Application Details

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Project Topic
Development of an innovative GIS methodology for assessing curve risk and the delivery of an interactive web viewer for a Safe Systems Signature project.

Project Name
New Zealand Transport Agency: Eastern Bay of Plenty Signature Project Curve Risk Prediction Model and ‘SignatureNET’ Online Interactive Tool
Introduction

The New Zealand Transport Agency commissioned Abley Transportation Consultants in March 2014 to develop a risk prediction model for the Eastern Bay of Plenty Safe System Signature project. The objectives were:

- To develop a risk prediction model that incorporates a vehicle speed model and identifies risk at specific parts of the network based on geometric road data.
- To combine the risk prediction model with existing risk models (Urban KiwiRAP and Economic Evaluation Manual crash prediction models) and other contextual information in an online interactive tool for the signature project team.

The outcomes of this project are helping the New Zealand Transport Agency to deliver the government’s road safety objectives set out in the Safer Journeys Road Safety Strategy 2010-2020 through the delivery of Safe System Signature projects. For road controlling authorities, the outputs of this project will enable road controlling authorities to prioritise and investigate identified high-risk curves for road safety treatments.

Innovation

Identifying the Need

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\(^1\). The strategy is founded on the safe system approach to road safety, which focusses on creating safe roads, safe speeds, safe vehicles and safe road use.

The Safe System philosophy is based on creating a forgiving road system that acknowledges that people make mistakes and have limited ability to withstand crash forces without being killed or seriously injured. Under the Safe System, all parts of the system - roads and roadsides, speeds, vehicles, and road use, all need to be improved and strengthened - so that if one part fails, other parts will still protect people involved in a crash.

Safer Journeys signifies a shift in focus, from reducing crashes to minimising the likelihood of high-severity crash outcomes. In order to give effect to Safer Journeys, new analytical approaches have been developed that prioritise sites on the likelihood of future fatal and serious casualty occurrence and risk.

Safe system signature projects are identified in the Safer Journeys Action Plan 2013-2015\(^2\) 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 and have the potential to make demonstrable advances in reducing road trauma for all road users.

The Eastern Bay of Plenty (EBoP) region 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. Most EBoP roads are low volume remote roads with many rural road crashes occurring on curves (57.9% of all fatal and serious rural road crashes 2004-2013\(^3\)). Due to the remote nature of the region’s roads, fatal and serious crashes tend to occur sporadically on parts of the network where high-severity crashes have not occurred in the recent past. In these areas, relying on

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\(^1\) Ministry of Transport (2010), Safer Journeys New Zealand’s Road Safety Strategy 2010-2020
\(^3\) Statistics from the New Zealand Transport Agency Crash Analysis System (CAS)
crash history alone is not a robust method of predicting where future crashes are likely to occur. Because of this, a new methodology that could assess and identify all high-risk curves on the network independent of crash history was required.

Existing methodologies, including Urban KiwiRAP and Economic Evaluation Manual predictive risk models, are useful for highlighting safety issues along corridors and at intersections, but they do not identify the risk of individual geometric elements of the road’s design that may be a contributing factor for these types of crashes. Similarly, the Star Rating of roads using the iRAP protocols provides a strong basis for assessing the underlying safety of a section of road based on built features. However, calculation of Star Rating is manually intensive and is carried out on selected corridors – not an entire network.

The Austroads operating speed model for rural roads provides a procedure for calculating operating speeds along road sections based on the geometric features of the road, taking into account the typical behaviour of drivers and vehicles on higher speed rural roads. Using road geometry, the speed model includes figures for modelling acceleration along straights, deceleration through curves, and the identification of curve design limits based on approach speeds and curve radii.

The Austroads model is used by road designers to estimate operating speeds on relatively short, discrete corridors of highway. The model requires designers to assess the overall terrain and curvature class of the corridor, identify all the curves (including curve radii) and measure the distance between them. Corridors must be manually divided into discrete operating speed sections with minimum and maximum operating speeds. Speed behaviour is modelled in both directions as either:

- Acceleration on straights, or curves where the approach speed is less than the operating speed.
- Speed maintenance on straights less than 200m, or where approach speeds fell within operating speed ranges.
- Deceleration on curves where the approach speed is higher than the operating speed.

The Austroads methodology includes figures for modelling acceleration based on the length of straight and the initial speed, and deceleration based on the curve approach speed and curve radius. The model requires users to manually read these figures, calculating the exit speeds for each curve or straight which is then the approach speed for the following element.

One of the outputs of the Austroads methodology is the identification of design limits for curves, which can be used as a proxy for curve risk when considered in conjunction with the approach speed. Curves are classified as one of the following, in ascending order of risk:

- Within limit (a driver could safely accelerate through this curve)
- Desirable
- Undesirable
- Unacceptable

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, Abley Transportation Consultants considered it may be possible to automate the operating speed modelling methodology using a new Geographic Information Systems (GIS) methodology. If successful, the automated model would facilitate the calculation of the operating speed across the entire EBoP region by direction thus enabling all high-risk curves to be identified and targeted for safety improvement.

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[2] In the Austroads model operating speeds are defined as 85th %ile speeds.
Innovative Thinking

The Safer Journeys Strategy identifies innovation as an important component of the safe system approach to road safety—“being innovative may mean taking some risks and trying new techniques that are not fully proven”. In this project, both the high-risk curve identification methodology and automation of the speed model on a macro scale was entirely innovative. 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. This GIS methodology used in this project has never been undertaken before and is unique globally.

Innovation is one of Abley Transportation Consultants four values. As such, we are constantly searching to identify new and better methods of delivering outcomes for our clients. Within the framework of innovation through safe systems signature projects, Abley Transportation Consultants were able to combine geospatial, engineering and road safety expertise to identify alternative methods for assessing risk and build and test alternative GIS-based workflows.

The development of a GIS curve identification methodology is an example of innovation in both geospatial and engineering sciences. Using a high-quality GIS road centreline dataset, a methodology was developed using linear referencing and dynamic segmentation techniques to divide the road centreline into 10m sections for the purpose of calculating a rolling 30m average radius for each arc section. Figure 1 illustrates how radius is calculated over rolling 30m sections of road.

Figure 1 - Illustration of how radius is calculated using arc segments and 30m rolling sections of road

Discrete curve sections were then extracted by combining road segments where:

a) the calculated radius is less than 800m;

b) at least one 10m section has a radius of 500m or less; and

c) the apex (direction) of the curve did not change.

[6] Linear referencing is a method of storing geographic data by using a relative position along an existing line feature (e.g., road or waterway). Dynamic segmentation is the process of transforming linear referenced data that have been stored in a table, into features (e.g., curves and straights) that can be displayed and analysed on a map.

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.

Because the curve identification methodology developed for this project was a new and untested methodology, the results were compared against an existing New Zealand Transport Agency out-of-context curve dataset for the State Highway network to assess the accuracy of the methodology. An example of this comparison is displayed in Figure 2. The new methodology resulted in the matching of 96.8% of curves in the State Highway dataset. The high correlation between curve radii values using the two approaches is further evidenced in Figure 3.

![Figure 2](image.png)

*Figure 2*  
Comparison of modelled curves (red) against NZTA out-of-context curve dataset (green) on a section of SH2, Waioeka Gorge

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8 The New Zealand Transport Agency out of context curve dataset is only calculated for curves with a radii of less than 400m.
The strong correlation between the automated operating speed model and State Highway out-of-context dataset gave the project team confidence that the model could be rolled out to all other roads in the region. In doing so, the model identified a total of 6,985 curves in the EBoP region. A breakdown of the number of curves in each category is shown in Table 1.

<table>
<thead>
<tr>
<th>Curve Category</th>
<th>Total Curves</th>
<th>% of all Curves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unacceptable</td>
<td>600</td>
<td>8.6%</td>
</tr>
<tr>
<td>Undesirable</td>
<td>815</td>
<td>11.7%</td>
</tr>
<tr>
<td>Desirable</td>
<td>941</td>
<td>13.5%</td>
</tr>
<tr>
<td>Within Limit</td>
<td>4,629</td>
<td>66.3%</td>
</tr>
</tbody>
</table>

Analysis was then completed to investigate the strength of the link between curve risk categorisation and actual safety performance. The analysis involved identifying all loss of control crashes by curve risk category (Figure 4 and Table 2). This analysis demonstrated 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. This finding means that curve risk can be used as a means of prioritising safety improvements.
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.
Innovative Technology

This project required the innovative use of GIS technology to improve the affordability and scale of the project. While it is technically feasible to manually apply the operating speed model methodology across all 1500 km of road, this would be hugely time-consuming and costly. Manually identifying and calculating the radii of almost 7000 curves would have been a prohibitive exercise. In addition, the analysis underpinning the project involved using existing geospatial datasets, no new or expensive data collection was required. The power and scalability of GIS enabled the analysis of the EBoP road network at a micro-level of scale, in a quick and cost-effective manner.

GIS linear referencing tools are traditionally used by geospatial analyst for storing data about linear features such as roads and waterways and for performing basic analysis on this data, i.e. overlaying road surface and traffic count data. Using these tools to extract curvature, calculate rolling averages, and replicate driver behaviour through the speed model is entirely innovative. The Python programming language and ArcPy\(^9\) were also used extensively for advanced geospatial analysis tasks that could replicated through the ArcGIS Desktop interface.

Innovation in the use of technology was also delivered through the integration of risk mapping and contextual information through a single mapping website “SignatureNET” for all signature project partners to access. SignatureNET displayed all the risk metrics generated from the analysis, as well as contextual road safety data including administrative boundaries, communities at risk\(^{10}\), crashes (categorised by crash severity and cause), and census statistics including deprivation and access to motor vehicles. The website also features Google Streetview integration to allow uses to view actual road conditions. An example screenshot demonstrating the output curve analysis and Streetview integration is displayed as Figure 5.

\(^9\)ArcPy is a Python programming package for performing GIS functions available in ArcGIS

\(^{10}\)New Zealand Transport Agency (2014), Communities at Risk Register, April 2014
The approach of this project is well-aligned with the New Zealand Transport Agency’s focus on ensuring it receives value-for-money in all of its activities. It assists the Agency and the local authorities (Kawerau, Whakatane and Opotiki) to identify curves where targeted road safety interventions will deliver the greatest road safety benefits. This is an advancement in the assessment of road safety, as relying on crash history alone to inform decisions around safety interventions is fraught with risk in low volume rural environments, where crashes are more rare and random events. The risk-based approach enables the identification of curve hazards that may have ‘slipped under the radar’ due to the traditional approach to treating crash sites in New Zealand, i.e. focusing efforts on reducing crash occurrence at sites with the greatest number of observed crashes.

This approach supports the use of innovative technologies for reducing loss-of-control crash risk on curves. Low cost interventions using the outputs of this analysis could include delineation improvements on high risk curves, such as edge marker posts, audio-tactile marking, curve warning signs and chevrons. Another innovative application is to use curve categories as the basis for setting intervention levels based on SCRIM inputs. Higher risk (unacceptable or undesirable) curves can be set a higher intervention level compared to lower risk curves and thus be prioritised for resurfacing ahead of other parts of the network where high surface friction is less critical.
Effectiveness

Endurance of effect?

The automated operating speed model developed for the EBoP region as part of a Safe Systems Signature project is already making a difference to the way road safety issues are viewed and addressed in the region. The model provides the EBoP local authorities with a tool to identify risk across their networks and to proactively target interventions. Delivered in October 2014, the tool is already being used for the audit high-risk curves to ensure that adequate warning and delineation is provided to alert motorists. The tool is sufficiently sophisticated that curves may be considered out-of-context in one direction of travel, but not the other, thereby enabling road controlling authorities to treat specific approaches rather than both directions. This then enables limited road safety budgets to reach a greater number of high-risk locations within the region.

The model has been developed in a manner that allows it to be applied to any transport network in the country. As such, the model has the potential to provide an enduring benefit throughout New Zealand. In particular, those road controlling authorities with vast low volume rural networks will benefit from a tool that sheds light on the high-risk parts of the network and allows safety interventions to be introduced in advance of crashes occurring.

Further potential applications of the operating speed model are currently being explored in conjunction with the New Zealand Transport Agency. The key one at present is the application of the model to all State Highways throughout the country for the purpose of informing the business case to support the Safer Speeds Programme. Specifically the operating speed model would help identify those parts of the high-speed State Highway network with the greatest difference between operating speed, posted speed and safe speed. As the inputs to the model are sensitive to the posted speed limit, the effectiveness of speed management techniques, such as reductions in posted speed limit, on crash risk can readily be tested.

Benefits to a wide range of transport system users?

The operating speed model is the first network screening tool that has been developed specifically to address the primary road safety risk, loss-of-control crashes on curves, in low volume rural areas. As such, the model has the potential to benefit communities that may have suffered from poorly targeted road safety investment in the past. The model provides a tool for road controlling authorities to make better informed decisions about the use of their limited road safety finds in a more efficient manner.

As noted above, the potential applications of the operating speed model are only just starting to be explored. Its use in the prioritisation of road sections for speed management intervention provides one example of the benefits that could be generated for all users of the transport system. The Safer Speed Programme not only focusses on roads where speed reductions would be appropriate, but also those parts of the network that could support an increased speed limit.

Scale of effect?

Early indications are that the automated operating speed model will be rolled out as a nationwide tool to assist all road controlling authorities with the road safety management of their networks. Whilst specifically produced in response to addressing the lack of a suitable tool for a low volume rural road network, the tool can readily complement other network tools available in metropolitan areas, such as Urban KiwiRAP, and the tools developed specifically for the State Highway network, such as SafetyNET.
There is potential that the model could be applied beyond New Zealand.

Public acceptance?

The traditional approach of identifying and addressing road safety issues in New Zealand has generally been targeted on the basis of historic crash performance; through crash reduction programmes, black-spot and black route analysis and treatments. While the crash clustering approach served New Zealand well in the past, it tended to place a strong emphasis on crashes with minor injuries.

Alternative approaches were introduced to overcome this, including the ranking of sites by the social cost of crashes. However, this had the opposite effect and ended up placing excessive focus on recent fatal crashes. As fatal crashes very rarely occur at the same location within a five-year period, the approach of prioritising sites for treatment based on social crash costs is fraught with the risk of reaching false conclusions about crash risk because of a low number of observations. Prioritising in this manner also drew criticism from the general public who were unaccepting of an approach of waiting for someone to die or be seriously injured before the funding of improvements could be justified.

The automated operating speed model provides a proactive approach of targeting to risk at a network-wide level. The shift from a reactive to proactive approach to road safety is expected to receive strong support based on the public opposition to the previous regime.

Speed limit modifications are generally a contentious subject. The model allows differences between the operating speed, posted speed and safe speed to be understood thus enabling decisions to be made on a well-informed basis, limiting the potential for public opposition. One such example would be using the model to identify sections of road where both the safe speed and operating speed are below the current posted speed limit. These sections of road could represent ‘quick wins’ for speed limit intervention as part of the wider Safer Speed Programme, particularly where the existing crash performance is poor and risk is high.

Results

The results of the automated operating speed model have been presented in earlier sections. The points to note are:

- The model provides a high correlation with existing datasets for out-of-context curves on the State Highway network;
- The relative risk of a curve is a function of the extent to which the curve is out-of-context with the approach speed;
- The model provides a robust basis for identifying high-risk curves within a road network, which targets the primary road safety issue in low volume rural networks;
- The model is the first network screening tool specifically developed for low volume rural road controlling authorities.

The innovative nature of the project has already been acknowledged formally. It received the ‘Best Road Safety Poster Award’ at the Australasian Road Safety Research, Policing and Education Conference in Melbourne, November 2014. This award was judged and awarded based on this project’s potential contribution to road safety, the originality in its development and delivery, and the demonstrated links between the need for the project and its results.