An Automated Process of Identifying High-Risk Roads for Speed Management Intervention

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Abstract

Infrastructure Risk Rating (IRR) is a significant input to the speed management framework, set to be introduced as part of NZ Transport Agency's Speed Management Guide. It is a road assessment methodology designed to assess risk based on infrastructure elements and interactions with surrounding land use, independent of crash history. The road safety risk is assessed by coding each road and roadside feature; such as land use, road stereotype and alignment; that feeds into the IRR model so that a risk rating can be determined. The methodology was originally developed as a manual coding exercise using street view imagery. However, this approach is neither economic nor time efficient when applied across a large network as is the requirement of the speed management framework.

This paper presents a geospatial process to automate the calculation of IRR. The process utilises various national and regional geospatial datasets to extract road features needed to calculate IRR. A comparison of the automated process outputs with manually coded IRR data of the same network resulted in a matching rate of almost 90 percent, hereby confirming the validity of the automated process. Aside from demonstrating the true potential of transport related data, this innovative approach will enable road controlling authorities to efficiently identify parts of their network where speed management intervention is most likely to reduce road trauma.

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 (Ministry of Transport, 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 New Zealand Government's vision for road safety is to be achieved.

The second action plan of the Strategy, Safer Journeys 2013-15 Action Plan, aims to address speed as a cause of road death and serious injury (New Zealand Transport Agency, 2013). Therefore, NZ Transport Agency (NZTA) is tasked with delivering a Speed Management Guide that provides a framework to better align travelling speeds with road function, design, safety and use.

This speed management framework provides a single assessment method for determining safe and appropriate speeds on New Zealand's entire road network. The aim is to identify parts of the network where there is misalignment between the posted speed limit and the safe and appropriate speed and then prioritise investment to those parts where speed management intervention is most likely to reduce death and serious injuries.

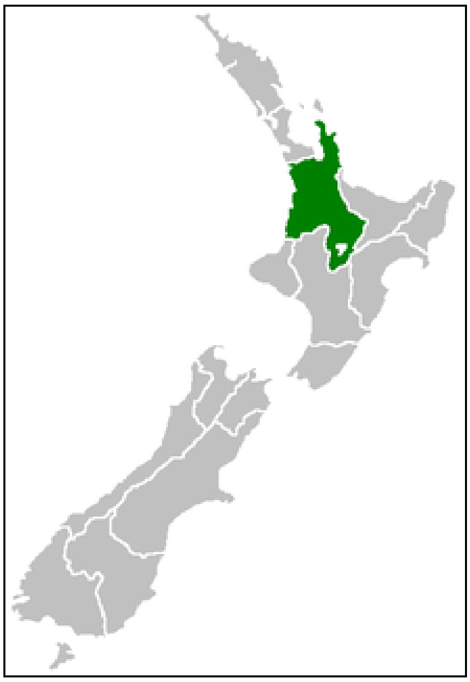

Figure 1. Waikato region locality map

In order to progress the Speed Management Guide to final status, NZTA initiated a speed demonstration project in the Waikato region of New Zealand to test and inform the speed management framework. The Waikato Speed Demonstration Project is an essential element in proving the robustness of the assessment methodology and building confidence in the process.

Infrastructure Risk Rating (IRR) is one of the three metrics, along with road classification and historic safety performance, required to classify a safe and appropriate speed to a road corridor. The IRR assessment methodology was originally developed as a manual exercise of coding road attributes using street view imagery or high speed video. However, manually coding the whole of Waikato region in order to demonstrate the framework is neither economic nor time-efficient.

Therefore, as part of the Waikato Speed Demonstration Project, NZTA commissioned Abley Transportation Consultants to develop an automated process of calculating IRR across a large network. The Top of the South region of New Zealand was chosen to develop and refine the automated process before being applied in the Waikato region.

Infrastructure Risk Rating

IRR is a predictive road assessment methodology that has been developed by NZTA (Waibl et al., 2016). It is based on the Star Ratings process and involves coding a number of road and roadside attributes. These attributes then feed into the IRR model, resulting in a five-band risk rating, ranging from 'low' to 'high'. The overall IRR score for a road corridor is calculated by assigning a category-based risk score to the attributes given in Table 1.

Table 1. IRR Attributes and their Categories

Road Attribute	Categories
Road stereotype	• Divided – non-traversable or one-way • Divided – traversable • Multi-lane undivided • Two lane undivided • Unsealed
Horizontal alignment	• Straight or gentle, Curved, Winding, Tortuous
Lane width	• <3m – narrow • 3m to 3.5m – medium • >3.5m – wide
Shoulder width	• 0m to <0.5m – very narrow • 0.5m to 1m – narrow • >1m to 2m – wide • >2m- very wide
Surrounding land use	• No access (Freeway) • Remote rural • Rural residential • Rural town • Controlled access (Urban arterials)

	• Commercial big box/ Industrial • Commercial strip shopping • Urban residential
Traffic volume	• <1000 veh/day • 1,000 to <6000 veh/day • 6,000 to <12,000 veh/day • >12,000 veh/day
Intersection density	• <1 intersection/km • 1 to <2 intersections/km • 2 to <3 interesections/km • 3 to <5 intersections/km • 5 to <10 intersections/km • 10+ intersections/km
Access density	• <1 access/km • 1 to <2 accesses/km • 2 to <5 accesses/km • 5 to <10 accesses/km • 10 to <20 accesses/km • 20+ accesses/km
Roadside hazards	• Low, Minor, Moderate, High, Severe

The IRR assessment is designed to predict road safety risk on long sections of road. These long sections are referred to as 'homogenous sections' and are identified based on little variation in IRR features along the length of the section. In a rural environment, homogenous sections are around 5km in length, whereas urban sections are generally shorter due to frequent changes in road attributes such as surrounding land use and road stereotype.

As with other risk rating methodologies, divided carriageways are separated from undivided carriageways and coded in both directions. Short changes in IRR features such as a dividing median on the approach to an intersection or a turn along a straight corridor are ignored when identifying homogenous sections. In broad terms, homogenous sections are those where the speed limit would be same.

Methodology

A majority of the road attributes that feed into the IRR model are stored in national or regional geospatial road datasets. Therefore, to deliver the Waikato Speed Demonstration Project in a cost-efficient manner, the process of calculating IRR was automated using geographic information systems (GIS). This included the development of GIS models that accurately extract road attributes from various geospatial datasets and applying assumptions based on engineering analysis and professional judgement. This methodology is discussed, in brief, below.

Corridor Aggregation

The first step in automating the IRR methodology is to develop a method of aggregating road corridors that is comparable to manually identifying homogenous sections. Figure 2 summarises the geospatial process developed to automate this process. A road centreline dataset was initially dissolved into long corriors defined only by the posted speed limit and the road name. These corridors were then progressively segmented based on the IRR attributes that have the most significant influence on the overall score.

According to the speed management framework, the primary factor in distinguishing different road environments in terms of setting speed limits is the surrounding land use. As IRR is used to determine safe and appropriate speeds, land use has been used as the first order of segmentation.

Corridors with a uniform land use are then segmented further based on changes in road stereotype, alignment and traffic volume. These attributes were analysed to have a significant weighting to the overall score. For example, access density score has a difference of only 0.3 between the highest and the lowest risk category compared to road stereotype and alignment which have the same difference of 10 and 6 respectively (Waibl et al., 2016).

The segmentation thresholds (minimum lengths) where chosen to avoid segmenting corridors due to short changes in road attributes such as overtaking lanes or short divided medians. These thresholds have been adjusted as the methodology has been refined in order to align the automated process of corridor aggregation with manually identifying homogenous sections.

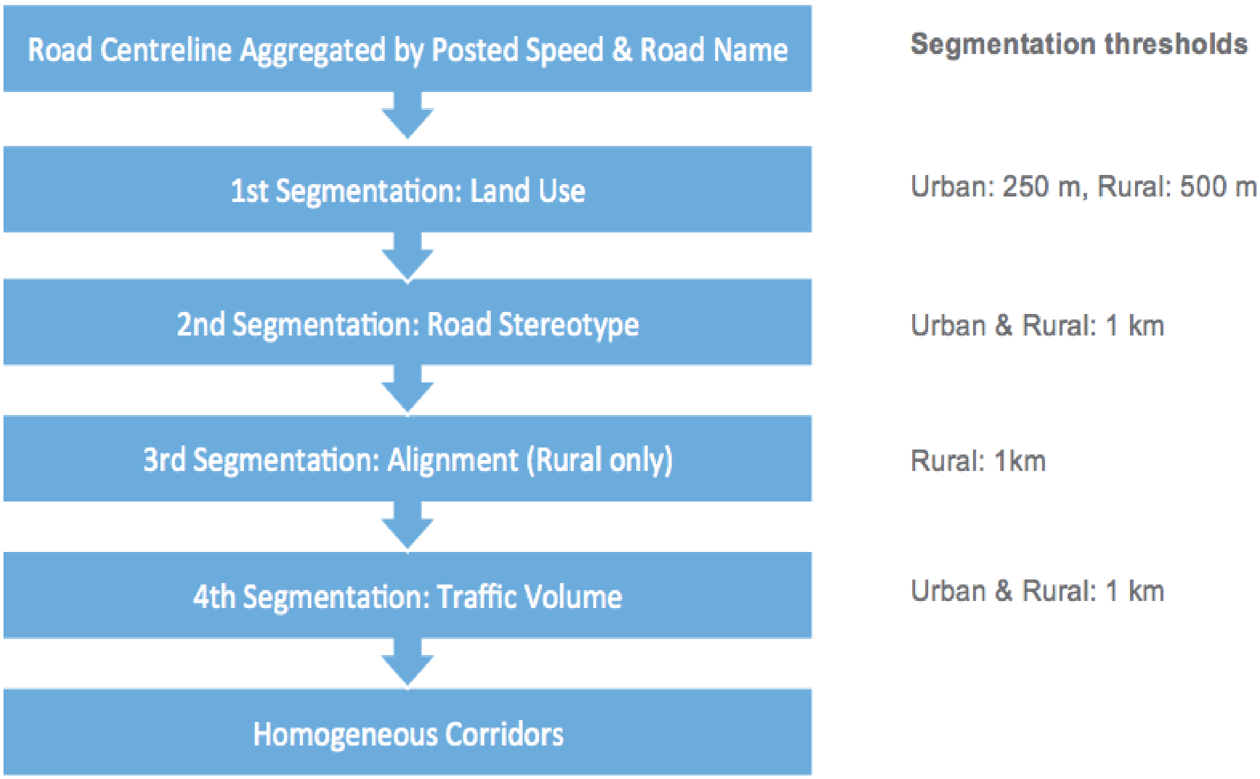

Figure 2. Corridor Aggregation Process and Segmentation Thresholds

Figure 3 shows an example of a rural corridor initially dissolved into a long section based on road name and posted speed limit. The corridor remains aggregated at the first and second order of segmentation as the land use is ‘remote rural’ and road stereotype is ‘two lane undivided’ along the entire length. There is a distinct change in alignment category that is longer than the segmentation threshold of 1km and therefore, the corridor is segmented at this stage of the process. There is no further segmentation as the traffic volume category remains consistent along the segmented sections.

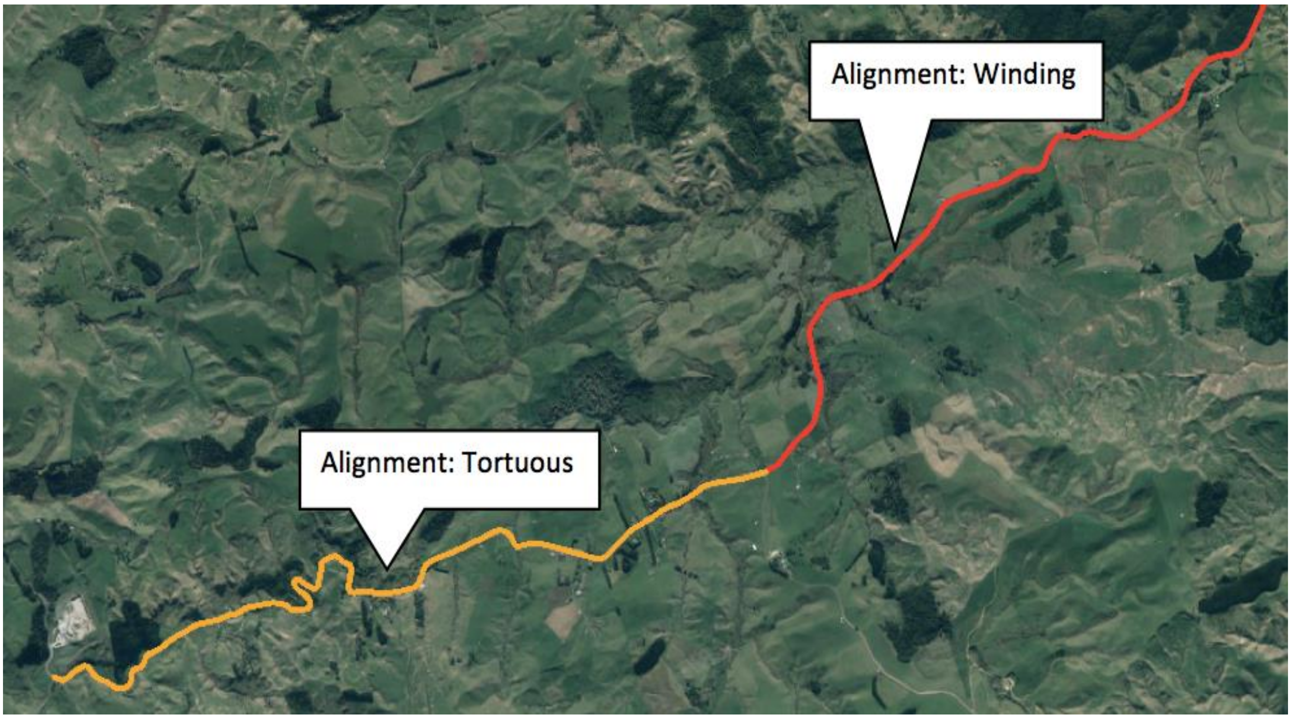

Figure 3. An Example of Corridor Segmentation

Geospatial Datasets

The GIS models have been developed to extract IRR attributes from various geospatial datasets. These include a national road centreline dataset with speed limit, road name and alignment data, and Road Assessment and Maintenance Management datasets maintained by local territorial authorities. Land use was modelled using urban and rural boundaries and the density of residential and commercial developments sourced from planning zones, Open Street Map (OSM) and Land Information New Zealand (LINZ) datasets.

Figure 4 shows how the automated process calculated each IRR attribute along with the datasets used to extract the attributes.

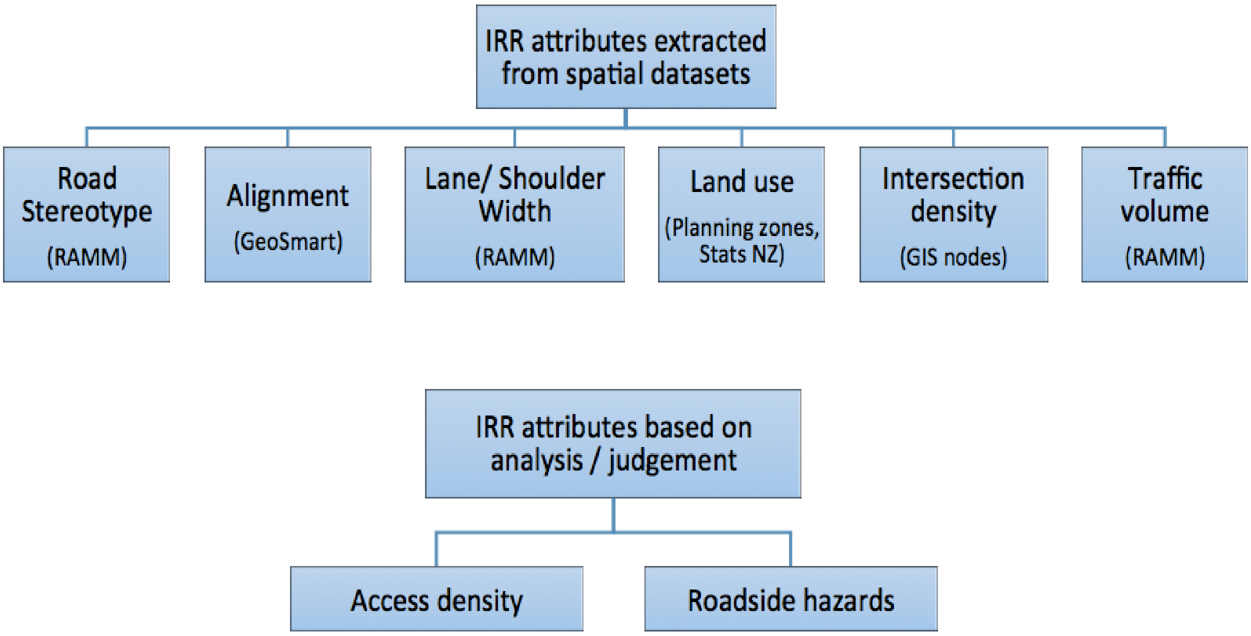

Figure 4. IRR Automation Overview and Datasets Used

Assumptions

While most IRR attributes can be extracted from spatial transport datasets, the automated process incorporates assumptions regarding access density and roadside hazards.

Regression analysis of almost 600km of manually coded IRR data identified that the combination of land use and posted speed limit is a robust predictor of access density. This data was collected for urban and rural parts of New Zealand's road network and represented a good sample upon which to base the access density model.

A comparison of actual and predicted access density categories, as shown in Figure 5, shows that the derived equation incorporating land use and posted speed limit variables predicted the right access density category for almost 70 percent of the sample network. This result is considered adequate considering that access density has the least influence on the overall IRR score.

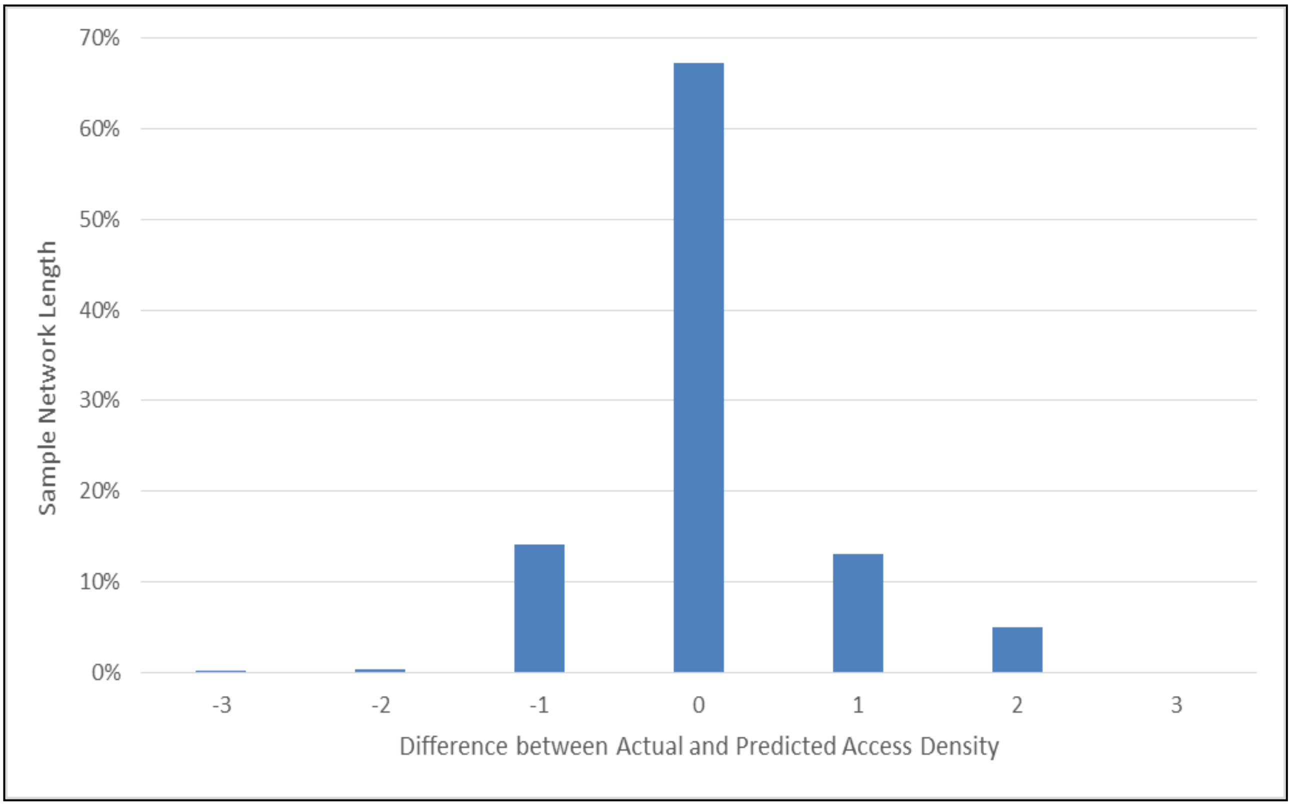

Figure 5. Comparison of Actual and Predicted Access Density

The roadside hazard attribute was determined using a combination of manual identification and applying assumptions based on sample IRR data. In addition to trees and poles, roadside hazards also include aggressive rock face, deep drainage ditches and cliffs with steep drop offs. These hazards were identified manually where possible using high quality spatial imagery and topographic maps.

Further analysis of the sample IRR data showed that the roadside hazard attribute correlates most with the combination of land use and road alignment. Generally, sample corridors with a rural land use were coded as 'moderate' to 'moderate-high' in terms of roadside hazards and urban corridors were coded as 'high'. One exception to this is corridors with the combination of 'tortuous' alignment and 'remote rural' land use which were generally coded as 'high' in terms of roadside hazards due to mountainous terrain in most cases.

In terms of speed management, assuming a consistent roadside hazard category along a particular land use ensures that the presence or absence of hazards intermittently does not have an impact on the resulting safe and appropriate speed.

Results

As part of testing and refining the methodology, 50 homogenous sections in the Top of the South region, equaling to a network length of approximately 134km, were manually coded and also run through the automated process. These roads were selected to have a mixture of surrounding land use with varied IRR attributes and included some of the highest risk corridors in the region in terms of historic safety performance.

As shown in Figure 6, the automated process successfully predicted the IRR of almost 90 percent of the sample network length while the remaining parts of the network were predicted to within one band of the manually coded rating.

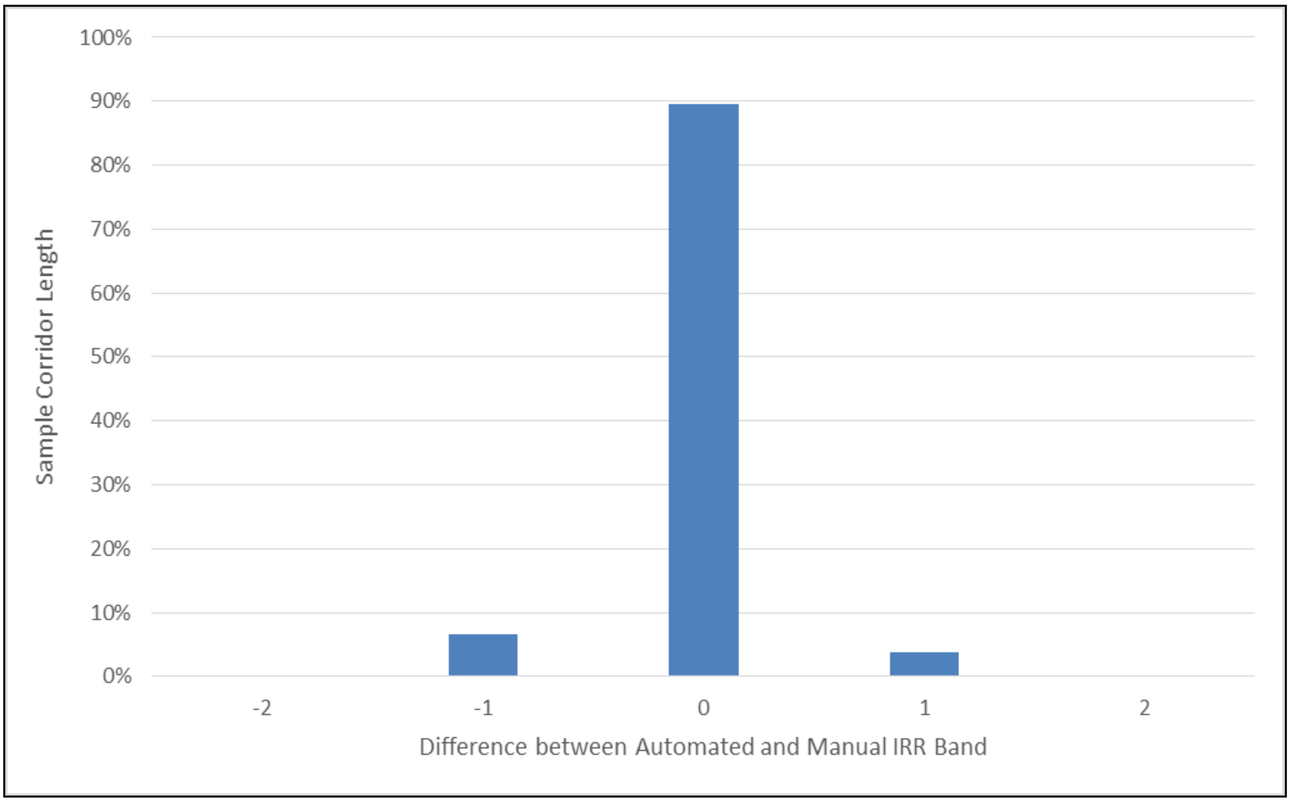

Figure 6. Comparison of Automated and Manual IRR Bands

Furthermore, the automated process successfully predicted the IRR of almost 97 percent of rural corridors in terms of network length. Whereas, only 78 percent of the urban network was successfully predicted which suggests that some refinements may be required to this part of the methodology.

IRR scores calculated from manual coding and applying the automated process were also compared in order to gain further insight into the validity of the model. These scores have been plotted in Figure 7 for the 50 homogenous sections.

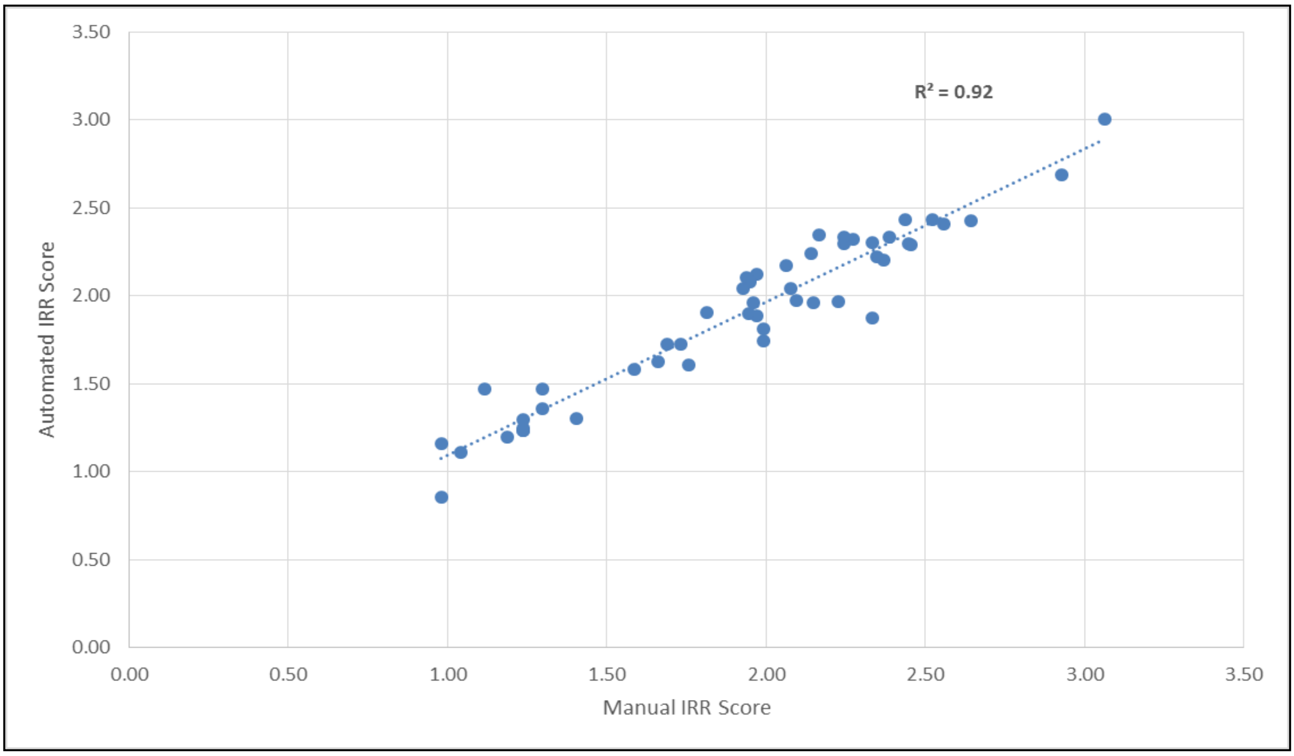

Figure 7. Plot of Automated and Manual IRR Scores

The high correlation between the manual and automated scores confirms that the GIS-based process is robust in automating the IRR methodology. This result gives confidence to road controlling authorities that the automated process is an efficient tool to proactively assess road safety risk in terms of speed management.

The outputs of this methodology were delivered through the integration of IRR with risk maps based on historic crash performance through a single mapping website. IRR attributes assigned to each corridor were displayed along with Google Street View integration to allow users to view actual road conditions. An example screenshot demonstrating the IRR outputs displayed on the website is shown in Figure 8.

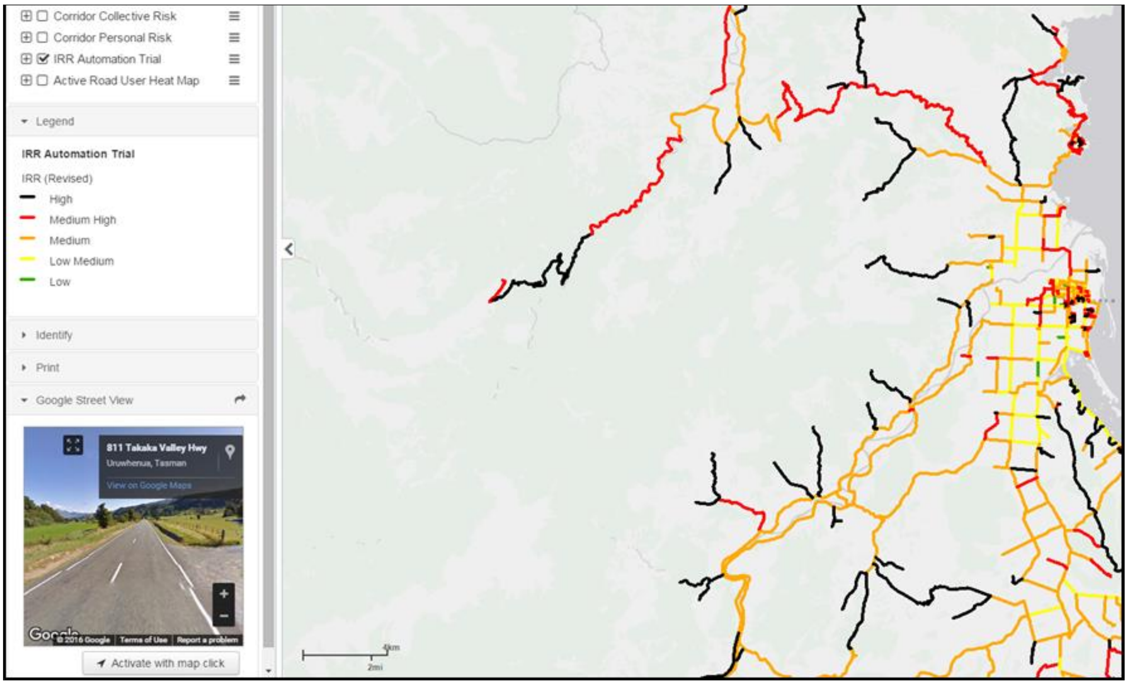

Figure 8. IRR Outputs Displayed on the Website

Discussion

The automated process developed to efficiently calculate IRR across a large network is considered a significant step in demonstrating the proposed speed management framework. The model has been developed in a manner that allows it to be applied to any transport network and therefore has the potential to provide an enduring benefit throughout New Zealand and overseas.

Effectiveness

The IRR methodology, while still being refined as part of proving the speed management framework, can be used to proactively assess road safety risk across a large network, especially on lower volume roads where crash history can be an unreliable indicator of risk. The automated process enables the methodology to be applied in a cost effective manner and the convenience of GIS allows the process to be easily adjusted.

This project required the innovative use of GIS technology to improve the affordability and scale of applying the IRR methodology. While it is technically feasible to manually code road attributes and calculate IRR, the process is hugely time-consuming and cost prohibitive when applied at network level as is the requirement of the speed management framework. Furthermore, the analysis underpinning the automated process involves using existing geospatial datasets and therefore, no new or expensive data collection is required in applying the process.

Feedback from various stakeholders regarding the IRR and resulting safe and appropriate speed outputs indicates that the automated process produces sensible results when applied as a screening tool to identify parts of the network requiring speed management intervention. As an input to the speed management framework, the GIS-based methodology is intended to be rolled-out across New Zealand in an effort to assist all road controlling authorities in identifying corridors where speed management intervention is most likely to reduce death and serious injuries.

Limitations

The automated process of calculating IRR is of greatest value to road safety practitioners when it is used as a network screening tool for speed management intervention. The methodology should be applied with care when considering individual corridors. The process incorporates assumptions regarding roadside hazards and access density due to the lack of such data. Therefore, these site specific attributes should be taken into account when identifying or prioritising speed management interventions at a corridor level. Aerial imagery, Google Street View and other contextual data can be used while undertaking desktop reviews. The simplicity of the IRR model allows users to easily modify the roadside hazard and access density categories as part of sense testing the modelled outputs.

Conclusion

The automated IRR methodology demonstrates that innovative assessment methods and tools are required in order to efficiently deliver the action plans of the Safer Journeys strategy. Current application of this methodology in New Zealand relating to the demonstration and refinement of the proposed Speed Management Guide demonstrate the potential of this methodology in supporting the safe system philosophy. The automation of corridor risk rating methodology presented in this paper will be of particular interest to any road controlling authority wanting to efficiently identify parts of their network where speed management intervention may be an appropriate response to improving road safety performance.

References

NZ Transport Agency. (2015). *Speed management guide: Volume 1 the speed management framework (Final Draft)*. Wellington, New Zealand: Author.

Ministry of Transport. (2010). *Safer journeys New Zealand's road safety strategy 2010-2020*. New Zealand: Author.

New Zealand Transport Agency. (2013). *Safer journeys action plan 2013-2015*. New Zealand: Author.

Waibl, G., Brodie, C., Tate, F., Durdin, P., Turner, S., Zia, H. (2016). *Infrastructure Risk Rating Manual (Draft V10)*. Unpublished manuscript, New Zealand Transport Agency, Wellington, New Zealand.