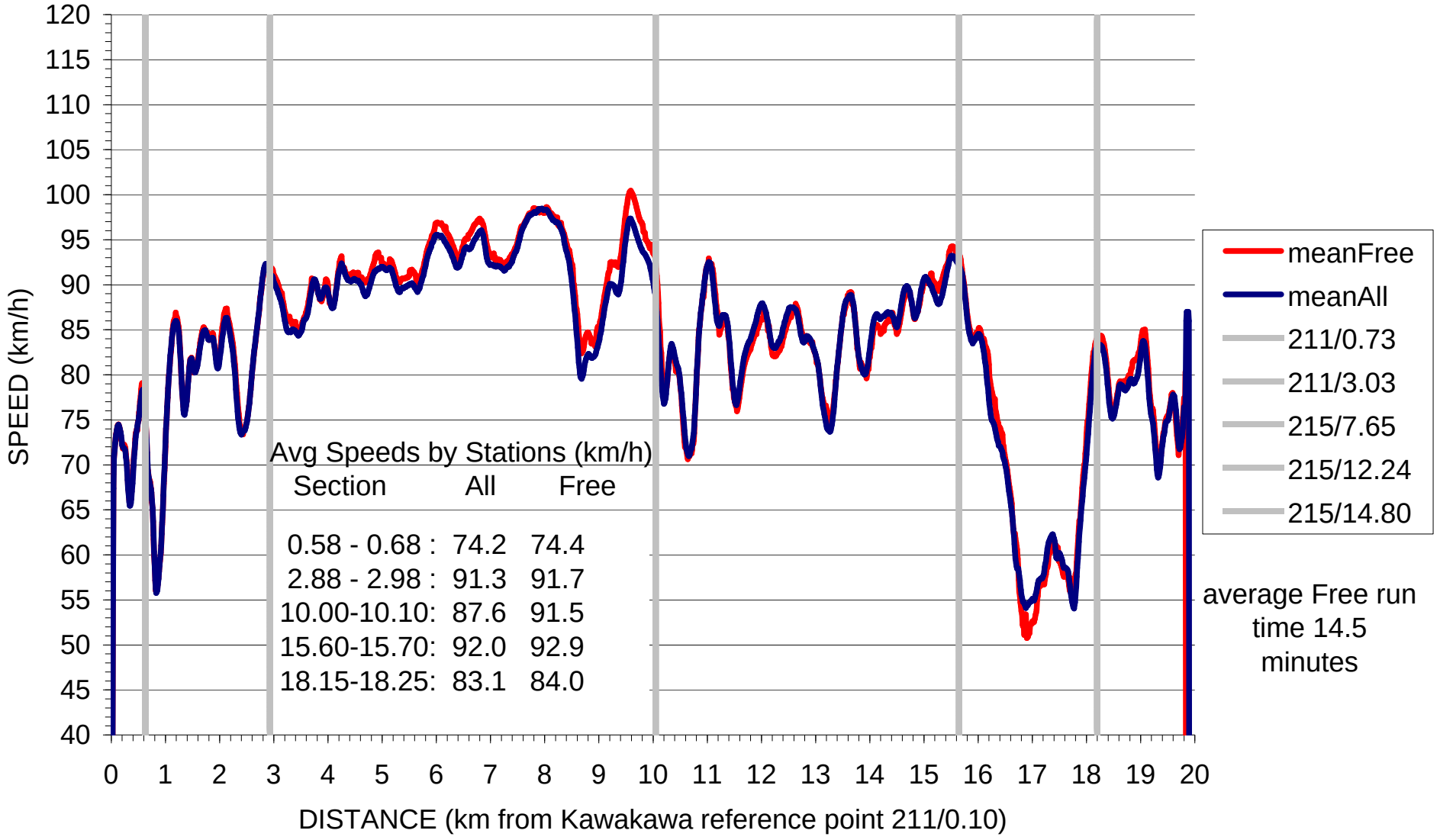
Approach

- 6 nominally 20km sections of state highway
- Driven 4 times by 12 drivers using
- Instrumented vehicle >> speed profiles
- Profiles “cleaned” and mean profile develoepd
- Profiles adjusted to reflect 85%ile speed
- Speed matched to road geometry data
- Crashes matched to road geometry and speeds

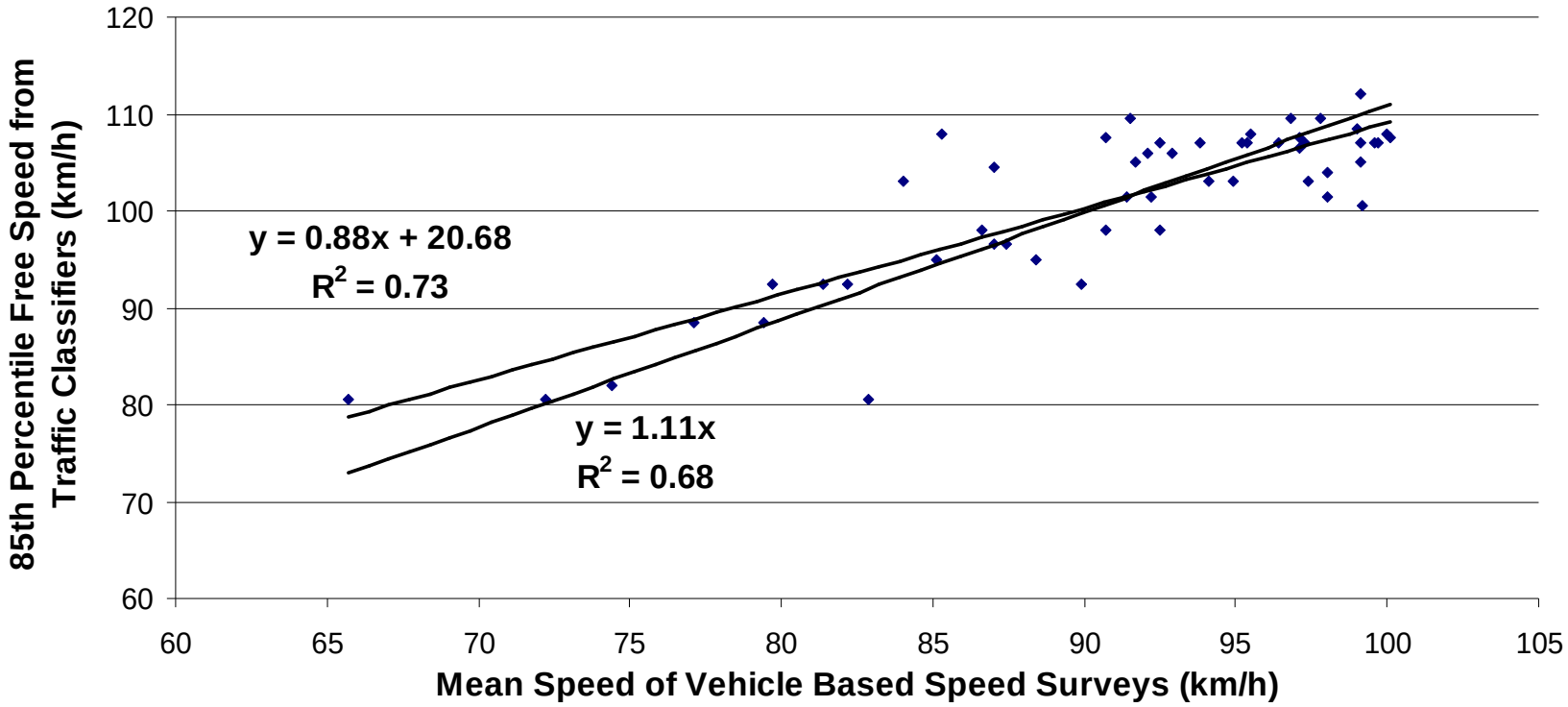
Sites

Location		AADT	Length (km)	Curve Crashes		All Loss of Control	
				Injury	Non Injury	Injury	Non Injury
1	Whangarei North	5640	19.8	13	8	32	47
2	Whangarei South	10430	25.5	29	43	48	77
3	Wanganui-Turikina	7850	19.8	23	32	29	54
4	Turikina-Bulls	5500	20.0	7	17	16	33
5	South Blenheim	3250	21.0	18	21	22	25
6	SH 75	2850	25.5	8	22	10	26
Total			131.6	98	143	157	262

- ***Limited***
  - *Day/night (25%-45%)*
  - *Wet/dry (25%-45%)*
  - *AADT (3,000 – 10,000*
- ***488 curves***


SPEED (km/h)
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
DISTANCE (km from Kawakawa reference point 211/0.10)
Avg Speeds by Stations (km/h)
Section All Free
0.58 - 0.68 : 74.2 74.4
2.88 - 2.98 : 91.3 91.7
10.00-10.10: 87.6 91.5
15.60-15.70: 92.0 92.9
18.15-18.25: 83.1 84.0
meanFree
meanAll
211/0.73
211/3.03
215/7.65
215/12.24
215/14.80
average Free run time 14.5 minutes

Speed Profiles v 85 %ile Speeds



$S_{85} = 12.428 + 0.968\ V_{mean} + 5.946L_1 - 2.966L_5$ R sq'd =0.84

Where

S_{85} = the 85th percentile speed of all free vehicles

V_{mean} = the mean speed of vehicle based surveys

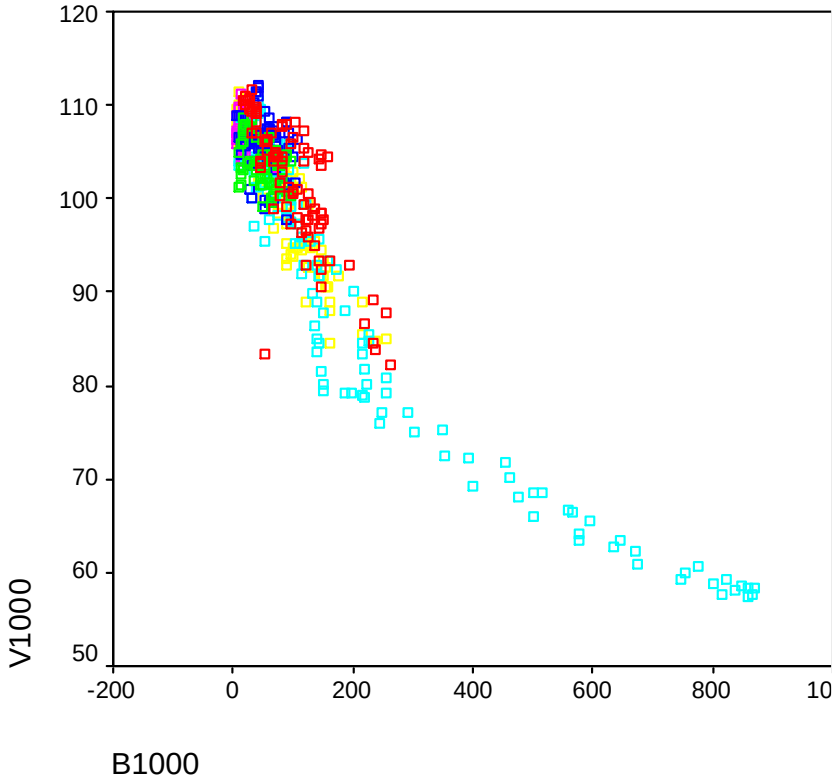
L_x = 1 if the location of the survey is Location 1 or Location 5 else 0

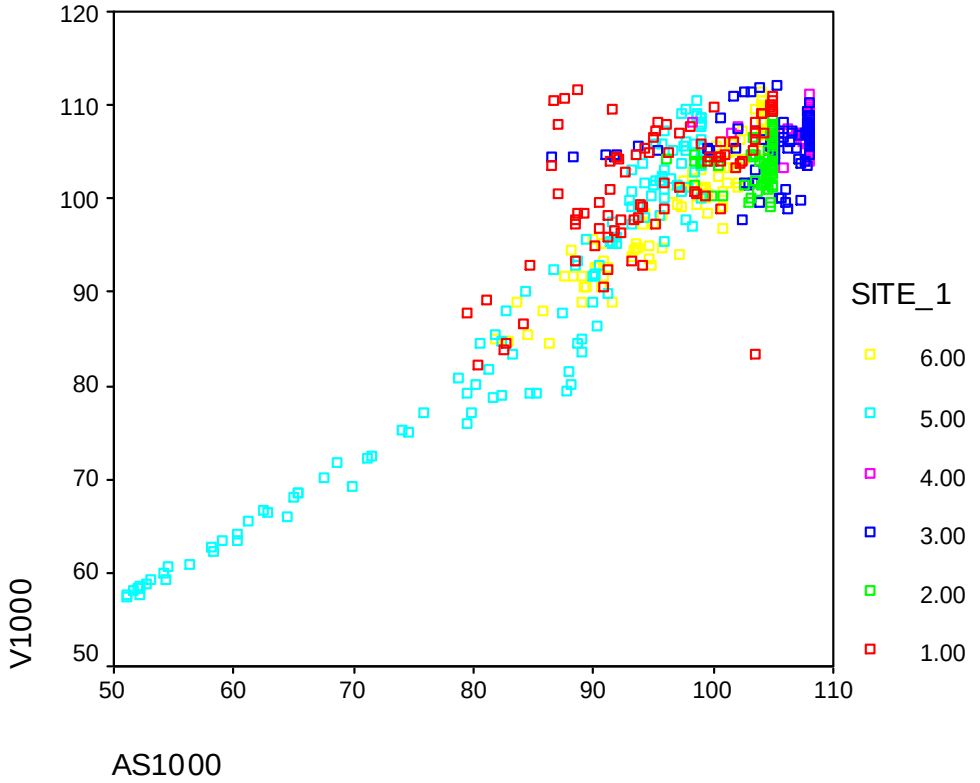
Analysis

- **What is the best predictor of operating speed environment?**
- **Which geometric elements determine curve negotiation speed?**
- **What are the safety impacts of inappropriate curve negotiation speeds?**

Speed Environment

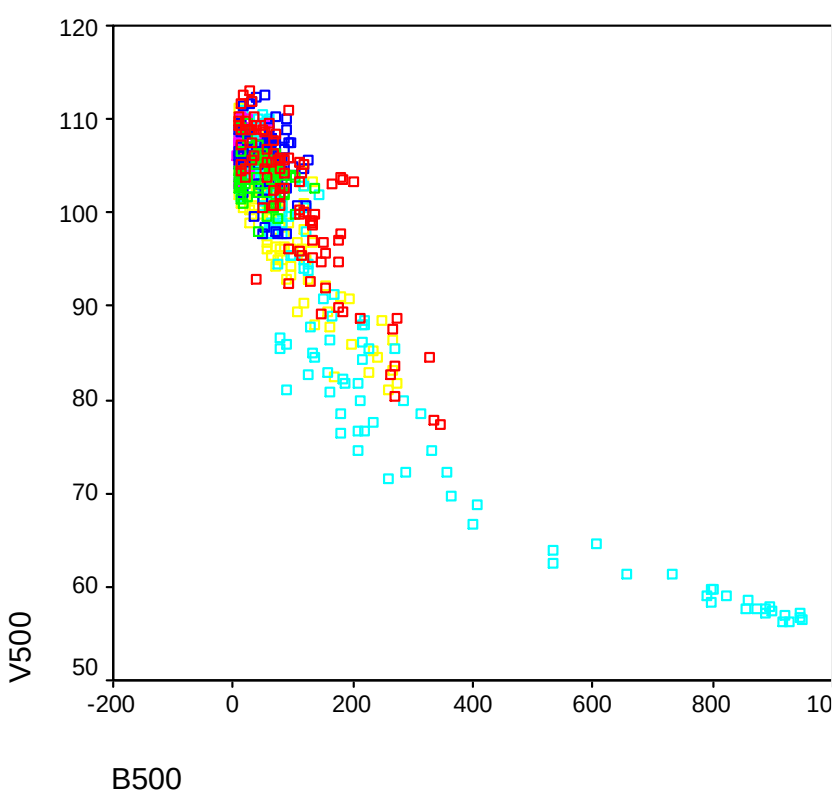
Dependant Variable (Y)	Independent Variable (X)	Model Form	a	b	c	R^2
V_{1000}	B_{1000}	$Y=aX^2+bX+c$	0.000075	-0.124	110.425	0.89
V_{1000}	As_{1000}	$Y=cX^b$	1.8347	0.873		0.88

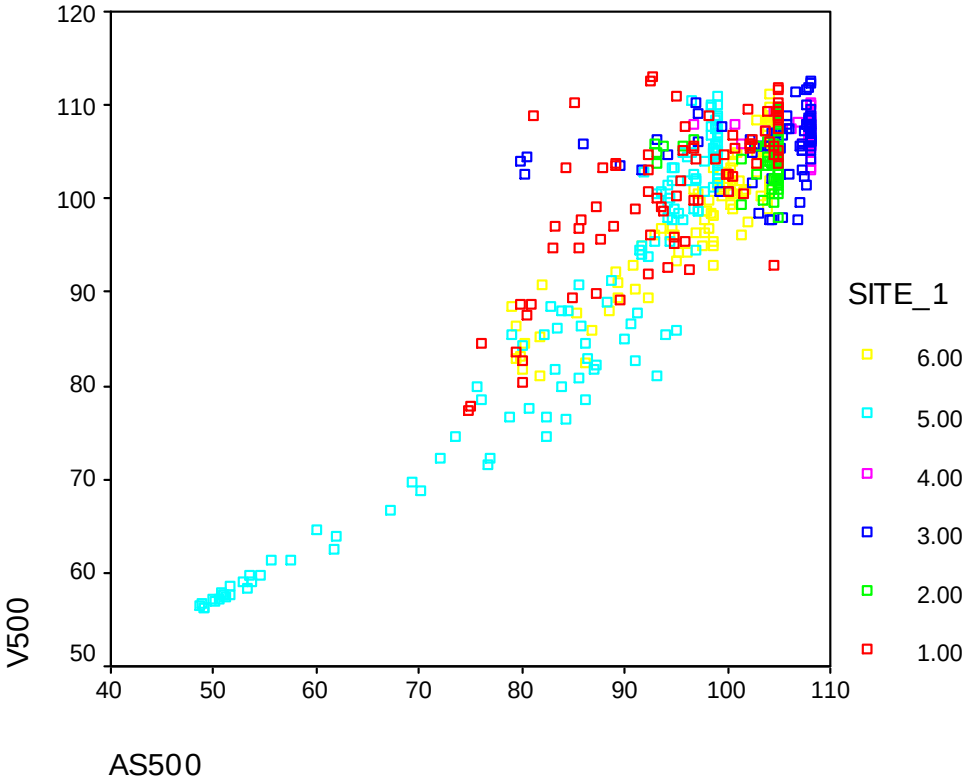




Speed Environment

Dependant Variable (Y)	Independent Variable (X)	Model Form	a	b	c	R^2
V_{500}	B_{500}	$Y=aX^2+bX+c$	0.000066	-0.118	109.565	0.86
V_{500}	AS_{500}	$Y=cX^b$	2.1019	0.843		0.86





Curve Negotiation Speed

- **Range of variables tested**
  - Estimated 85 %ile speed
  - Mean, minimum, minimum over 30m
  - Design speed, deflection and length, AS,
  - Radius –best model

$$V_c = e^{(4.7142 - 26.736/R)}$$

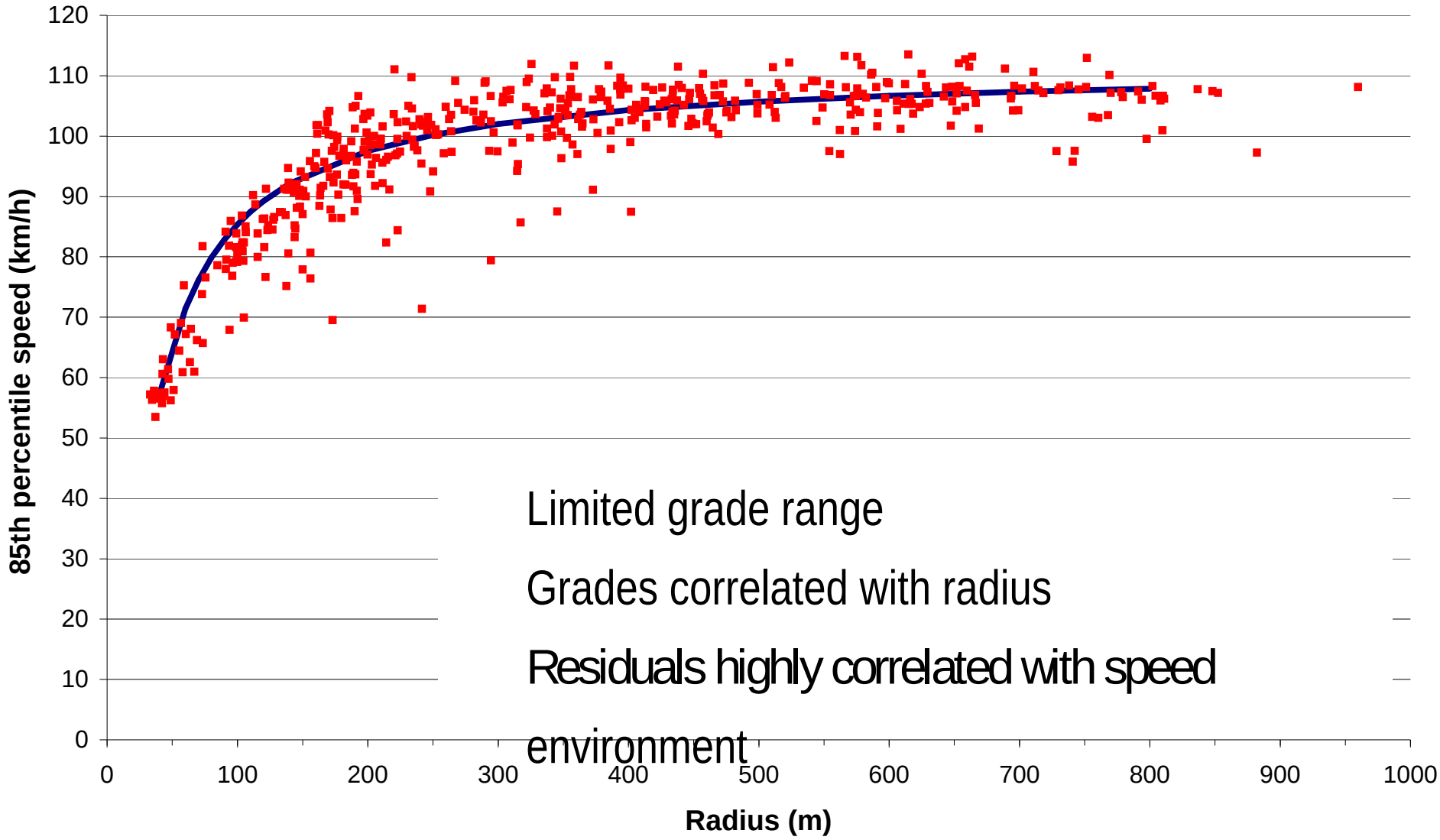
Where

V_c = 85th percentile speed around the curve (km/h)

R = the minimum radius of the curve (m)

Adjusted R^2	df regression (residual)	F	Model Parameters				
			Terms	Coefficients	Std. Error	t	Sig.
0.853	1 (483)	2801.4	(Constant)	4.7142	0.0036	1299	.000
			Coefficient B	-26.736	0.5017	-55.64	.000

Radius Negotiation Speed



Curve Negotiation Speed
Improved Model

$$V_c = -24.967 + 0.397V_{500} + 0.741e^{(4.7142 - 26.736/R)}$$

Where

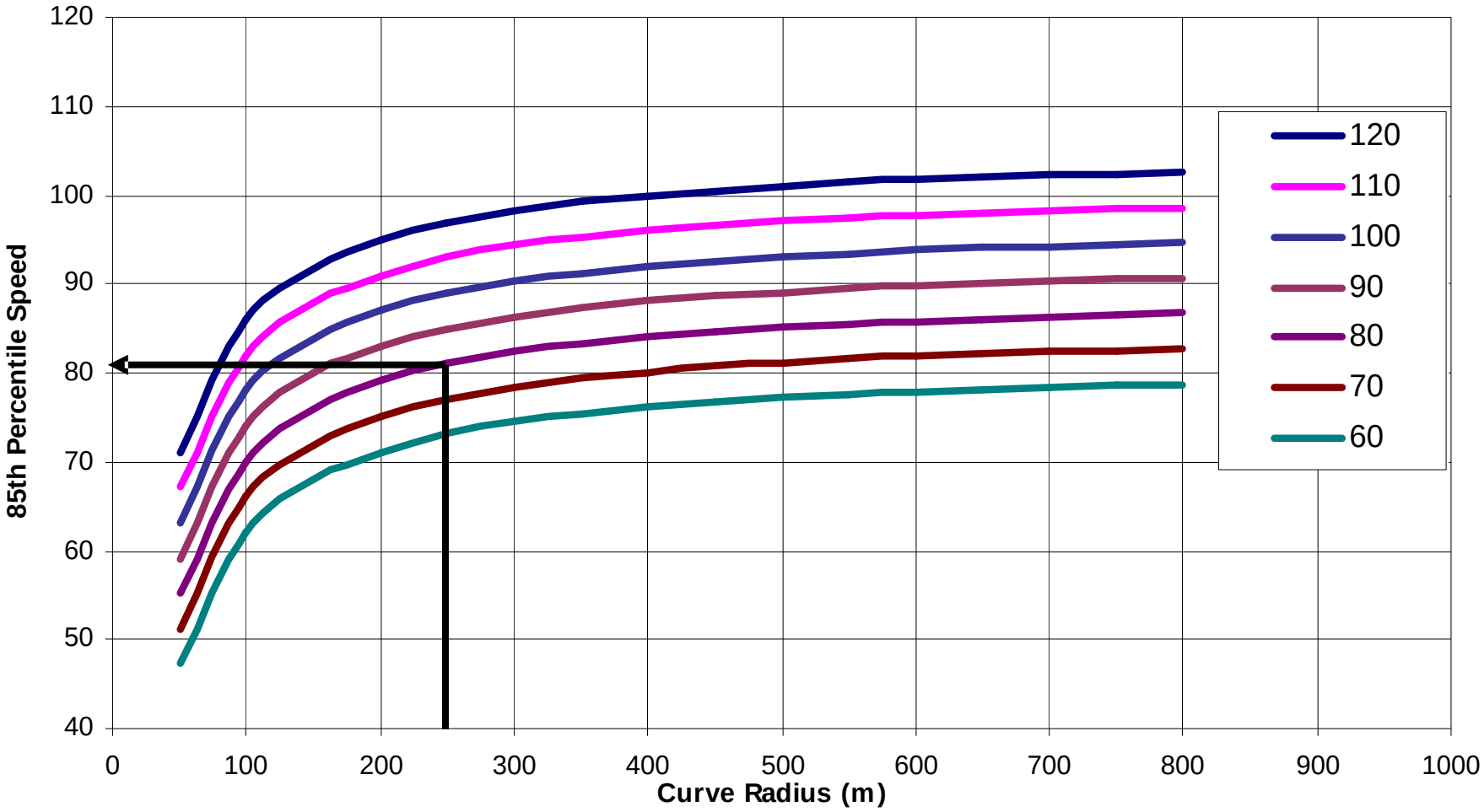
V_c = the average 85th percentile speed around the curve (km/h)
V_{500} = the average 85th percentile speed over the previous 500m (km/h)
R = the minimum radius of the curve (m)

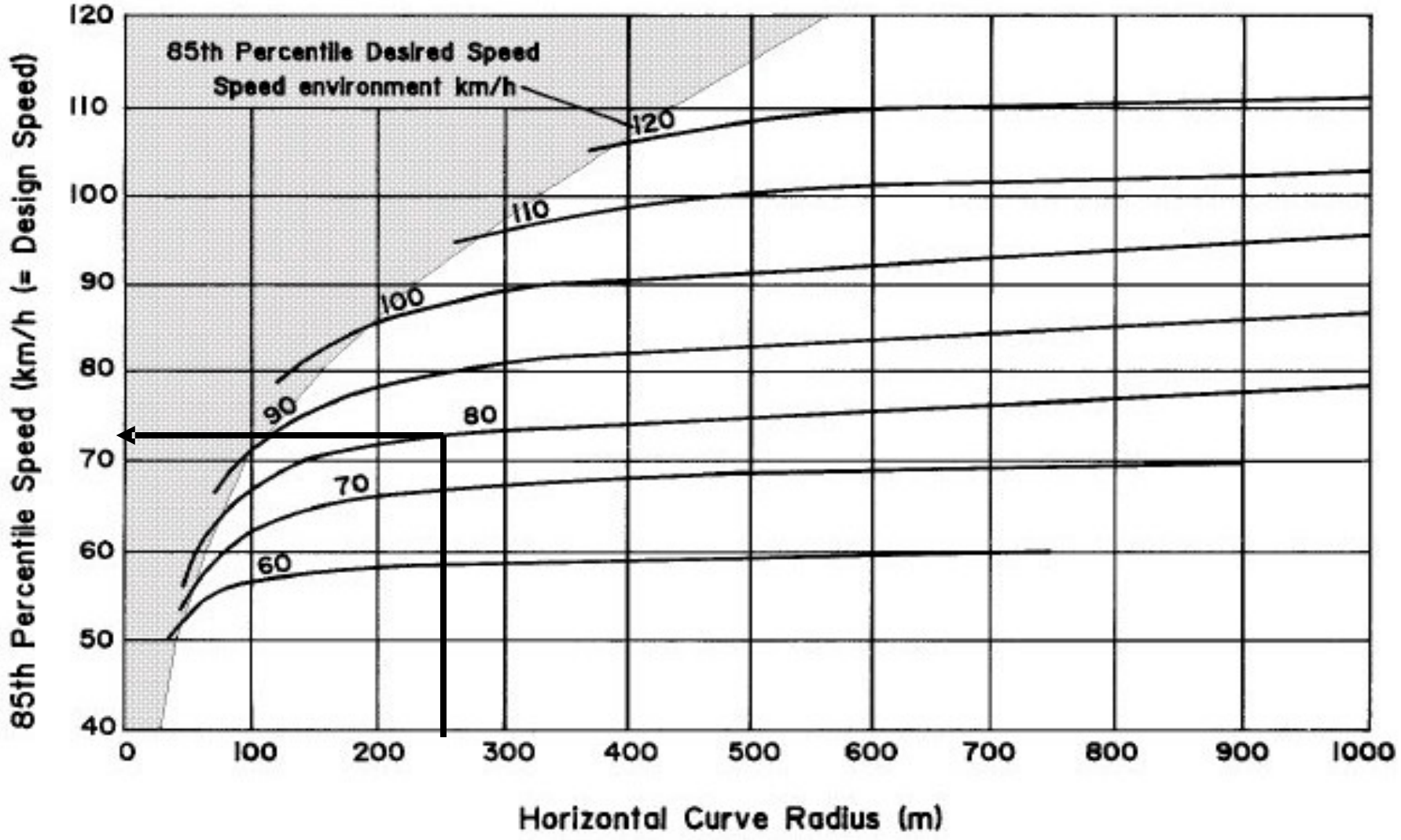
Adjusted R^2	Deg.free. regression (residual)	F	Model Parameters				
			Terms	Coefficients	Std. Error	t	Sig.
0.904	2 (482)	2279	(Constant)	-24.967	1.665	-14.996	.00
			$e^{(4.7142 - 26.736/R)}$	.741	.026	28.537	.00
			V_{500}	.397	.025	16.103	.00

$$V_{500} = 0.000066(B_{500})^2 - 0.1179\ B_{500} + 109.565 \quad \text{for } 8 < B_{500} < 900$$

OR

$$V_{500} = 2.1019(AS_{500})^{0.8432}$$


120
110
100
90
80
70
60
50
40
85th Percentile Speed
0
100
200
300
400
500
600
700
800
900
1000
Curve Radius (m)
120
110
100
90
80
70
60


85th Percentile Desired Speed
Speed environment km/h
120
110
100
90
80
70
60
85th Percentile Speed (km/h (= Design Speed)
120
110
100
90
80
70
60
50
40
0
100
200
300
400
500
600
700
800
900
1000
Horizontal Curve Radius (m)

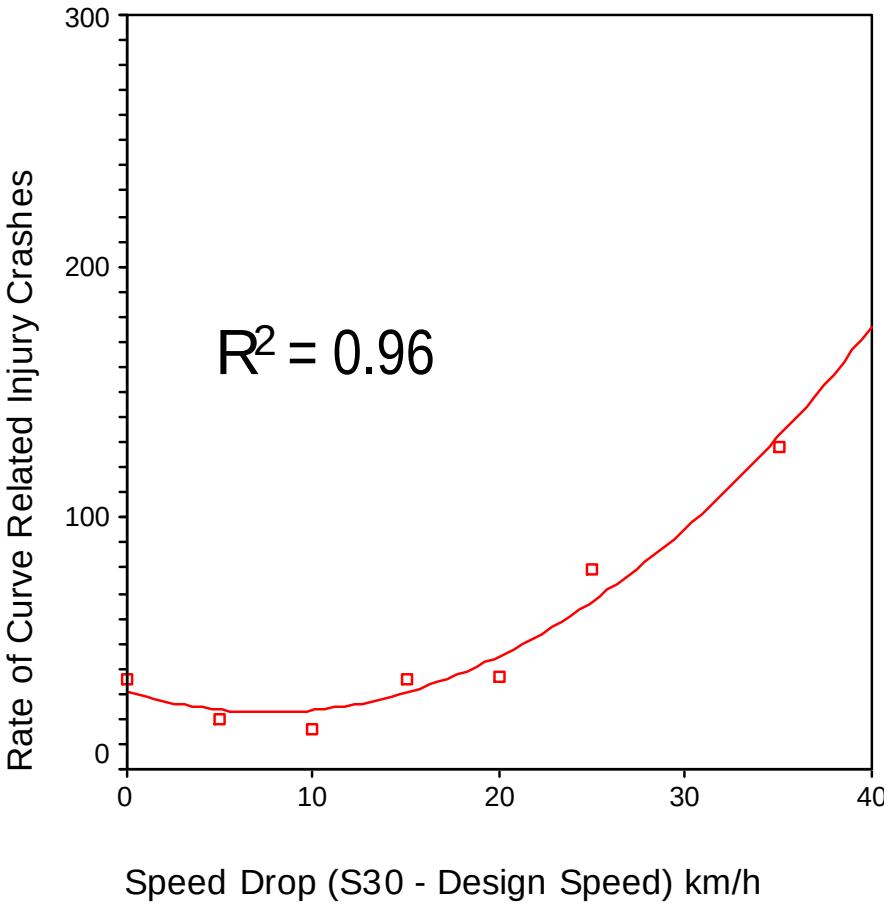
Crashes Considered

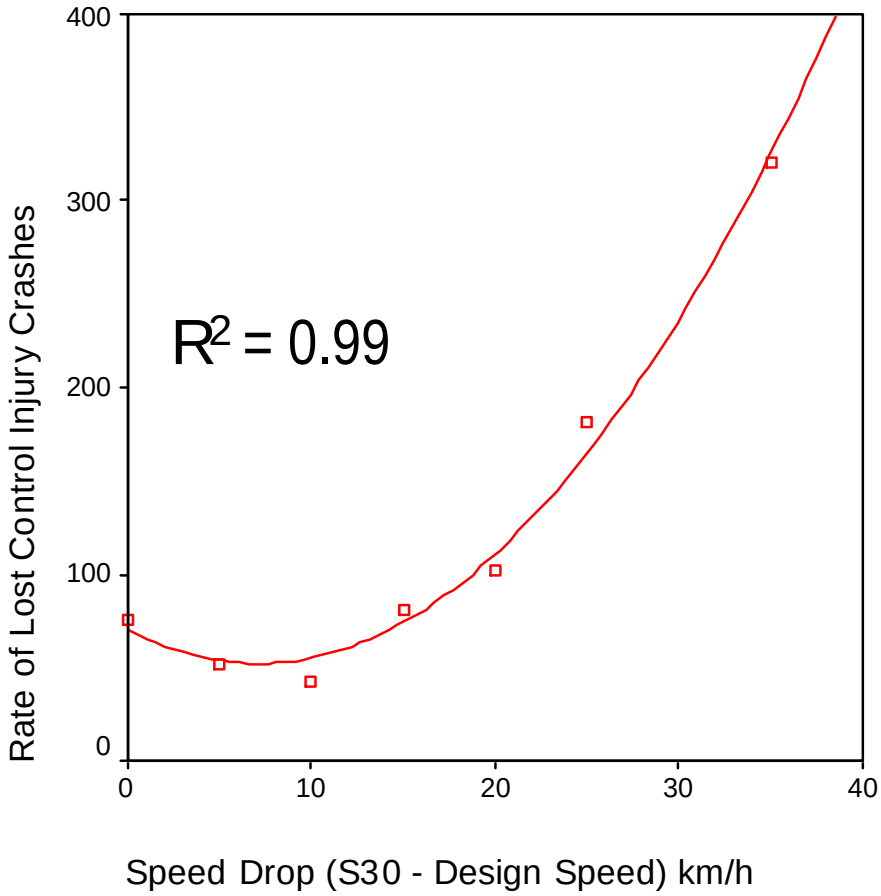
Crash Set	Crash Movements
Curve related crashes	BB BC BD BF DA DB 
All loss of control and head-on crashes	BA BB BC BD BE BF  CA CB CC DA DB 

- **Crashes Matched to Alignment**
  - By direction
  - Nearest upstream curve
  - Straight lost-control associated with curve if close

Crash Implications (1)

- **Aggregate on basis of speed drop**
- **Crash rate crashes/100 million VKT**
- **Best relationships use reported injury crashes**





Conclusions

- **Speed environment best defined by Bendiness deg/km**
- **Curve negotiation speed most effected by**
  - curve radius
    preceding alignment
- **Current SHGDM under predicts likely curve negotiation speed (<100km/h)**
- **It appears crashes rise rapidly once speed difference is above 15 to 20 km/h**
- **Larger sample or better modelling needed to confirm this**

Acknowledgements

- **Dr Shane Turner Beca**
  Co Author

- **Land Transport New Zealand**
  Project Funder
  Note however the views presented here are solely those of the author and not those of Land Transport New Zealand

- **The subjects who took part in the project**