How Drivers Judge the Safety of the Road

Dr Turner[a], S., Khoo[b], J., England[c], J.

[a] National Specialist – Road Safety, MWH New Zealand Ltd, Christchurch, New Zealand
[b] Senior Transport Engineer, Beca Ltd, Auckland, New Zealand
[c] Senior Road Safety Engineer, MWH New Zealand Ltd, Wellington, New Zealand

Abstract

The 'objective' crash risk of a road section can be estimated using either historical crash data or using crash risk relationships based on road features and operating conditions. Understanding the 'perceived' crash risk of a road section is more difficult as it's based on how drivers judge the safety of the road. Perceived risk is important as drivers behaviour is linked to how safe they think a specific section of road is. Road safety can be compromised when the perceived risk is a lot lower than the objective crash risk. Drivers need clear messages of where the road is safe and where it's less safe, so they drive more carefully in less safe situations. This research compares the perceived risk specified by surveyed drivers for various road sections with the objective risk, as calculated using the KiwiRAP crash risk rating method. Drivers rated perceived risk using three different surveys methods; an online web-survey of over 500 drivers rating the risk of various sites from photos; a sample of drivers rated video files and photos of road sections in Waikato and Canterbury, New Zealand; and participants drove a route in Canterbury and rated the risk and likely safe speed of road sections. Participants also ranked benefits of potential counter-measures. Results showed drivers rated curves and narrow road sections with a high perceived risk, while roadside hazards typically had a lower risk.

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Introduction

Driver perception of crash risk has been found to have an impact on whether crashes occur at a site or along a stretch of road. While two sites may have the same level of objective risk, the site that looks less safe to drivers (higher perceived or subjective risk) often has a lower number of crashes than the one that looks safe (lower perceived or subjective risk).

A key role of road safety professionals is to ensure that the motoring public are made aware of the risk they face when driving on various sections of the road network so that they can behave in a manner required to safely negotiate the risk. This is generally achieved by applying safety countermeasures with visual cues such as delineation (e.g. raised reflective markers, edge-lines, chevrons and edge marker posts), signage and hazard markers.

While there is considerable research on the impact of safety countermeasures on objective risks (or the actual number of crashes), there is limited research, especially in New Zealand, on perceived or subjective crash risk. The purpose of this research is to better understand where the objective (directly measurable) road safety risk matches drivers' subjective (indirectly measurable) risk, and its effects on driver behaviour. A better understanding of the drivers' subjective risk will allow the risk associated with specific roads to be communicated more effectively to the drivers using them.

The project aims to clarify in a New Zealand context:

- where objective (directly measurable) risk matches drivers' subjective (indirectly measurable) risk: i.e. the road is self-explaining in terms of risk;
- where objective risk is greater than drivers' subjective risk: the road environment is not as safe as perceived by drivers;
- what perceptual cues are used by drivers to measure their subjective level of risk.

By identifying the factors contributing to correlation between objective and subjective risk, the research indicates areas of further investigation and trials in terms of ways to use cues in the road environment, to align objective risk afforded by the road, with drivers' subjective risk perceptions.

In relation to the aims of this research, the four primary questions investigated in this research are:

- What level of risk is experienced by drivers on hazardous New Zealand roads?
- What road features do drivers use to judge driving risk?
- Which hazardous road situations are under-recognised by New Zealand drivers?
- What safety countermeasures can be used to convey a more accurate perception of risk?

This research was undertaken in collaboration with the TARS Research Group at Waikato University, who have also undertaken a research study on this topic for the AA.

Measuring Objective (Actual) Risks

The objective risks of various sections of the New Zealand state highway network have been assessed using KiwiRAP (New Zealand Road Assessment Programme). This risk measurement is based on both the historical crash data reported, as well as on the level of safety features 'built-in' to the road (and roadside).

Survey Method 1: Web Survey

An online web survey was chosen to obtain a cross-section of the subjective risks perceived by New Zealand drivers. The online web survey had an alternative forced-choice design, in which participants were 'forced' to rank two/three images by their levels of perceived risks.

As the focus of the study was on understanding the relative perceived risks of various road features by drivers, the photographs selected (see Figure 1 for an example) for use in the survey comprised of differing road features such as:

- Median barrier
- Road Markings
- Intersections
- Presence of Signs
- Curves (& grade)
- Road-side objects
- Road-side ditch
- Wide Median

The questions developed for the online web survey included questions related to demographics (age and gender) and driving experience (type of driving licence, driving distance) in addition to the drivers perception of relative safety risk (the images). This online survey was launched and distributed to the New Zealand Automobile Association members on the 4 April 2013, and ran until the 30 April 2013. A total of 559 respondents were collected during this period, which was higher than the 100 participants initially targeted.

Based on the online web survey results and analysis, the conclusions that can be drawn are:

- Curves ranked as higher risk (even with barriers) than straights with other roadside hazards (such as power poles).
- Undivided carriageway (with no power poles) ranked as higher risk than a divided carriageway with wide median and wire rope barrier.

Figure 1. Web Survey – Ranking of Perceived Risk Photos

- No significant difference in perceived risk between a curve with or without roadside barrier.
- Presence of barriers on straight ranked as lower risk.
- Perceived risks do not match with objective risks (see Figure 2), with no correlation evident. This is likely to be a result of the objective risk taking into account features, such as road-side objects that seem to have little influence on driver's perceived risk.

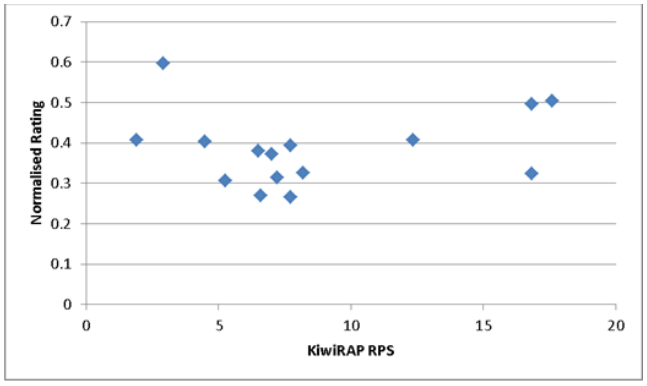


Figure 2. Relationship between Perceived Risk and Objective Risk (RPS)

(note the subjective rating data has been normalised as scoring was for two images in some cases and three images in others)

- Generally very little difference in the responses between different age groups and gender, although there is some evidence that the Under 35 participants have under-recognised the risks of the non-obvious roadside hazards on a straight road, such as roadside ditch and narrow/limited shoulder width.
- Presence of side road (even with wide centreline) consistently ranked as higher risk compared to presence of road-side furniture (i.e. power poles, barriers, warning signs).

The above findings are based on a forced-choice decision for the survey participants, and the results would probably suggest participants' perceived risk in a conscious state.

Survey Method 2: Video Survey

In-person interviews, using videos of several sections of state highways were carried out to assess subjective risk perception. A total of six participants viewed the video sections and answered a series of questions. The participants were also asked to assess the level of risks on counter-measures, which were digitally inserted into photographs.

The road section videos were selected to provide a range of objective and subjective risk elements and ranged between 2km and 5km such that the sections are relatively homogeneous throughout each of the segments selected. The segments of these videos were:

- SH1 between south of Taupiri to north of Ngaruawahia – RP 519 / 8.0-13.0
- SH1 between Tahuna Rd Interchange to end of divided carriageway - RP 502 / 8.0 – 9.8
- SH1 from end of divided carriageway to north of Huntly - RP 502 / 9.8 – 13.2
- SH75 (Christchurch to Akaroa route), selected 15km split over 4 sections

Table 1 shows the perceived risk (average of six participants) and objective risk (from KiwiRAP) of the seven road sections (including 4 sections on SH75). A lower KiwiRAP RPS indicates a safer road. For perceived risk a higher value (up to 10) is safer. In column 3 and 6 the ranking has been provided in brackets.

Table 1. In-person Video Survey Results Summary

Section	Perceived Safe Speed (km/h)	Average Safety Rating (10 being safest) / Overall Safety Ranking (1 being safest)	Noted Safe Features	Noted Unsafe Features	KiwiRAP RPS / Overall Safety Ranking (1 being safest)
SH1 between south of Taupiri to north of Ngaruawahia	Mean: 95 Std Dev: 6.1	7.8 (=2)	Passing lane Straight road Wide shoulder Well sign posted Flat terrain	Intersection / side road	11.0 (=6)
SH1 between Tahuna Rd Interchange to end of divided carriageway	Mean: 103 Std Dev: 9.4	8.5 (1)	Median / wire rope barrier Lamp posts (well lit at night) Relatively straight section Well sign posted Dual carriageway (easy to pass)	Merging	2.6 (1)
SH1 from end of divided carriageway to north of Huntly	Mean: 89 Std Dev: 8.4	7.3 (4)	No passing lines Wide shoulder Well sign posted	Intersection / side road Roadside activities (shops)	9.6 (3)
SH75 RP 35 / 0.0 -	Mean: 74 Std Dev:6.4	6.4 (7)	Well sign posted Good visibility	Lots of curves Narrow / limited shoulders	9.4 (2)
SH75 RP 35 / - 5.3	Mean: 84 Std Dev: 3.5	6.7 (=5)	Well sign posted Good visibility	Narrow / limited shoulders Limited overtaking opportunities	10.6 (5)
SH75 RP 24 / 0.0 -	Mean: 95 Std Dev: 14.7	7.8 (=2)	Well sign posted Good visibility Relatively straight section	Intersection / side road Sharp curves	11.0 (=6)
SH75 RP 24 / - 5.17	Mean: 77 Std Dev: 8.5	6.7 (=5)	Well sign posted Relatively straight section	Narrow / limited shoulders Sharp curves	9.8 (4)

The following findings can be drawn from the results above:

- Unsafe features mentioned mainly consist of the horizontal road geometry (i.e. sharp curves), narrow road width (including shoulders) and presence of side roads.
- Figure 3 does show there is some relationship between perceived risks and the objective risk (RPS), but the two are generally in opposition to each other, with perceived risk decreasing as objective risk increases. The exception is the section of SH1 between Tahuna Road interchange and end of divided carriageway, which is quite a lot safer than the other routes. The main outlier is the first section of SH1 (south of Taupiri) which has a lower perceived risk but a quite high objective risk. The relatively higher traffic volume, lack of a median barrier and presence of road-side hazards are the likely reasons for the high objective risk.

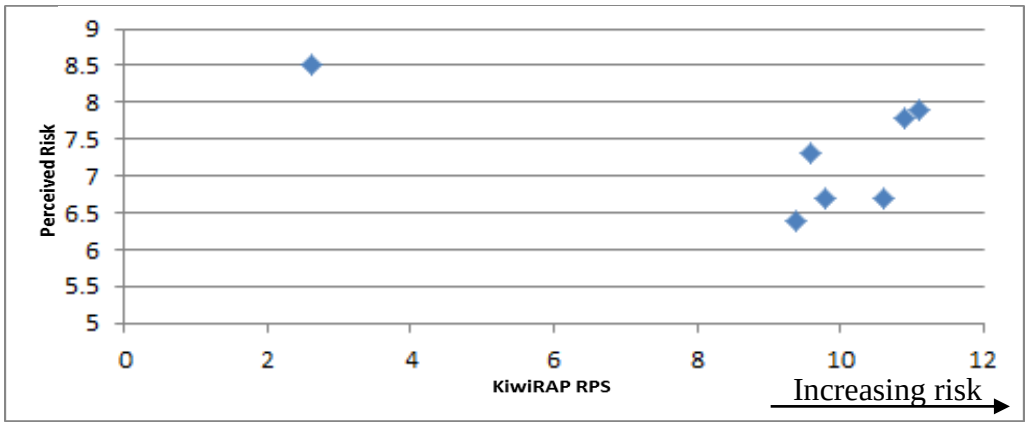


Figure 3.Perceived risk vs Objective risk (KiwiRAP RPS))

- Perceived safety features consist of signage and good road geometry (i.e. straight and open section)
- There is little mention of roadside hazards, such as roadside ditch, power/light poles and banks, which is taken into account and measured in KiwiRAP RPS. This indicates that over a longer distance (compared to a precise location survey carried out in the online web survey), the participants have not recalled or noted these to be of significant concern.

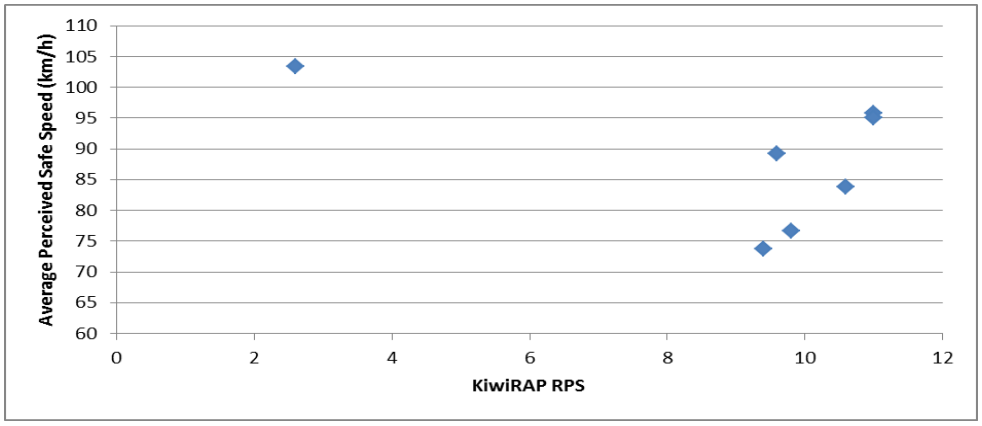


Figure 4.Perceived safe speed vs Objective risk (RPS))

- There is some relationship between objective safety and the perceived safe speed (Figure 4). Other than the section of SH 1 south of the Tahuna Road interchange (see Table 1), the drivers' specified higher perceived safe speeds for sections with higher objective risk. This result is of concern and needs further investigation, as we would expect the reverse of this.

A series of pictures were then digitally manipulated and participants were then asked to rate the level of perceived risks (out of 10, with 10 being safest). Figure 5 shows an example of the different road features/ countermeasures used in the survey.

Figure 5.Example of photos showing different Road layouts

The researcher who interviewed the participants noted that all participants intuitively tried to seek the differences between the images, and the researcher constantly reminded the participants that the purpose of the survey was to understand their perceived risks to avoid the participants being primed to provide the answers that were deemed as 'correct' answer.

Based on this countermeasures survey, the following conclusions can be drawn:

- The presence of curve advisory speed and signage was perceived to be safer. This finding is consistent with the findings from the in-person video survey where participants identified curve advisory speed and chevron signs as safer features.
- Median separation (such as wire rope in this case) was perceived as the safest countermeasure, followed by high crash rate sign, wide shoulder and wide centreline.
- Wide centreline was perceived to be less safe compared to the existing scenario without normal painted lane lines. This could be attributed to confusion attributed to unfamiliarity of the markings, as reported in the Wide Centreline Trial Report (Burdett, 2012), where drivers reported being uncertain as to what the road markings were indicating.

Survey Method 3: Drive-Over Survey

A sample of six drivers was selected to drive-over one of the 20km routes used in the video surveys (Method 2), accompanied by a researcher. The route selected for the drive-over was State Highway 75 (RP14/1.2 – RP35/7.5), approximately between Tai Tapu and Poranui Beach Road intersection (on the link between Christchurch and Akaroa). This route was used in previous risk evaluation research (by Tate & Turner, 2007).

In this survey, each driver was asked to firstly drive through the entire length in both directions. Each driver was then asked to drive through each study section (in both directions) and was stopped at a safe location to rate their perceived risk (on a scale of 1 to 10) and what they perceived to be a safe speed for that section. The drivers' actual speed was also recorded using GPS equipment. Table 2 shows the results (with site rankings in brackets).

From this drive-over survey, the following conclusions can be drawn:

- Average driven speed for each section is between 8km/h and 10km/h lower than the perceived safe speed.
- The correlation between the perceived risk and objective risks (RPS) was fairly high for the SH75 sections (see Figure 6), with one notable outlier (Section 4).
- There is correlation between the drivers' average driven speed and perceived risk, with the lowest average speeds (82km/h) occurring on the highest perceived risk sections (Sections 2 and 7), and higher speeds driven where there is a lower perceived risk (Sections 1 and 4).

Table 2. Drive-Over Survey Results (Average of all Participants)

Section	KiwiRAP RPS / Ranking (1st being safest)	Average Rated Safe Speed (km/h)	Average Driven Speed (km/h)	Average Rated Safety (10 being safest) / Ranking (1st being safest)
1	6.4 (=1)	97	87	8.3 (1)
2	9.2 (6)	91	82	7.2 (7)
3	8.5 (4)	88	80	7.5 (6)
4	11.0 (8)	96	88	7.8 (3)
5	6.4 (=1)	95	84	8.1 (2)
6	6.6 (3)	91	83	7.7 (4)
7	9.7 (7)	88	82	6.9 (8)
8	8.7 (5)	96	87	7.6 (5)

- The probable reason for the driven speed being 8-10km/h lower than the perceived safe speed is due to Odometer readings typically shower higher speeds than actual speeds. It is also acknowledged that some drivers may have been induced to drive slower than they normally would through having an observer present in the car watching them drive.
- From this survey, the features generally perceived to be safe were:
  - Sight distance / visibility
  - Signage and curve advisory speed
  - Raised pavement markers
  - Straight / gentle curve sections

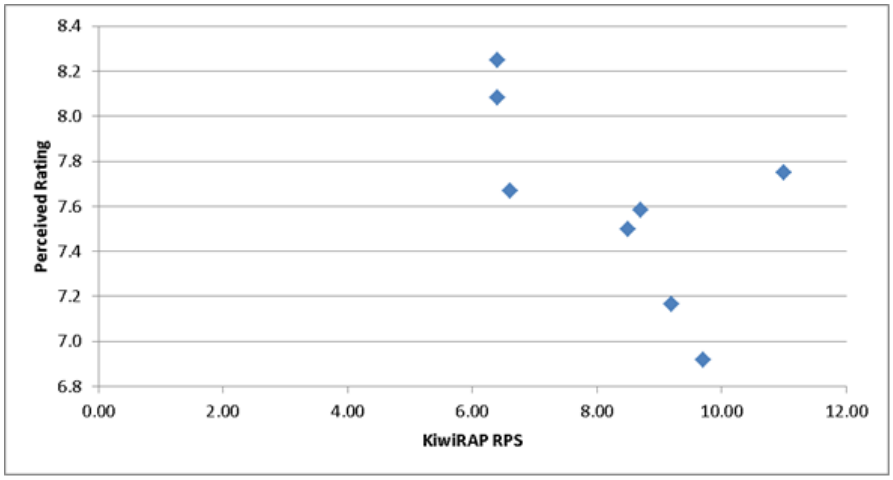
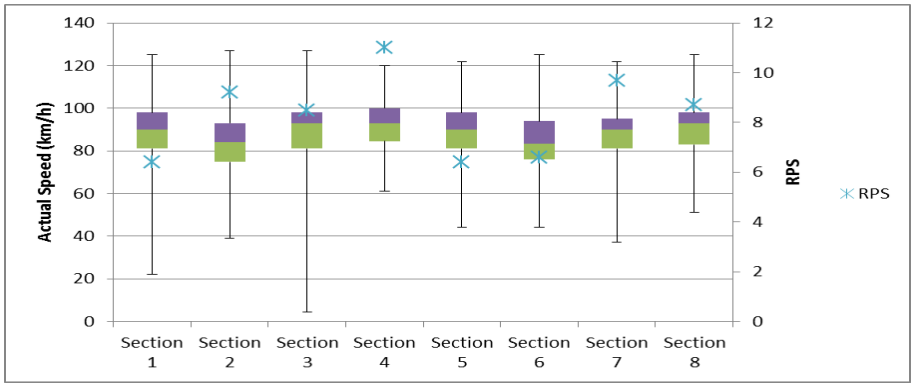


Figure 6.Perceived risk vs Objective risk (KiwiRAP RPS)

- The features generally perceived to be unsafe by the participants for this survey were:
  - Lack of double yellow lines
  - Narrow road section, including around some tight curves
  - Roadside objects (i.e. rockface) not protected
  - Series of (out of context) curves
  - Roadside drains/ditch
  - Side road vehicles entering

The inbound and outbound speeds for this drive-over survey were compared to the speeds from the drive-over surveys carried out in an earlier research study by Turner and Tate (2009). The Turner and Tate (2009) research carrying out more survey runs along SH75. The speed data was combined to produce a better estimate of the average driven speed of each section (from 18 drivers in total, including multiple runs). Figure 7 shows a box plot of the actual speeds from each section compared against the KiwiRAP RPS (objective risk).

This shows there was quite a large variation in speeds, which supports the need to obtain additional speed data. There also appears to be very little correlation between objective risk and driven speed. This may be due to some of the objective risk factors, notably road-side hazards, which are included in the RPS, not impacting on driver's perception of safety or their choice of speed.



Note:
Box and whisker plots showing spread between the minimum (bottom whisker), 25th percentile (bottom of box), mean (purple/green interphase), 75th percentile (top of box) and maximum (top of whisker) speeds

Figure 7.Actual Speed Data (Combined with Turner and Tate, 2009) and RPS

Perceptual Countermeasures Meta-Analysis

The metadata collated from the three surveys, namely the online web, in-person video and drive-over surveys, were collectively analysed in combination with observations derived from the Wide Centreline Report (Burdett, 2012) and Transverse Lines Marking Report (Martindale and Urlich, 2010). This dataset, comprised of these five metadata fields, provided information specific to Risk Countermeasures as was the focus of this analysis.

In the analysis of this metadata the following primary aspects were considered in deriving the underlying patterns and themes from which the analysis findings are outlined:

- Survey Participant demographics
- Test image content including;
  - Geometric road network layout
  - Road Markings
  - Signage
  - Roadside (and on road) features
- Subjective ratings
- Subjective opinions and comments
- Actual speeds (In-person drive over survey)
- Objective risk ratings
- External report findings

Subjective ratings, opinions and comments from participants were compared against one other and the features of a given image or road section. A number of common themes were identified as flowing through the metadata and those have been identified and expanded on as findings below.

The online web-based survey, with 559 respondents, provided a diverse range of metadata where themes common throughout the analysis provide a reasonable level of confidence with analysis findings. In the case of both the video and in-person surveys the limited sample set (6 participants for each) displayed the influence of subjectiveness in respondent risk ratings. This limitation resulted in inconclusive data spread and a low level of confidence in the findings, except when this data was supplemented with risk ratings from the online web-based survey or other research.

Analysis of this metadata can become clouded when considering a respondents subjective rating to a still image of say an un-signposted (30km/h) curve. When un-signposted the objective risk is high due to the possibility of a driver failing to negotiate it safely, while data would indicate that the subjective opinion would tend to rate this un-signposted curve as carrying a medium-high subjective risk, as a still image does not portray the intensity of the curve out of sight distance.

When the same curve is considered with a posted curve advisory speed sign and chevrons; the objective risk calculation equates to a lower objective risk rating whereas a respondent's subjective opinion will tend to be either the same or higher than the un-signposted image now that they are aware the curve is in fact a 30km/h curve. Thus, the subjective evaluation by the respondent requires consideration of the curve in its entirety rather than a single image on entry. In reality, a driver would read the 30km/h sign, slow down to negotiate the curve and then retrospectively subjectively rate the curve as having a lower subjective risk than if reality had given them an un-signposted 30km/h curve to negotiate. Therefore a direct comparison and analysis of still image based against video or in-person surveying cannot in essence provide a similar flow of data.

From this research, the following countermeasures were analysed on their use to convey more accurate perception of risk include:

Curve speed advisory signs and chevrons – Analysis indicated that drivers perceived a reduced safety margin through the positioning of curve speed advisory signs. Where curve speed signs were present in trial images, data showed that sample drivers considered these sections of road to be 16% safer than without these advisory signs installed. Drive over study data indicated that curves which were not signposted with recommended curve speeds carried a much higher objective risk than was subjectively perceived by the driver prior to entering the curve. (CONFIDENCE LEVEL: HIGH)

High crash rate signs – Analysis indicated that the presence of high crash rate signs effectively conveyed to drivers that safety margins for that stretch of road were reduced. These signs aided in aligning the perceived (subjective) risk judgement and the actual (objective) risk of a section of road. (CONFIDENCE LEVEL: HIGH)

Double yellow lines – Analysis indicated that the presence of double yellow (no-overtaking) lines resulted in a reduction in perceived (subjective) risk. This finding contradicts any suggestion that as safety margins decrease, due to the reasons for a double yellow lines section e.g. horizontal curve and/or vertical crest curve, so should there be a resultant increase in the driver's perceived (subjective) risk. It could be considered that the actual (objective) risk introduced by the road layout is over shadowed by the reduced possibility of collision due to opposing traffic crossing the centreline. (CONFIDENCE LEVEL: LOW)

Median barriers – Analysis indicated that where median barriers were installed the perceived (subjective) risk was reduced as a result of the additional protection provided against collisions with oncoming traffic. (CONFIDENCE LEVEL: MEDIUM)

Wide centreline – Although not conclusive, a small sample in the digital image manipulation comparison test indicated a minor increase in perceived (subjective) risk when a wide centreline was compared against the standard white dotted line. This may indicate a level of driver confusion due to the unfamiliarity of the markings, as reported in the Wide Centreline Trial Report (Burdett, 2012), where drivers reported being uncertain as to what the road markings were indicating, although the tested image had a side road, found to be perceived as high risk in this research, which may influence the risk perception. (CONFIDENCE LEVEL: LOW).

Slow down advisory signs (electronic) – Analysis of the data set indicated that electronic 'Slow Down' advisory signs were an effective method of conveying the actual (objective) risk and aligning it with the subjective risk judgement. (CONFIDENCE LEVEL: MEDIUM)
Low light countermeasures - While not specifically measured in this set of surveys participants acknowledged that the presence of reflective edge markers (delineation) and road lighting aided in providing an increased accuracy of objective risk for low light driving e.g. during hours of darkness. (CONFIDENCE LEVEL: LOW)

Final Remarks / Summary

Based on the experimental methods carried out in this research, the details of research findings have been summarised below to answer the four primary questions investigated in this research.

What level of risk is experienced by drivers on hazardous New Zealand roads? From all three surveys undertaken in this research, there is not a strong relationship between drivers' perception of risk and the actual hazard level on New Zealand roads (as measured by the KiwiRAP RPS). The level of risks experienced by drivers on hazardous roads varies significantly from site to site, with drivers perceiving some roads to be safer than their actual risk and vice versa.

What road features do drivers use to judge driving risk? The road features that drivers use to judge driving risk (perceived risk) could broadly be summarised as:
Road geometry. From this research, it has been found that horizontal curves were perceived as higher risk (even with barriers) than straight roads with other roadside hazards (such as power poles).
Signage. Presence of signage such as curve advisory signs / chevrons, high crash rate signs and slow down speed signs, were perceived to convey a message of reduced safety margins.
Intersection / presence of side road. Presence of side road (even with wide centreline) was found to be consistently perceived as higher risk compared to presence of road-side furniture (i.e. power poles, barriers, warning signs).

Which hazardous road situations are under-recognised by New Zealand drivers? This research has found that the risks for some road situations are under-recognised by New Zealand drivers. The features that are under-recognised are:
Roadside hazards. From the experimental surveys carried out, there is little to suggest that drivers perceive the risks of roadside hazards.
Double yellow lines. While the research has found that drivers perceived the more open sight distance from a straight road to be of lower risk compared to curves, the presence of double yellow lines indicated a reduction in perceived (subjective) risk.

What safety countermeasures can be used to convey a more accurate perception of risk? From the meta-analysis carried out, it has been found that certain safety countermeasures provide a more accurate perception of risks. These include:
Signage – Presence of signage such as curve advisory signs, chevrons, high crash rate signs, slow down speed signs, were perceived to convey reduced safety margins. Analysis indicated drivers perceived a reduced safety margin through the location of curve speed advisory signs.
Road markings – There is some evidence that drivers rely on road markings as one of the cues for risk perception. Analysis of datasets indicated that road markings such as double yellow lines have an effect on risk perception. Although not conclusive, a small sample in the digital image manipulation comparison test indicated a minor increase in perceived (subjective) risk when a wide centreline was compared against a standard centreline. Based on this research, there is anecdotal evidence that other road markings, such as transverse line markings could also be effective perceptual safety countermeasures to indicate reduced safety margins.

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