What is Self-Explaining, Anyway?
An Investigation of Speed Variability on Rural New Zealand Roads

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ABSTRACT
The concept of self-explaining roads is becoming increasingly talked about in the context of a safe system approach to transport delivery. This technical note looks at the diversity of New Zealand's rural road network and presents a method for analysis of what self-explaining might mean for our country of varying alignment and road function, and range of road users. As one of the criteria for self-explaining is homogeneity within a road section, this note investigates whether there is any meaningful relationship between speed variability, and personal crash risk, across a range of rural State Highway sites. It is found that there is a positive correlation between standard deviation of speed, and personal crash risk when measured at a site. Across one corridor where multiple speed analyses were possible, a narrow overall distribution of speeds corresponds with low personal crash risk. It is concluded that if the transport profession is to collaborate to work towards self-explaining roads for New Zealand, there may be merit in using speed data more effectively to analyse homogeneity, and to improve road safety outcomes.

INTRODUCTION

New Zealand's current guiding document for road safety, *Safer Journeys* (Ministry of Transport, 2012) promotes the design of safe roads that are '*self-explaining in that their design encourages safe travel speeds.*' The term 'self-explaining' has been in use for almost twenty years (Theeuwes and Godthelp, 1995), though it remains perhaps an elusive and misunderstood goal. In their original paper, Theeuwes and Godthelp (1995) defined a self-explaining road as a traffic environment that '*elicits safe behaviour simply by its design'*. Thirteen criteria for such an environment were proposed, including '*unique behaviour for a specific category (homogeneous within one category and different from all other categories)'*. This study suggests that homogeneity can be measured by analysis of traveling speeds, and in particular, speed variation.

Crash risk for a section of road midblock has long been understood to be proportional to average travelling speed (Nilsson, 1982; Elvik et al, 2004). The relationship between crash risk and speed variability on a road section is less clear. One summary study (Aarts and van Schagen, 2006) concluded that while there may be a correlation between speed variance and crash rate, the larger speed variance tended to be associated with relatively low average traffic speeds.

A recent study in Auckland (Charlton et. al, 2010) found that visually distinct road categories corresponded with improved homogeneity of speeds in an urban environment. To date, no study has investigated New Zealand rural roads in particular, with regard to the relationship between speed variability and crash risk. This technical note looks into whether standard deviation of speed at a point and along a corridor across a range of rural State Highway sites could be used as a proxy measure for homogeneity. Given the prevalence of serious injuries on rural roads in particular (183 out of 259 fatal crashes in New Zealand in 2011 took place on 'open roads' (NZTA Crash Analysis System, 2012)), the issue of defining self-explaining in a rural context is important if *Safer Journeys* goals are to be met.

STUDY METHOD

To investigate the relationship between speed variability and crash risk, speed data collected by the NZTA was analysed in conjunction with crash data from the NZTA Crash Analysis System, CAS. The following criteria were used to select candidate traffic count sites:

- Within Waikato and Bay of Plenty (for ease of correlation with crash data)
- Posted speed limit of 100km/h
- Not within 1000m of another State Highway intersection
- Not on a seemingly out-of-context curve (generally in fitting with the surrounding road curvature; a subjective assessment)

Ten sites were identified as candidates for analysis of their speed distribution, as isolated sites. Three of these sites were located within a 13km corridor and were therefore selected for a single corridor analysis of speed variation. All of the available speed data for the 2012 calendar year was analysed to find the overall mean speed, and standard deviation of speed. As speed data was only provided in 10km 'bins', the median of each bin was used to determine the mean speed. The standard deviation was found using established methods to estimate standard deviation from a frequency table. Site locations are shown in Figure 1.

The route position and reference station from each count site was referenced and five years of crash data was obtained from CAS (2007 – 2011), for one kilometre upstream and downstream of each count site. As the count sites were considered to represent topography roughly indicative of the surrounding two kilometres, this range was considered appropriate for the crash analysis as a starting point for investigation. This, combined with the published Annual Average Daily Traffic volume (AADT), enabled calculation of a measure of 'personal risk' for each site, in terms of crashes per vehicle-kilometre travelled. This calculation enabled a fairer comparison across sites of different traffic volume than a simple crash-rate comparison. For the crash analysis, crashes at intersections (where the CAS code defined the crash location as being at an intersection) were excluded.

It is noted that the KiwiRAP definition of ‘personal risk’ (KiwiRAP, 2012) is equivalent to the ratio of fatal and serious crashes only, to distance travelled. In the case of this study, as the risk calculation covered only a short two kilometre range, there was not enough crash data to analyse only fatal and serious crashes. The ‘personal risk’ referred to here includes exposure to all reported crash severities, including non-injury crashes.

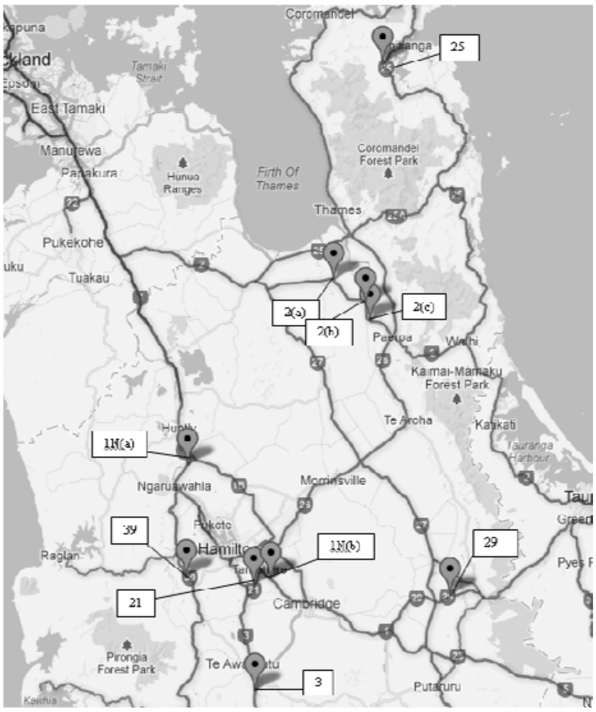

Figure 1 Count/speed site locations

RESULTS & DISCUSSION

Individual sites

The speed and crash data for analysed sites is summarised in Table 1 and Table 2. The associated relationship between standard deviation of speed, and personal crash risk, is shown in Figure 2.

Table 1 Speed Data

Chart Reference (Figure 1)	State Highway	Site Reference	Reference Station and Route Position (RS/RP)	AADT (veh/day, 2011)	Mean speed (km/h)	Standard Deviation of speed (km/h)
1N(a)	1N	1N00529	519/9.56	14911	90.8	8.5
1N(b)	1N	1N00563	557/6.24	17501	90.7	9.0
2(a)	2	00200052	48/4.0	5264	95.4	9.6
2(b)	2	00200062	61/1.0	6786	94.3	8.7
2(c)	2	00200066	61/4.8	5960	94.2	8.6
3	3	00300034	16/17.355	7407	91.8	9.2
21	21	02100004	2/2.08	4921	94.5	9.3
25	25	02500134	127/7.08	2915	81.6	9.8
29	29	02900057	50/6.55	4609	97.6	8.0
39	39	03900024	18/5.65	3133	97.4	9.9

Table 2 Crash Data

Chart Reference (Figure 1)	Crashes within 1000m: all	Crashes within 1000m: Fatal and Serious	Crash Risk/million veh-km/year
1N (a)	7	2	47
1N (b)	13	1	74
2 (a)	8	2	152
2 (b)	7	1	103
2 (c)	7	2	117
3	12	0	162
21	5	0	102

Chart Reference (Figure 1)	Crashes within 1000m: all	Crashes within 1000m: Fatal and Serious	Crash Risk/million veh-km/year
25	4	1	137
29	2	0	43
39	5	1	160

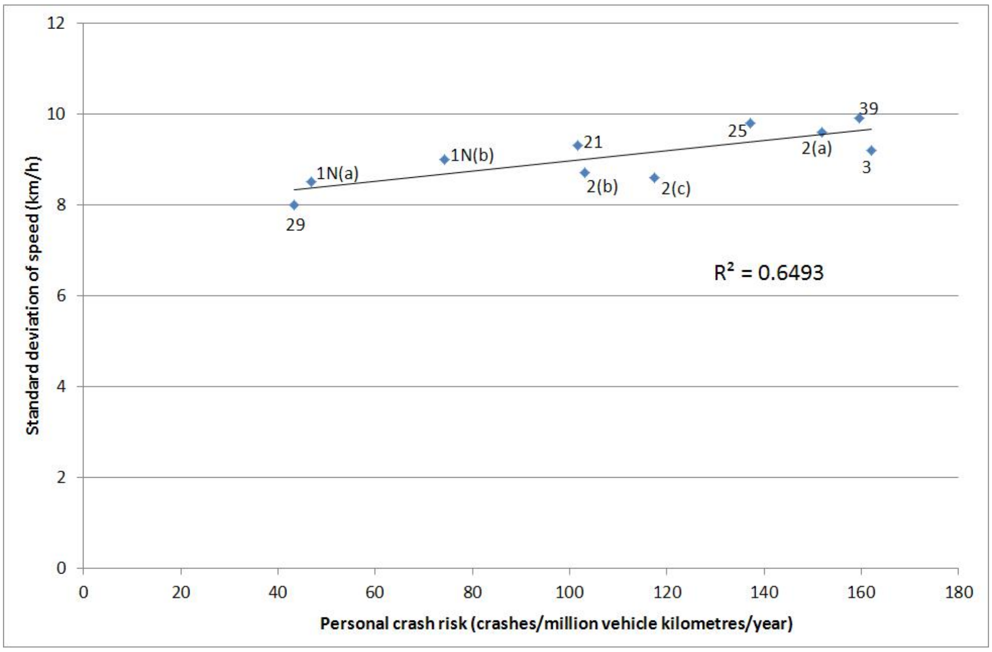

Figure 2 Crash risk vs standard deviation of speed

The results showed a positive correlation between standard deviation of speed, and personal crash risk. It is not surprising that there is variation in the data, given the complexities affecting both traffic speed and crash occurrence. Some factors affecting the deviation from the linear trend shown in **Figure 2** may include:

- The crash data used for calculation of personal risk was from 2007 – 2011 inclusive. The speed data was from 2012. It is possible that road and roadside conditions may have changed between the 2007 crash data, and the 2012 measurement of speed.
- Sites showed different mean speeds. The data could be further transformed with a power model to account for this, though it is noted that personal risk did not show a strictly increasing trend with mean speed for the study sites; the site with the highest mean speed, for example (SH29), had the lowest corresponding personal risk.
- Known road environment features that contribute to crash risk (for example alignment, road geometry and lane widths etc) were not analysed.
- The percentage of heavy vehicles at each site was known to have varied but was not analysed further.
- The traffic count data was presented in speed 'bins' at 10km/h increments. Therefore the resultant standard deviation was an estimate only. Future studies could make use of raw speed data to remove this effect.
- The traffic speed 'bins' started at "<60km/h". Some sites were discarded as a significant proportion of the data involved speeds below 60km/h, making the distribution non-normal. This effectively meant that only high-speed sites were able to be analysed.
- Increasing traffic volumes do not relate in a linear manner with increasing crash risk. Therefore sites with higher traffic volume can be expected to exhibit crash rates lower than a linear relationship would suggest. The analysis did not specifically account for traffic volume effects on crash rate.
- All traffic count data was used (not free speeds in isolation), therefore the higher the traffic volume, the higher the proportion of following vehicles, which will have influenced distribution of speeds.

- Though intersection crashes were excluded, not all reported crashes are directly influenced by speed. It is likely that some crash types will be more directly related to speed profile parameters than others.

Corridor analysis
As self-explaining roads are defined in terms of a road category, and not a single point, the speed distributions for the three sites covering an approximate 13km length of SH2 near Paeroa were graphed (**Figure 3**) to show an example corridor distribution, for subsequent discussion in relation to personal crash risk.

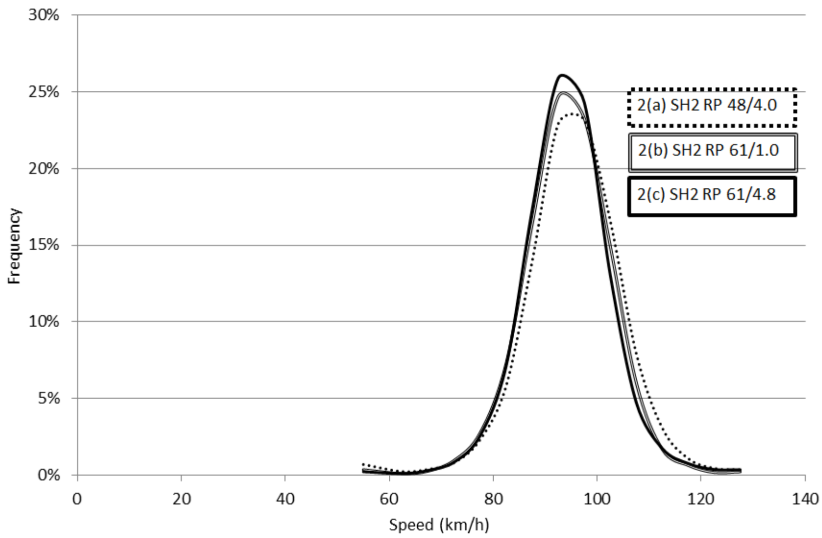

Figure 3 Speed distribution, SH2 sites

It is clear from **Figure 3** that the speed profiles are very similar at these locations, suggesting that factors influencing driver speed choice do not vary much along its length. In terms of self-explaining roads, if standard deviation of speeds can be used as a proxy measure for homogeneity, then corridors (rural or otherwise) showing speed profiles such as this would correspond with reduced personal crash risk, relative to other corridors. The personal crash risk along this corridor according to the 2012 crash risk maps (KiwiRAP, 2012) shows that this section of SH2 has ‘low’ crash risk (the lowest possible ranking), based on analysis of fatal and serious crashes from 2007 – 2011.

CONCLUSION
Given the huge range of issues affecting speed and crash risk generally, it is perhaps remarkable that any relationship at all is found between standard deviation of speed, and crash risk. It was found that the smaller the standard distribution of speeds at a point, the lower the personal crash risk. Along an example corridor, a narrow distribution of speeds as a whole corresponded with low personal crash risk for a wider length containing that corridor. It is noted however that this corridor analysis relies on a very small sample.

The findings of this introductory study support further investigation into the relationship between speed variation and crash risk (at a point, and along a corridor) if we are to work towards a self-explaining road network. A better understanding of the factors influencing speed distribution on rural roads will help inform collaboration among transport professionals in delivering roads across the rural network that elicit safe behaviour by design.

RECOMMENDATIONS
Further investigation into engineering factors that determine self-explaining roads
This paper has studied one potential method to measure a key criterion of the concept of self-explaining roads, and has used a rural context as its example. The results of this study support more investigation into the relationship between variability of speed, and crash risk. More

importantly, the design decisions influencing homogeneity of speeds, and how design parameters can grouped into visually distinct categories, ought to be further investigated.

More and better collection of speed data

This study's investigations were limited by the available data. The Ministry of Transport collects speed data that may have been more useful for this study, and this data ought to be explored for any further investigations. Nevertheless, many of the sites used to count State Highway traffic could be better placed to provide useful speed information, while also collecting the required count data. For example, many sites are within 300m of another State Highway intersection. There is therefore a significant proportion of accelerating and decelerating traffic at these sites. Moving these count sites some 500m farther from the intersection would yield the same traffic count data, while providing more useful speed information. This data could be used not only for analysis of speed variation as proposed by this study, but for a range of other uses, including before/after studies of road safety improvement projects, for example.

Collaboration between road controlling authorities

As stated in this note, drivers do not drive point to point, or even within a single corridor, but all over the country across all Road Controlling Authority (RCA) regions. If self-explaining roads are not to be confined to local area residential traffic calming, we need collaboration so that the homogeneity within and between road categories is meaningful, not just for one RCA and its network, but in terms of the actual journeys that New Zealand drivers undertake. Importantly, this does not mean that a rural journey of several hundred kilometres need elicit homogenous behaviour along its entirety, but that visually distinct categories ought to be developed in accordance with the safe speed range appropriate for each road segment within that journey.

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