Cycling Risk on Rural Roads

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Abstract
There have been several high profile cyclist crashes on rural roads recently, igniting debate among the driving public about the suitability of our rural roads to safely accommodate cyclists mixing with high speed traffic. There is good guidance for road designers in the High Risk Rural Roads Guide, based on traffic volume and crash risk. There is also risk advice for drivers, with KiwiRAP risk maps showing relative risk for different routes. These maps are freely available online.

This paper sets out to provide similar design guidance, and public advice, for cyclists, based on analysis of traffic volume, operating speed, carriageway width and sealed shoulder width. By analysis of the relative safety of cycling with these different parameters, the cycling public can make more informed choices about the risk of different rural cycling routes. Where demand for cycling is high despite relatively high risk, the analysis can help local authorities to prioritise investment to improve safety for all road users.
INTRODUCTION

Fatal and serious crashes involving cyclists on rural roads in New Zealand have lead to debate in the media about risk and responsibility. In the ten years from 2003 to 2012, there were 50 cyclist fatalities and 289 serious injuries on rural roads in New Zealand (NZTA, 2013), that is, on roads with a posted speed limit of greater than 70km/h. Less than one percent of all reported rural road crashes involved cyclists, but over 40% of those crashes resulted in a fatal or serious injury to the cyclist. Cyclists are particularly vulnerable in high speed environments, with estimates suggesting that the risk of cyclist serious injury or death in a collision with a vehicle traveling at 70km/h or greater, is close to 100%, as shown in Figure 1.

![Figure 1 Cycling risk relative to vehicle occupant risk](source)

Current guidance for road controlling authorities around the provision of infrastructure for cyclists on rural roads is vague. It is widely acknowledged that interaction of cyclists with high-speed traffic presents significant risk, and that wide shoulders and separated paths are desirable, as outlined in the Cycle Network and Route planning Guide, Section 4.6: Rural Arterial Roads:

*In New Zealand’s rural areas, cyclists rarely have any alternative but to use the same road system as motorised traffic. State highways are often the only suitable routes between settlements. Because this traffic is fast, a high proportion of rural cyclist crashes involves deaths or serious injuries. Cyclists particularly benefit from a sealed road shoulder. Separate paths have even greater safety benefits on rural roads, so their feasibility should always be considered. Narrow rural bridges are a particular hazard.*


Guidance is provided around risk and infrastructure for urban roads as shown in Figure 2 below, from the Cycle Network and Route Planning Guide. Despite including speeds up to 100km/h, the chart itself notes that this guidance is not suitable for rural road design.
OBJECTIVES
Rural roads are by definition higher speed environments than urban roads, which means that the risk of serious injury or death is higher for all road users. It is clear that the more separation there is between cyclists and vehicles, the lower the risk. It is also clear that the lower the speed, and the lower the traffic volume, the lower the risk of crashes occurring, and the lower the severity will be for any particular crash. These intuitive parameters are developed in this paper into an objective and publishable risk chart for rural roads, so that the general cycling public can be informed about the relative risk on different parts of the road network. As well as informing cyclists, the risk assessment can be used by local authorities to prioritise investment in infrastructure. Shoulder widening can reduce risk on popular cycling routes, and capacity investments in State Highways can divert traffic off rural roads with a local access function, making them safer and more attractive to cyclists.

The objectives of this research are to:
- Use an objective assessment method to assess risk for cyclists on rural New Zealand roads;
- Communicate risk on rural roads with a chart displaying relative risk based on traffic speed, traffic volume and carriageway factors; and
- Identify the likely benefits to individual cyclists and to road safety generally that may be realised through greater awareness of relative risk for cyclists on rural roads.

LITERATURE REVIEW
The risks of travel by motorised vehicle are well defined. In 2008, risk maps were published for vehicle travel, for all New Zealand State Highways (KiwiRAP, 2013). These maps show relative risk per kilometre of road (collective risk), and per kilometre travelled (personal risk). The risk is based on exposure to crash risk, that is, the number of reported fatal and serious crashes per...
kilometre of road (collective risk), and the same crashes per kilometre travelled (personal risk).

It is possible to produce vehicle crash risk maps because motor vehicle crashes are much more frequent, and more frequently reported, than cycling crashes. Information about cycling risk is limited because internationally, there is not much data about cyclist volumes on any particular route (e.g. Reynolds et al., 2009), and because crashes are rare and under-reported, though the reporting rates for fatal and serious crashes are higher than for minor and non-injury crashes (Turner, Francis & Roozenburg, 2006).

Cycling risk was considered as an input in development of the New Zealand Cycle Trail (NZCT). For the on-road sections of this trail, roads with a 100km/h posted speed limit were assessed for inclusion and for grading based on a combination of Average Annual Daily Traffic (AADT) and sealed shoulder width. The grading decision matrix is shown below (Figure 3). The numbers and gradings in this Figure were assessed based on discussion among transportation professionals, considering best practice standards and guidelines, and subjective experiences of cyclists themselves.

![Figure 3 New Zealand Cycle Trail on-road grading matrix](image)

Of course, risk maps such as those provided for KiwiRAP rely on accurate travel data. While vehicles are counted frequently on most rural New Zealand roads, information about cycle travel is limited. Most of our information about cycling comes from the New Zealand Household Travel Survey (Statistics NZ, 2013) which summarises journey-to-work information. As the average cycling trip length in this database from 2009 - 2012 is 4.1km, it is unlikely to include much rural cycling. Recreational cycling, which likely makes up most of the rural cycling kilometres travelled in New Zealand, is not measured.

**Rural cycling risk and sealed shoulder width**

Conversion of best-practice guidelines to risk maps suggest that 1.5m sealed shoulder is optimal for New Zealand rural roads. International guidance refers to 1.2m being an acceptable shoulder width to allow room for a single cyclist to be overtaken, with 0.9m an absolute minimum (http://www.trailsandtours.com/upload/pdf/bike_rural_road_shoulders.pdf) Though the data in Figure 1 suggest that there is no increase in cycling risk above traffic speed of 70km/h, there is evidence to suggest that with a speed environment closer to 70km/h than 100km/h, a motorist will have a longer reaction time in the event of a likely collision, making such collisions marginally less likely to occur, or possibly to occur at lower than average travel speeds, given braking opportunity.

Therefore these bands are defined for this study as defining high, medium and low risk on rural roads as follows:

- **>0.9m**: High risk, all speeds above 70km/h
- **0.9m – 1.5m**: Medium risk, 70-80km/h; high risk, >80km/h
- **1.5m – 1.8m**: Low risk, 70-80km/h; medium risk, >80km/h
- **>1.8m**: Low risk, all speeds
Rural cycling risk and traffic volume
Australian research suggests a threshold at 3,000 vehicles per day (Cox, Lennie & Arndt, 2012). Shoulder width guidelines produced by the Road Planning and Design Manual suggest shoulder widths of 1.5m for AADT below 3000 vehicles per day, and 2.0m above. For very low volume roads (below 1,500 vehicles per day), risk of collision is lower than higher volume roads due to low exposure. Therefore these roads are assigned as ‘low’ or ‘medium’ risk depending on sealed shoulder width and traffic speed.

New Zealand data shows that above 4,000 to 6,000 vehicles per day, the proportion of head-on crashes overtakes the proportion of loss of control crashes. This suggests that driver frustration and overtaking likelihood increase at the threshold of 4,000 to 6,000 vehicles per day. This volume is therefore taken as a threshold for increased cycling risk due to meaningful increases in potential conflict.

It is known that crashes do not increase linearly with respect to traffic volume. Turner, Francis and Roozenburg (2006) developed accident prediction models for urban crashes involving cyclists. One of these models predicts mid-block cycling accidents excluding those involving interaction with parked vehicles. This model appears most suitable for estimating the relationship between traffic volume and crash risk for rural roads. The model is

\[ A = b_0 \times Q^{b_1} \times C^{b_2} \]

where
\[ A = \text{accidents} \]
\[ b_0, b_1 \text{ and } b_2 \text{ are model parameters} \]
\[ Q = \text{the two-way flow along the link, and} \]
\[ C = \text{the two-way cycle flow along the link.} \]

\[ \text{Equation 1} \]

In this model, the value of parameter \( b_1 \) describes the relationship between cyclist accident rate and traffic volume. The value of \( b_1 \) for this equation is 1.1557. As this number is very close to 1, the relationship between cycle crash risk and traffic volume for the purposes of this exercise is assumed to be linear.

RISK MAP METHODOLOGY
Considering the literature and guidance, the following principles informed development of the risk map criteria:

- Crash survivability decreases markedly from 40km/h, and decreases to 0 at any impact speed above 70km/h
- Cyclist exposure to crash risk reduces linearly with traffic volume, with risk thresholds at 1500, 4000 and 6000 vehicles per day
- Sealed shoulder width at or above 1.2m is desirable for vehicles to pass cyclists safely

These principles result in the risk charts below.
Figure 4 Cycling risk on rural roads, wide shoulder

Figure 5 Cycling risk on rural roads, medium shoulder

Figure 6 Cycling risk on rural roads, narrow shoulder
RISK MAP EXAMPLE
The charts above were used to plot relative risk on a portion of Waikato District, popular with road cyclists due to its proximity to Hamilton and its flat to rolling terrain. Shoulder width, traffic volume and speed data was provided by Waikato District Council for all rural local authority roads. Data for State Highway 1B was found from the KiwiRAP Analysis Tool, KAT, from the intersection with Peach Road (SH1B RS0 RP13.2) in the north to the intersection with Holland Road (SH1B RS15 RS11.3) in the south. In this example, none of the State Highway section has a sealed shoulder width greater than 1.2m. Combined with traffic volume and speed, all of the State Highway section is therefore ‘high risk’ in this example.

The Waikato District roads in this example vary from low to high risk. Speed data is not comprehensive for these links, with some roads having a single speed measure applied to their entire mapped length. Waikato District were also unclear in providing speed data, about whether this speed measure is a mean speed, or some other measure, therefore clearly the risk map below is an example of how such a map might be produced, and is not considered representative of risk as determined by the methods developed in this paper. More reliable speed data would improve the reliability of the risk map.

There are urban areas (Gordonton and Hamilton) included in Figure 7 which do not have risk mapped in Figure 7.

Figure 7 Risk map of sample area

DISCUSSION
As an introductory study, this paper demonstrates the feasibility of objective risk mapping for New Zealand rural roads. The resulting map example is similar to KiwiRAP risk maps for vehicle traffic, though factors influencing risk for rural cyclists have not been as rigorously established as those for factors influencing KiwiRAP ratings.

It is noted that the analysis presented considers road links, in isolation from intersections. There would be merit in a separate analysis of risk factors for cyclists at rural intersections.
For any risk mapping exercise to be useful, it is important that the data informing risk profiles is accurate. Some of the data in the example presented here was averaged over significant lengths of road. Some categories of data (for example, those provided in KAT) differ from the categories used to establish risk profiles in this study. It may be that existing categories can be used in a future iteration of the risk profiles, though it is likely that district council data in particular is variable in the way that it is collected.

The effect of cyclist volumes on crash risk was not investigated for this study, though it is known that generally, increasing numbers of cyclists results in a reduced risk per-cyclist. That is, for cyclists as well as for vehicular traffic, there is a non-linear relationship between volume and risk. One reason for this may be that as numbers of cyclists increase, drivers become increasingly aware of their presence and are therefore more likely to notice and accommodate them in overtaking and intersection manoeuvres. It may also be that increasing cyclist volumes results in more groups of cyclists, which are likely to be more visible than a single cyclist. However, the nature of this relationship between cyclist volume and crash risk is not well defined. That is, it is unclear what increase in number of cyclists is meaningful. It may be that there is a threshold that results in meaningful change in risk, rather than a simple addition of small numbers of cyclists to any particular route.

Though rural cyclist volumes are not known to be counted in any routine way, increasingly it may be possible to use technology to establish the relative popularity of different cycling routes. Websites such as MapMyRide (www.mapmyride.com) publicise cycling routes as mapped by cyclists. The increasing volume of mapped routes provides some indication as to the relative popularity of different road links, at least as used by the users of MapMyRide. If cyclist volumes were collected, data could be used in conjunction with risk maps to prioritise investment in shoulder widening. Screenshots from MapMyRide that include portions of the study area are shown below.

![Figure 8 Examples of public mapped cycle rides, from MapMyRide](image)

In summary, if more comprehensively developed, the risk mapping as demonstrated in this paper could be used to inform cyclists about relative risk on rural roads, in the same way that publicised KiwiRAP risk maps inform motor vehicle drivers about risk on State Highways. Though there is little evidence to suggest that drivers use KiwiRAP in this way, those who organise cyclist routes for some groups may be more considered. For example, organisers of group cycling events such as school training groups, club rides and races, which attract anywhere from dozens to thousands of cyclists, could benefit from risk mapping more than an individual cyclist might. The increasing focus on risk management in schools, clubs and organised events may support use of tools such as risk maps.
It is important to note that cycling trips, particularly rural cycling, are generally undertaken for exercise and recreation, that is, for the trip themselves, as opposed to motor vehicle trips which are generally undertaken to travel between an origin and a destination. Rural cycling trips often start and finish at the same place and the route is selected for reasons other than directness. Therefore there is perhaps more potential to inform cycling route choice with risk mapping, than there is to inform motor vehicle trip choice.

Mapping can also help road controlling authorities to prioritise shoulder widening investment, particularly when used in conjunction with information about cyclist numbers on particular links.

**RECOMMENDATIONS**

It is recommended that the risk mapping methods presented here be further developed in consultation with the cycling public and with transportation professionals. In particular, the difference in risk between roads and intersections ought to be further investigated.

Once developed, it is recommended that a trial district be mapped and the risk maps published to further evaluate the tool’s usefulness for cyclists and road controlling authorities. Over time, iterations of the risk mapping may be used to inform best practice through increased understanding of the relationship between cyclist and traffic volume, sealed shoulder width, traffic speeds, and cycle crash risk.

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