DEVELOPING A RISK PREDICTION MODEL FOR A SAFE SYSTEM SIGNATURE PROJECT

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ABSTRACT

The Safer Journeys Action Plan 2013-2015 identifies safe system signature projects as a strategic action to achieve the Safer Journeys vision. The rural roads of the Eastern Bay of Plenty (EBoP) region were identified as an area where a signature project has the potential to make demonstrable advances in reducing road trauma for all road users.

This paper describes a GIS-based curve risk prediction model that has been developed as part of the EBoP signature project. This included the development of methodology that uses GIS to identify curves, predict vehicle operating speeds along road corridors, and assess curve risk using approach speeds and radius. The results of this methdology display a high correlation between high risk curves and the occurance of loss-of-control crashes.

The outputs of this project include the ‘SignatureNET’ web viewer, a tool that enables all the signature project partners to view road safety data and make well-informed road safety investment decisions. This tool can be rolled out across other regions using existing GIS data and methdologies, and will be of interest to road controlling authorities wanting to target loss-of-control crashes on rural roads. Both the web viewer and curve assessment methodology also demonstrate that innovative assessment methods and tools can be developed within a safe systems signature project environment.

INTRODUCTION

Safer Journeys, New Zealand's Road Safety Strategy 2010-20 has a vision to provide a safe road system increasingly free of death and serious injury (MoT, 2010). This Strategy adopts a safe system approach to road safety focused on creating safe roads, safe speeds, safe vehicles and safe road use. These four safe system pillars need to come together if the Government's vision for road safety is to be achieved.

Safe system signature projects are identified in the Safer Journeys Action Plan 2013-2015 (NZTA, 2013) as exemplar projects that adopt a complete safe system approach to road safety. Safe systems signature projects provide a platform for trialling innovative approaches and treatments across the four safe system pillars.

The Eastern Bay of Plenty (EBoP) region (Figure 1) was identified as a candidate for a safe systems signature project as it is a region with significant rural road safety issues; particularly speed, use of alcohol/drugs, poor restraint use and inexperienced drivers. The scope of the project includes rural State Highways and local roads. Most EBoP roads are low volume remote roads, where crashes tend to be sporadic and difficult to predict using reactive crash prediction models. Therefore a new approach to assessing road risk, independent of crash history, was required.

Abley Transportation Consultants was commissioned by the New Zealand Transport Agency (the Transport Agency) to develop a risk prediction model and mapping interface "SignatureNET" to support the delivery of this signature project. This included building a vehicle speed model to identify high risk curves, assessing road risk using the urban KiwiRAP risk mapping methodology (Brodie et al, 2013), and applying rural road risk prediction models.

Figure 1 - Eastern Bay of Plenty region

VEHICLE SPEED MODEL AND IDENTIFICATION OF HIGH RISK CURVES

Many rural road crashes in EBoP occur on curves (57.9% of all fatal and serious rural road crashes 2004-2013). Due to the remote nature of the region's roads, fatal and serious crashes tend to occur on parts of the network where high-severity crashes have not occurred in the recent past. In these areas, relying on crash history alone to predict where future crashes will occur is unreliable. A new methodology that could identify and assess the risk of all the curves on the network that was independent of crash history was developed.

The Austroads (2009) operating speed model for rural roads provides a procedure for calculating speeds along road sections based on the geometric features of the road. Using calculated speeds and horizontal curve radii, the model allows users to assess the design limit of curves.

With 1500 km of rural road, manually assessing the risk of each curve in the EBoP region using the Austroads model would be time-consuming and cost-prohibitive. As the inputs to the Austroads operating speed model are available in a spatial format, the model was therefore automated using a new Geographic Information Systems (GIS) methodology. This included the development of GIS models that identify curves, predict vehicle operating speeds along road corridors, and assess curve risk using approach speeds and radius.

Data requirements

The analysis relied on a number of road and environmental datasets. The most important dataset was a high-quality road centreline sourced from a third-party data supplier. This dataset closely represented actual road alignment and could be used to accurately identify curves and calculate curve radii.

Other road datasets, including Road Assessment and Management (RAMM), were used to extract road characteristics including surface type, carriageway width and ADT. A digital elevation model (DEM) with 15 metre resolution (University of Otago - National School of Surveying, 2011) was used to extract terrain using advanced analysis in GIS. Crash data from the Crash Analysis System (CAS) was used for risk mapping and speed model validation.

Data preparation

The first step in preparing the data for speed modelling was extracting the rural roads and identifying unique corridors that replicated unimpeded travel along a road corridor. Corridors could only be 'broken' where vehicles would be required to slow or stop at an intersection, or meet an urban boundary (Figure 2). The start speed for each road corridor was then estimated according to the start context (Table 1).

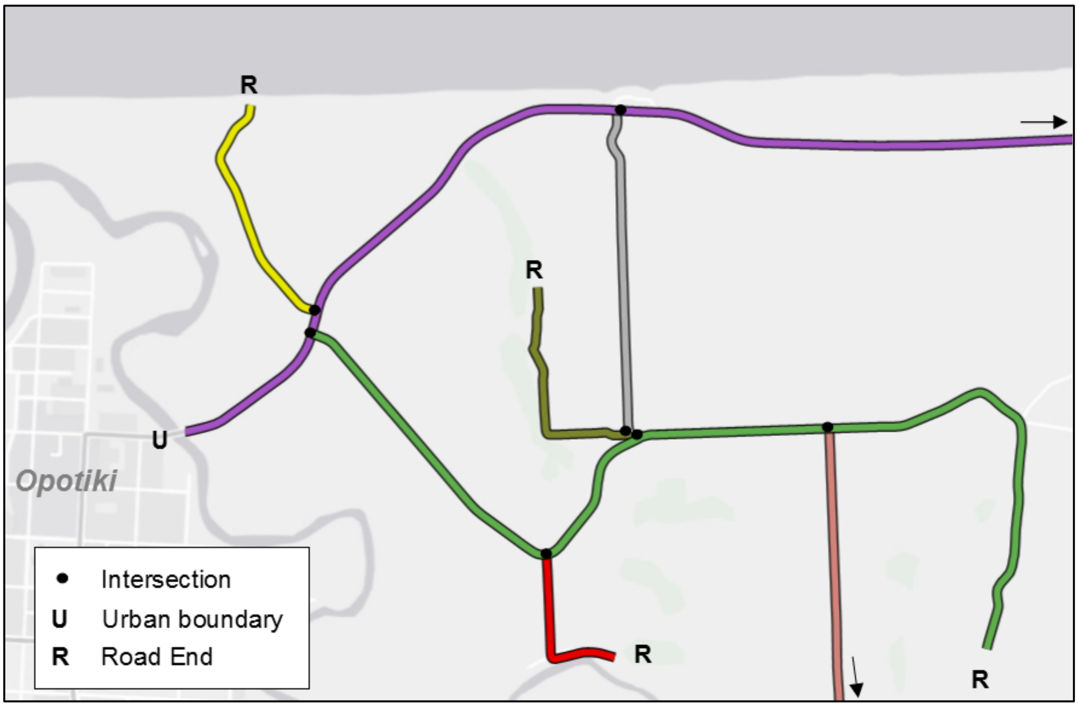

Figure 2: Corridor example

Corridor start context	**Start speed**
Intersection	20 km/h
Road end	20 km/h
Urban boundary	50 km/h
Outside the study area	Maximum speed (see below)

Table 1: Corridor start speeds by context

The maximum speed on any road was calculated as a function of curvature and terrain (Table 2). These values are based on the desired speeds in Austroads (2009) – the maximum speed regarded as acceptable to most drivers for the particular environment.

		Terrain (and grade %)			
Curvature		**Flat** (< 2%)	**Undulating** (2-4%)	**Hilly** (5-7%)	**Mountainous** (>=8%)
	Straight	110 km/h	110 km/h	95 km/h	90 km/h
	Curved	110 km/h	100 km/h	95 km/h	90 km/h
	Winding	90 km/h	90 km/h	85 km/h	80 km/h
	Tortuous	75 km/h	75 km/h	75 km/h	70 km/h

Table 2: Maximum speed by curvature and terrain

Curvature data, measured as degrees of turn per kilometre, was provided by the Transport Agency with the centreline dataset. Terrain (flat, undulating, hilly, mountainous) was calculated using geospatial analysis and the digital elevation model. For each 10m of road, raw grade was calculated over 100m and an average grade calculated over 1000m.

Curve identification

Curves were identified by adapting the methodology in Cenek et al. (2011). Using GIS linear referencing tools, the road centreline was divided into 10m sections and the rolling 30m average radius calculated for each arc section, as demonstrated in Figure 3.

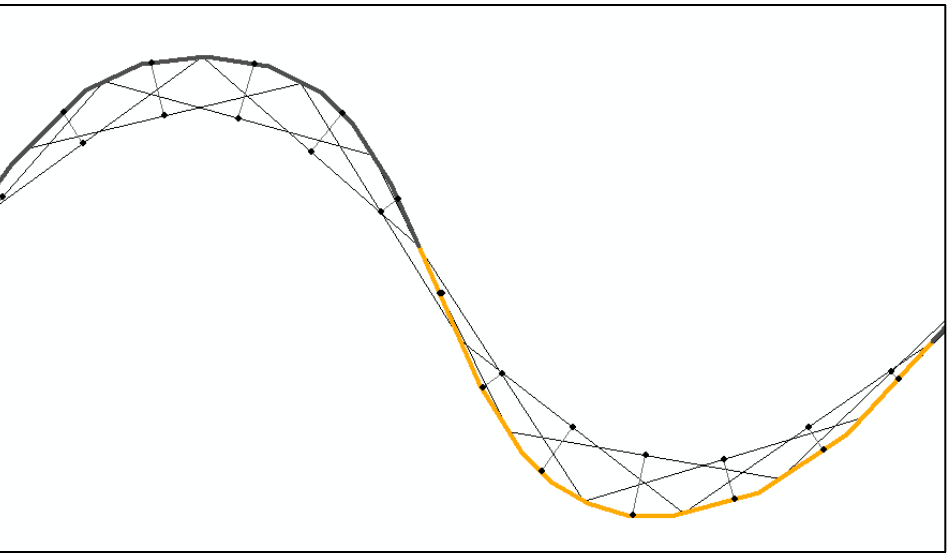

Figure 3: Example of curvature calculation

Discrete curve sections were extracted by combining road segments where:

(a) the radius was less than 800m;
(b) at least one 10m section had a radius of 500m or less; and
(c) the apex (direction) of the curve did not change.

Contiguous 10m sections of road that met these criteria were dissolved into a single curved segment, with the radius (m) of the curve defined as the minimum radius across all the sections that make up the curve.

Speed modelling

The Austroads (2009) operating speed model predicts the operating (85th percentile) speed of cars travelling in each direction along a section of rural road. The model mimics the real-world behaviour of drivers based on a large number of car vehicle observations. As such, the model only applies to cars and cannot be used to predict the operating speeds of other types of vehicle.

Once curves had been identified (see above), each road corridor was divided sequentially into a series of curves with known radii, and straights with known lengths. Speeds were then modelled along the road centreline in both directions.

Sections of road with curves of a similar radius separated by short straights (less than or equal to 200m) were identified as discrete sections with an operating speed identified within a narrow range of values (minimum and maximum operating speeds). When drivers travel through a series of curves with a similar radii, their speeds stabilise to a level they feel comfortable with (Austroads, 2009). Section operating speeds for single, isolated curves were also calculated.

Working along the road corridor, speed behaviour was modelled as either:

(a) Acceleration – on straights longer than 200m, or on curves where the approach speed is less than the operating speed of the curve.
(b) Speed maintenance – on straights less than 200m, or where the speed falls within the section operating speed range.
(c) Deceleration – on curves where the approach speed is higher than the operating speed for the curve (or series of curves).

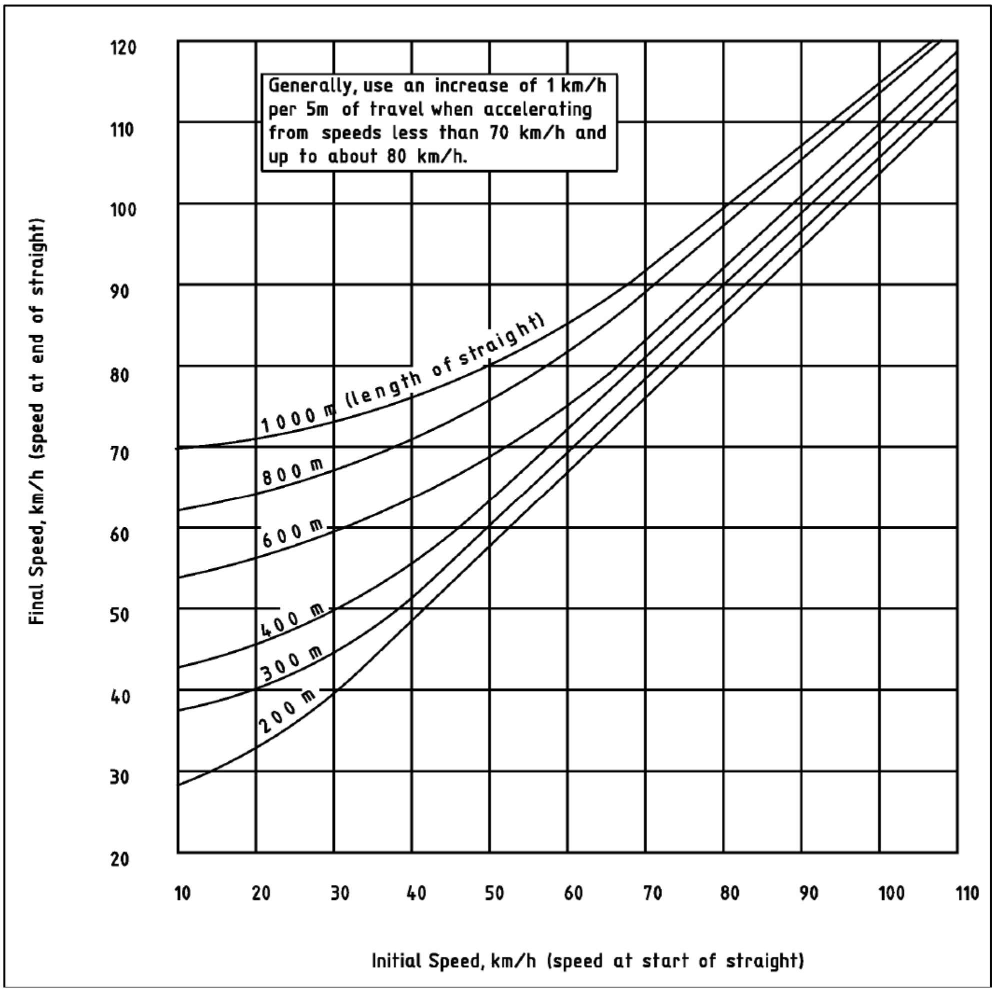

Figure 4: Acceleration on straights (source: Austroads, 2009)

Rates of acceleration and deceleration were modelled using the methodology in Austroads (2009) (Figures 4 and 5). Extrapolation of values was required to estimate some acceleration and deceleration outputs, including acceleration for straights longer than 1000m (Figure 4) and deceleration where curve approach speeds are less than 60 km/h (Figure 5).

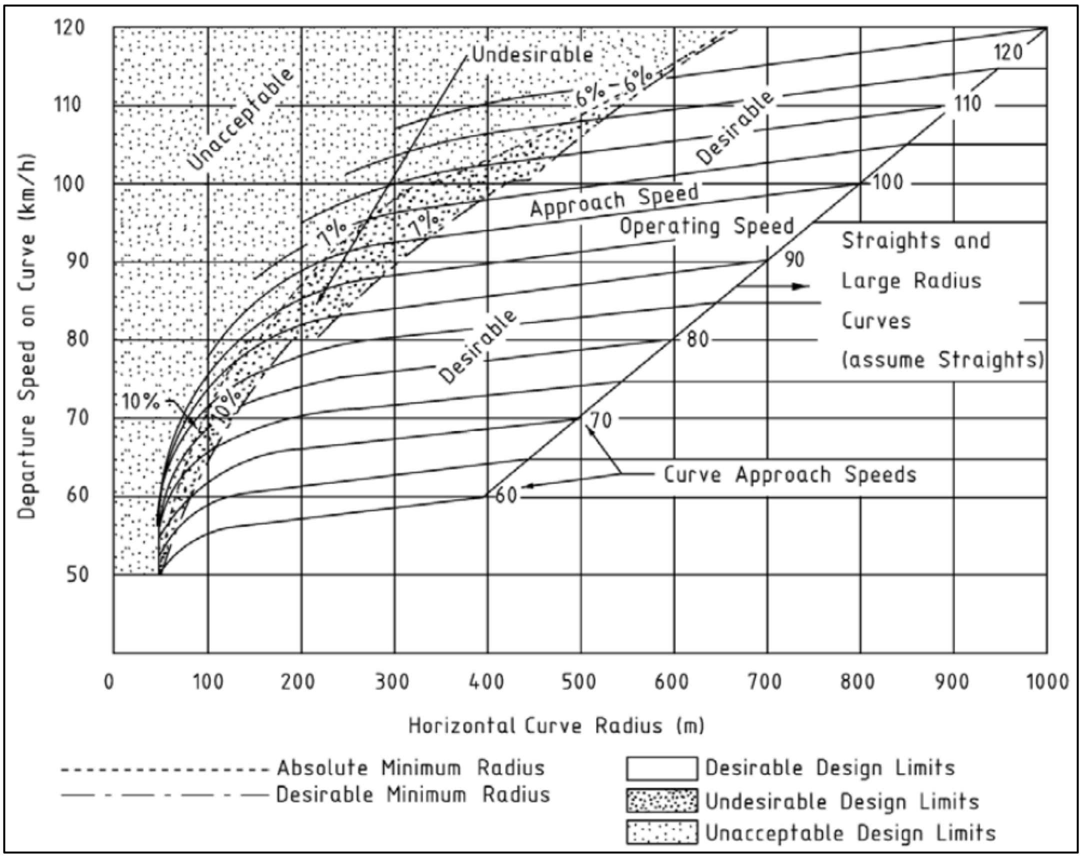

Figure 5: Deceleration on curves and design limits (source: Austroads, 2009)

The exit speed at the end of each curve or straight is applied as the approach speed for the following section of road. For each curve where deceleration is modelled, the design limit is identified as either out-of-context (unacceptable or undesirable) or within context (desirable) (Figure 5). Curves where no deceleration is modelled are also considered to be ‘within limit’.

Results

The curve identification methodology recognised 6,985 curves across the EBoP region. Each curve was classified by design limit (in both directions) according to the Austroads speed model (Figure 5). The number of curves identified by category are displayed in Table 3. Where curves were classified differently in opposing directions, the worst (most out-of-context) classification has been applied. For example, a curve that is ‘undesirable’ in one direction but ‘within limit’ in the reverse direction would be categorised as ‘undesirable’.

Curve Category	**Total Curves**	**% of all Curves**
Unacceptable	600	8.6%
Undesirable	815	11.7%
Desirable	941	13.5%
Within Limit	4629	66.3%

Table 3: Eastern Bay of Plenty curve categorisation

Correlation between curve category and loss-of-control crashes

Further analysis was undertaken to identify the number and percentage of loss-of-control crashes by curve category. For the purposes of this analysis, loss-of-control crashes were defined as those with movement code ‘BF’, ‘DA’ or ‘DB’ in CAS. In the 10-year period from 2004 – 2013, there were 589 loss-of-control crashes on the curves identified. The number and percentage of loss-of-control crashes by curve category are presented in Table 4.

Curve Category	Total LOC Crashes	% of all LOC Crashes
Unacceptable	226	38.4%
Undesirable	166	28.2%
Desirable	64	10.9%
Within Limit	133	22.6%

Table 4: Eastern Bay of Plenty loss-of-control crashes by curve category

The results show that two thirds (66.6%) of all loss-of-control crashes occur on out-of-context curves i.e. those identified as ‘unacceptable or ‘undesirable’. This is a particularly important finding as it means road controlling authorities in the Eastern Bay of Plenty can target efforts on 20.3% of all curves where 66.6% of all loss-of-control crashes occur.

Further analysis of the number of loss-of-control crashes by curve category (Figure 6) demonstrates that curves rated ‘unacceptable’ or ‘undesirable’ in either direction have a higher incidence of loss-of-control crashes compared to curves that are within context (‘desirable’ or ‘within limit’). This demonstrates that the relative risk of a rural curve is a function of the extent to which the curve is out-of-context with the approach speed.

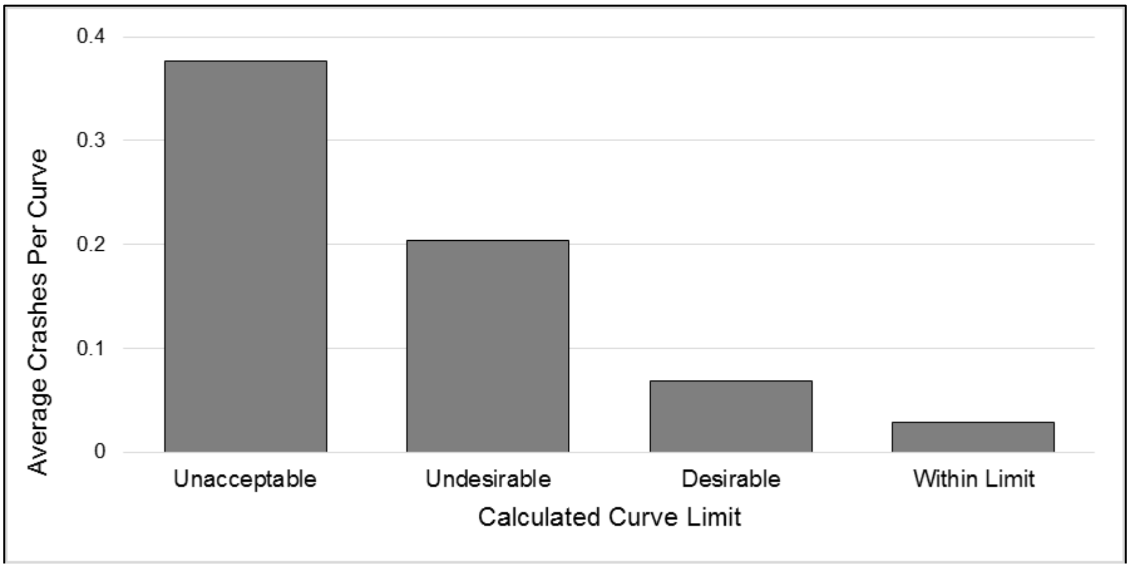

Figure 6: Loss-of-control crashes per curve by curve limit class

Correlation with existing out-of-context curve data

The outputs were compared against a Transport Agency state highway out-of-context curve dataset to determine the accuracy of the curve identification methodology. The new methodology accurately identified the location of 96.8% of curves in the state highway dataset, with a high correlation between curve radii values ($R^2 = 0.86$) (Figure 6). Outlier values were generally attributed to errors in the geometry of the road centreline dataset.

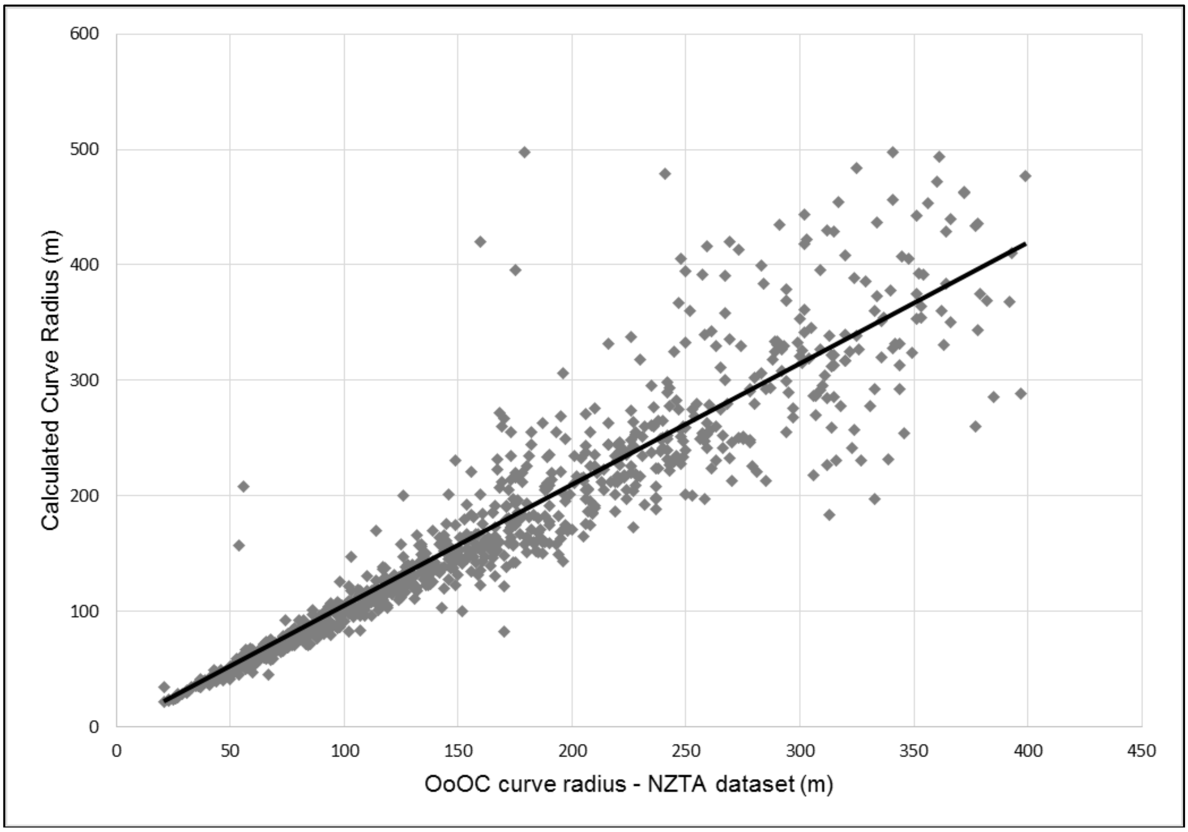

Figure 7: Comparison of calculated curve radii against NZTA out-of-context curve dataset

RURAL ROAD RISK PREDICTION

In addition to the identification of high-risk curves, road risk was also analysed using the GIS-based Urban KiwiRAP risk assessment process (Brodie et al, 2013). The Urban KiwiRAP risk mapping methodology applies to all roads not covered in the original KiwiRAP programme[1]. There were two components to this assessment: an intersection component and a corridor component. The analysis used information about the physical and operating characteristics of intersections and corridors, as well as crash history, to generate measures of collective and personal risk.

Rural road risk was calculated using the Transport Agency's Economic Evaluation Manual crash prediction model for high-speed, rural two-lane roads (MoT, 2010). The inputs to this exposure-based calculation are terrain type (level, rolling, mountainous), AADT, and carriageway widths. Predicted crash rates were then compared to actual crash rates to identify roads that performed better or worse than expected.

'SIGNATURENET' WEBMAP VIEWER OUTPUT

The deliverable was a mapping website ("SignatureNET") displaying the risk metrics generated from the analysis, as well as contextual road safety data including administrative boundaries, communities at risk (NZTA, 2014), crashes (categorised by crash severity and cause), and census statistics including deprivation and access to motor vehicles (Figure 8). The SignatureNET web viewer is available for all the signature project partners to access and query and features Google Streetview integration to allow users to view actual road conditions.

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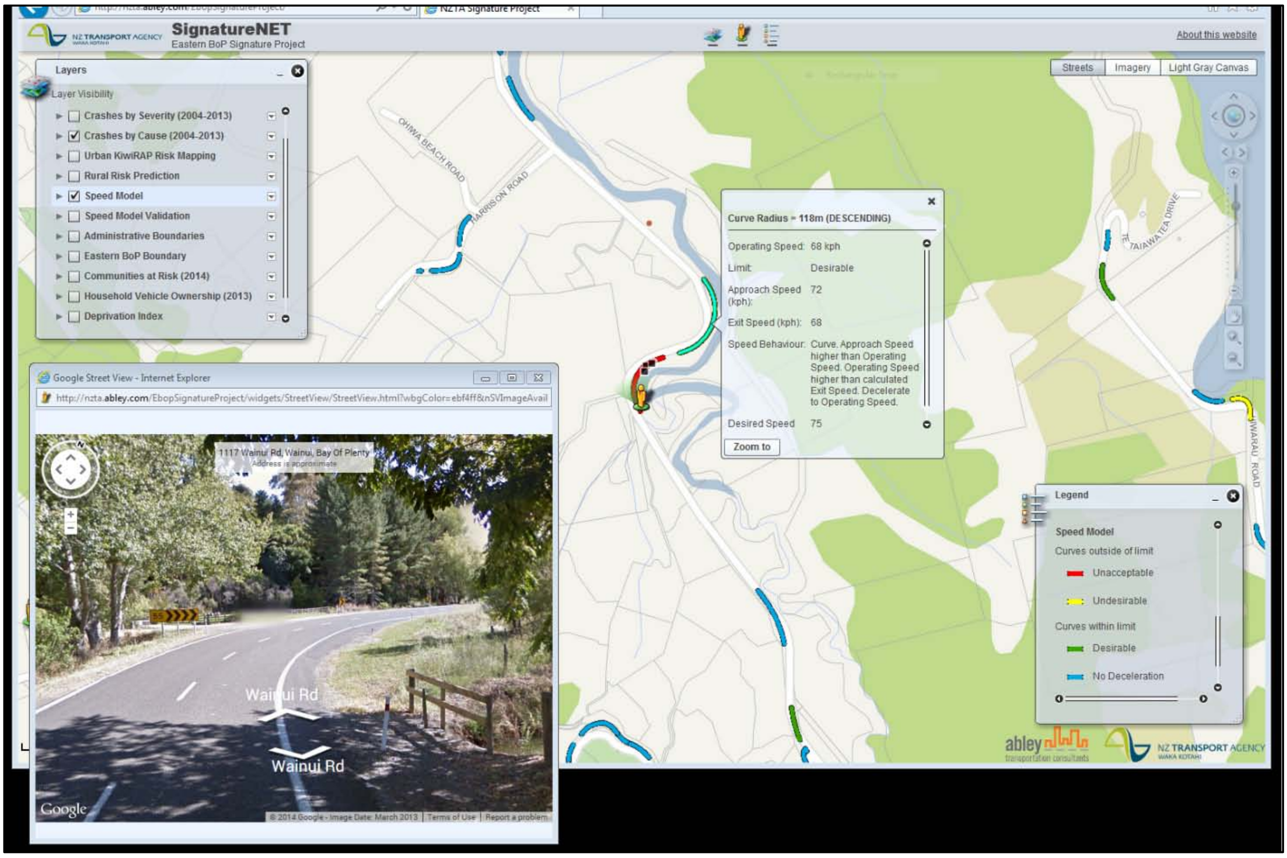
[1] The original KiwiRAP programme only applied to high-speed (80km/h+) state highways.



Layers

Layer Visibility

- ☐ Crashes by Severity (2004-2013)
- ☑ Crashes by Cause (2004-2013)
- ☐ Urban KiwiRAP Risk Mapping
- ☐ Rural Risk Prediction
- ☑ Speed Model
- ☐ Speed Model Validation
- ☐ Administrative Boundaries
- ☐ Eastern BoP Boundary
- ☐ Communities at Risk (2014)
- ☐ Household Vehicle Ownership (2013)
- ☐ Deprivation Index

Curve Radius = 118m (DESCENDING)

Operating Speed: 68 kph
Limit: Desirable
Approach Speed (kph): 72
Exit Speed (kph): 68
Speed Behaviour: Curve. Approach Speed higher than Operating Speed. Operating Speed higher than calculated Exit Speed. Decelerate to Operating Speed.
Desired Speed 75

Zoom to

Figure 8: SignatureNET mapping website screenshot

DISCUSSION AND CONCLUSION

SignatureNET and the new high risk curve assessment methodology demonstrate that innovative assessment methods and tools can be developed within a safe system signature project environment. Combining the speed and risk prediction models and related context data into a single mapping website has also provided the signature project partners with a tool to make well-informed road safety investment decisions. Both the SignatureNET website and underlying analysis can now be readily rolled-out across other regions using existing data and GIS methodologies.

The curve identification and analysis techniques presented in this paper will be of particular interest to road controlling authorities wanting to reduce loss-of-control crashes on rural roads. Low cost interventions using the outputs of this analysis could include delineation improvements for high risk curves (eg edge marker posts, curve warning signs and chevrons). Another potential application is to use curve categories as the basis for setting intervention levels in SCRIM. Higher risk (unacceptable or undesirable) curves can be set a higher intervention level compared to lower risk curves.

Further enhancements to the speed model and high-risk curve identification include:

- Enhancing the speed model by exploring the relationship between curve risk category, road surface and carriageway widths and actual road safety performance.
- Exploring the relationship between curve risk category, star rating and the road safety performance of State Highways
- Enhancing the speed model by comparing calculated operating speeds against known operating speeds, for example using data collected using GPS.

ACKNOWLEDGEMENTS

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