Development of a Road Safety Engineering Modelling Tool

Samuel G. Charlton, Ph.D.

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Background

The work described in this report is part of a research programme aimed at developing methods of identifying and improving high-risk interactions between vehicles, roading situations, and drivers. To date this has involved the use of high-resolution video analysis, computer simulation, and full scale field testing. The research objectives guiding this work employ a systems approach to understanding and improving our road transport system; addressing vehicle performance (stability, tracking etc), road configurations (signage, geometry etc) and driver behaviour collectively. Part of this approach has been directed at analysis of the driver’s perception-decision-action cycle in responding to various driving situations. As it has been hypothesised that driver attentiveness is a key variable affecting the time course of the perception-decision-action cycle (Neisser, 1976; White & Thakur, 1995), our work has included analysis of driver attentiveness in terms of: 1) a driver’s momentary level of cognitive workload (overall demands on cognitive resources), and 2) the proportion of those resources dedicated to the driving task (as reflected in the driver’s momentary situation awareness).

Within this context, our previous research examined drivers’ reactions to road hazards, maintenance of speed and following distances, and the differential properties of explicit (attentional) and implicit (perceptual) features of road safety engineering solutions across a range of traffic and road situations (Charlton & Baas, 1998; Charlton, Mueller, & Baas, 1999; Charlton, 2000; Charlton, Alley, Baas, & Newman, 2002; Charlton, 2003). Some traffic control devices and road safety treatments are designed to provide information to drivers by means of an explicit alerting function. For example, speed limit signs and many hazard warning signs are designed to direct drivers’ attention to road or traffic conditions and undertake recommended or required driving behaviours; the information is explicit as it relies on a driver consciously attending, comprehending, and responding to the information. In contrast, some treatments are designed to work at an implicit, or perceptual level, by affecting drivers’ perception of their speed without conveying an explicit or specific message. For example, transverse road markings and lateral edge line treatments have been implemented at many locations overseas to reduce vehicle speeds by modifying the visual information used to perceive speed subconsciously (Fildes & Jarvis, 1994). The
desirability of road safety treatments based on implicit perceptual cues lies in their unobtrusiveness; they do not place any additional processing demands, distractions, or frustrations on the driver, they do not involve introducing any additional hazards on the roads, and in some cases they may be the only way to influence drivers who refuse to obey the law.

For any given treatment, however, it is an open question whether the effectiveness (or lack thereof) is the result of explicit alerting characteristics or implicit perceptual cues. In the case of transverse line treatments in particular, they appear to exhibit both alerting effects and speed perception influences (Godley, Fildes, Triggs, & Brown, 1999). Conversely, it has been shown that oversized explicit speed control signs placed at urban thresholds may have a perceptual quality, forming a “gateway” and slowing drivers’ speeds, even without any speed restriction information on the signs (Charlton, Alley, Baas, & Newman, 2002). It has also been suggested that the effectiveness of perceptual treatments may be dependent on drivers’ perceptions of safety in a particular situation. Fildes & Jarvis (1994) reported that when perceptions of risk were low, modifying the environment may change drivers’ speed estimation but was less likely to be translated into slower vehicle speeds.

The goal of the present experiment was to develop and demonstrate an analysis tool that would allow road safety professionals to compare the effectiveness of a range of road safety engineering treatments, including treatments with implicit and explicit features, as they related to a specific road with a known pattern of crashes. This work involved two distinct phases of enquiry: first, selection of a road with a well-documented history of crashes and analysis of specific sections of the road as regards their amenability to various road safety treatments; second, a comparison of the treatments’ effectiveness by means of an accurate 3-D re-creation of the road in a driving simulator and a representative sample of drivers.
Phase 1: Crash analysis and treatment identification

Methodology.

The road selected for the study was a 25km stretch of State Highway 2 (SH2) from Katikati Township to Bethlehem in Transit New Zealand’s Region 4. SH2 is the main north south route along the Bay of Plenty East Coast and is the northern access route for the port of Tauranga. It is also the key logging route between forestry in the northern Bay of Plenty, Coromandel, South Auckland and beyond to the port at Mount Maunganui and central north island processing facilities. Along the length of the route studied there are numerous commercial orchards and vineyards, and thus the route contains many intersections (37) and a significant number of access points (sealed and unsealed) used by vehicles servicing the agricultural operations. SH2 is also a scenic drive (posted as the Pacific Coast Highway from SH1 south of Auckland) and is heavily trafficked by tourists and holiday makers. The traffic volumes calculated for the study route range between 12,000 and 16,000 vehicles per day with an 11% component of heavy vehicles.

The route has been the subject of several Transit New Zealand crash reduction studies in the past including: Athenree to Wairoa Intersection Upgrading Strategy (March 1995); Selected Blackspot Sites (November 1998); Urgent Site Study SH2 Apata (August 1999); Strategic Length 1 Athenree to Te Maunga (June 2000); and Special Crash Reduction Study SH2 Athenree to Bethlehem (October 2000). Many of the recommendations made by these studies were implemented, including the upgrading of many intersections to include right and left turn bays. Although the route possesses a generally high standard of roadmarking and signage, this has not been enough to prevent a high number of crashes. In the five years from 1995 through 1999 there were a total of 237 reported crashes over the 25km study route, for a rate of 9.48 crashes per km, as compared to a national average crash rate for rural state highways of 3.35 during the same period. The severity of crashes along the study route have also been higher then the national average, with 7% of reported crashes involving a fatality (as compared to 3% nationally), 11% involving serious injury (9% nationally), and 32% involving minor injury (25% nationally). More recently, in the three years from 2000 through 2002 there were 170
reported crashes along the 25km study route; a 19% annualised increase in crash rates at a
time when comparable crashes decreased nationally (LTSA, 2003).

Following review and analysis of the available crash data from the Land Transport
Safety Authority’s (LTSA) Crash Analysis System (CAS) and the subsequent examination
of individual Traffic Crash Reports (TCR’s), high-resolution digital video of the
aforementioned stretch of SH2 was created, “filming” the road in both directions under
conditions of clear visibility at mid-day, by means of a vehicle equipped with two stable-
mounted digital video cameras. The road was also recreated in a 3-D simulation using road
geometry from Transit New Zealand’s Road Geometry Data Acquisition System (RGDAS)
database and road markings, road signs, and clear sight angles reproduced by consulting
local Geographical Information Systems (GIS) data, road surveys, and the digital video.
The 3-D simulation allowed the road features to be viewed from any perspective (including
drivers’ eye-level and top-down aerial views) using cursor controls, or “driven” by means
of steering wheel and foot pedals and a simulated vehicle dynamics model. These
resources were then presented to a group of expert road safety engineers empanelled to
discuss and assess potential road safety treatments that could be applied to this stretch of
SH2.

Participants.

Seven experts from the local road safety engineering community were recruited
from the Land Transport Safety Authority, Transit New Zealand, and Opus International
Consultants. All but one of the participants were male and their years of experience in the
transport engineering/road safety sector averaged 21.57 years (ranging from 2 to 45 years).
Three members of the expert panel rated their knowledge with the subject stretch of SH2 as
“Very familiar – driven and thought about frequently”, two of the panel rated their
knowledge as “Moderately familiar – driven occasionally, some discussion”, and the
remaining two rated their knowledge as “Slightly familiar – have driven and are aware
some problems exist”.

Materials.

The panel of experts were provided with an “Expert Panel Workbook” (shown at
Appendix A). The workbook contained: a background section asking several demographic
questions; five crash analysis sections containing historical crash data diagrams and questions regarding each of five pre-selected segments of the study road; and a summary section asking questions about the usability and value of the expert panel exercise. The digital video of the study road was presented on a 48.26 cm (19 in) colour monitor displaying 1280 x 1024 pixels. The study road could be displayed travelling in either direction (north or south), travelling at normal speed (approx 80km/h), or advanced frame by frame. The 3-D simulation of the study road was presented on a desktop driving simulation tool using measured 3-dimensional road geometry (from the Transit RGDAS database) to specify the roadway geometry. The road markings, road signs, traffic, and sight angles were modelled as 3-dimensional objects and placed along the roadway using data from GIS and road surveys and the digital video. The simulated scenes were presented in panorama across three display screens: one 53.34 cm (21 in) and two 43.18 cm (17 in) CRTs, affording approximately 130 degrees effective field of view at a frame rate of 150 frames per sec (see Figure 1). Navigation through the simulation was by means of either cursor controls or steering wheel and foot pedal controls. When navigation was effected through the steering wheel and foot pedals, movement through the simulation was governed by an interactive non-linear multi-body vehicle dynamics model.

Procedure.

The expert panels were convened in two separate sessions (one group of two participants and one group of five) in March of 2003. Each panel began with a description of the purposes of the study and an overview of the workbooks and the procedure. After completing the demographic questions, the participants progressed through the five pre-
defined segments of the study road. Each segment was first discussed in terms of its crash history and then viewed from both directions using the high-resolution video. The high-resolution video was used to allow the participants to safely assess the road, signage, and traffic characteristics of each segment. Discussion of possible treatments for each section was further aided by wide field-of-view simulation to help visualise how a specific treatment or roading change would appear in situ. After discussing each segment as a group, the participants individually rated the driving difficulty of the segment, the mental workload required of drivers for that segment, and noted the specific aspects of the road segment they felt to be unsafe and the road features they would most like to change. The discussion of each of the five segments lasted for between 15 to 45 minutes (average duration of 25 min) and the entire procedure lasted for 2 hrs 45 min for the first panel and 3 hr 35 min for the second panel.

**Results.**

During the course of the discussions about the five road segments, several noteworthy road safety engineering problems were identified by the participants. The most frequently mentioned problems were: very limited sight distances afforded by the numerous vertical curves (often coinciding with intersection locations); difficulties overtaking and a lack of overtaking lanes; the presence of many narrow bridges; narrow (& variable) shoulder widths; and inconsistent and excessive signage. Of the five road segments discussed, the median rating on the seven-point driving difficulty scale for three of the segments was a 4, “somewhat difficult -- challenging” or worse. The remaining two road segments were rated less severely by the participants, with a median rating of 3, “moderately difficult.” The mental workload ratings for the road segments mirrored the driving difficulty ratings, with three of the road segments having higher median ratings (4 – “challenging but manageable”, and 5 – “demanding to manage”) than the other two (3 – “easily managed”). The driving difficulty and mental workload ratings for each of the five road segments are shown in Figure 2.
The participants identified drivers’ reducing speed and lateral deviation as the behaviours most needing change in order to improve safety across the five driving segments. In their comments, the participants pinpointed several locations of particular concern and identified specific treatments that could be used to achieve these changes in driver behaviour, including: rumble strips, lane colours, herringbones, and explicit speed restrictions. In their ratings of the usability of the road safety modelling procedure they had just used, the participants’ average SUS score was 71.8 (median score of 72.5) on the 10-item SUS scale. The SUS produces scores ranging from 0 to 100, with scores greater than 50 indicating the system being rated possesses a good level of usability (Brooke, 1996). The participants’ written comments on the procedure included the following statements:

“Would provide a useful analysis tool”; “Able to get a lot more people to view and comment on a site than at a physical location”; “I found the whole approach very interesting”; “I liked the way it integrated the various aspects of analysing the routes”; “Lots of potential”.

Figure 2. Median driving difficulty and mental workload ratings for the 5 road segments.
Phase 2: Simulator testing

Methodology.

The second phase of the study consisted of a comparison test of two road safety engineering treatments suggested by the expert panel participants. The comparison test was conducted using the simulation of SH2 and a representative sample of licenced drivers. The test was conducted at Waikato University throughout May and June of 2003 and was structured as a within-participants design such that all participants were exposed to every treatment type, with the order of presentation counterbalanced across participants.

Participants.

Thirty-five volunteers with a full New Zealand Class B Driving licence were recruited from flyers and notices posted in the local area. Four of the participants withdrew before completing the experiment, citing other time commitments, eyestrain, or feelings of dizziness while driving the simulator. Of the thirty-one participants completing the experiment, 17 were female and 14 were male, they ranged in age between 17 and 72 years (average of 32 years, std. dev. of 14.74). The testing protocols were reviewed and approved by the University of Waikato’s Psychology Research and Ethics Review Committee prior to testing.

Apparatus.

The primary experimental apparatus was the driving simulator described for the previous research phase. Participants drove the simulated road using the steering wheel and foot pedal controls. The vehicle dynamics of the simulated vehicle represented a passenger car with a 2 litre engine and an automatic transmission. The simulated road surface was high friction corresponding to dry asphalt and scene visibility corresponded to clear daytime conditions. Three driving scenarios were created: an “as-is” or standard representation of the 25 km study road; a scenario with perceptual countermeasures added; a scenario with explicit (attentional) speed restrictions added. Each of these three scenarios contained representative traffic densities (approximately 14,000 vehicles per day) modelled using information from traffic counts and video recordings of the study road. In addition, a 7 km practice scenario with reduced traffic levels was created from a short section of the “as-is” scenario to allow the participants to familiarise themselves with the simulator.
Of particular interest were four locations along the road identified by the expert panel members in Phase 1 of the study (selected from road segments 2 through 5). These locations included a concealed left/right intersection, an intersection on the drivers’ right, an intersection on the drivers’ left, and a left/right intersection with a stop sign (which also served as the end of the driving scenarios). The perceptual countermeasures scenario featured “herringbone” road markings placed at the approach to each of the four intersections as shown in Figure 3. The herringbone road markings extended 1.5 m from the left and right edge lines with a 3 m repeat interval and were placed at the four locations shown in Table 1. The explicit attentional scenario included speed reduction signs instead of the herringbone markings at three of the locations indicated in Table 1, with signs indicating a return to open road speeds after the intersections. At location 4, which already contained a speed reduction sign for all conditions, the attentional scenario introduced a warning sign prior to the intersection stop.
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Location 1</th>
<th>Location 2</th>
<th>Location 3</th>
<th>Location 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>300m downhill curve approach to concealed left/right intersection, followed by 400m downhill straight leading to narrow bridge.</td>
<td>600m downhill approach with “s” curves to intersection on right with flush median and right-hand turn bay beginning 110 m prior.</td>
<td>400m straight downhill approach to gentle curve with intersection on left, left-hand turn bay beginning 50 m prior.</td>
<td>300 m uphill to 60 kph speed reduction sign and flush median treatment, 420 m straight downhill to intersection with stop sign.</td>
</tr>
<tr>
<td>Perceptual</td>
<td>150m herringbone placed 270 m before intersection (ending 120 m prior) and 300m herringbone placed 100 m after intersection, ending at bridge.</td>
<td>300 m herringbone placed 410 prior to intersection (ending 110 prior).</td>
<td>300 m herringbone placed 410 prior to intersection (ending 110 prior).</td>
<td>280 m herringbone placed 418 prior to intersection (20 m after speed change sign) ending 138 m prior to intersection.</td>
</tr>
<tr>
<td>Attentional</td>
<td>80 kph speed sign placed 270 m before intersection, 100 kph speed sign placed 500 m after intersection (end of bridge).</td>
<td>80 kph speed sign placed 410 m before intersection, 100 kph speed sign placed 25 m after intersection</td>
<td>80 kph speed sign placed 410 m before intersection, 100 kph speed sign placed 25 m after intersection</td>
<td>“Stop ahead” warning sign placed 230 prior to intersection.</td>
</tr>
</tbody>
</table>
Procedure.

In the within-subjects experimental design employed, each participant drove the three driving scenarios across two 1-hr experimental sessions. During the first session each participant was asked to complete a brief questionnaire containing demographic questions (age, gender, etc.) and 28 questions about their driving habits. The 28-item survey, known as the Manchester Driver Behaviour Questionnaire (DBQ), categorises driver behaviour in terms of errors, lapses, and violations and has been found to be a good predictor of crash involvement (Reason, et. al., 1990; Parker, Reason, Manstead, & Stradling 1995). The questionnaire booklet completed by the participants is shown in Appendix B. Participants were also asked whether they required corrective lenses to drive, and if so, to wear them during the experiment. Then the participants were given instructions about the driving task and allowed to drive the practice scenario. After driving the practice scenario, the participants drove one of the three comparison scenarios, and during the second session (between 1 and 7 days later) drove the remaining two scenarios.
Results.

Shown in Figure 4 are the average speeds for the standard (as-is), perceptual (herringbone road markings), and attentional (speed restriction signs) scenarios. As can be seen, both the herringbone road markings and the explicit speed restriction signs reduced the participants’ speeds at the approach to the concealed left/right intersection (location 1), as compared to the as-is scenario. In contrast, the attentional scenario also produced reduced speeds at the right intersection (location 2) and left intersection (location 3), while the average speeds under the perceptual scenario were only slightly lower than the as-is scenario. At the stop intersection (location 4), the average approach speeds appeared more or less equivalent for the three scenarios.

Figure 4. Average speeds for the four locations in the standard (as-is), perceptual (herringbone), and attentional (speed signs) scenarios. (Note: placement of herringbone markings are indicated by shaded areas, speed signs by dashed lines, and the warning sign at location 4 indicated by the solid line.)
Interestingly, the effect of the perceptual scenario was different for the men and women participants. As shown in Figure 5, the herringbone road markings appeared to produce a greater reduction in the men’s speeds than it did for the women’s speeds at locations 1, 2, and 3. At location 1, the speed reduction signs in the attentional scenario produced roughly equivalent reductions in men’s and women’s speeds, while the herringbone markings produced an initial reduction in the men’s speeds, to even a slower speed than that of the women, even though the men’s average speed was higher at the approach point during that scenario. While the men drove at generally higher speeds than the women during the standard scenario, as shown at locations 2 and 3, their speeds under the speed restrictions of the attentional scenario were approximately equal. Of particular interest, however, was the finding that the herringbone road markings of the perceptual scenario produced reductions in the men’s speeds (particularly at location 3) when they had no apparent effect on the women’s speeds. While this could be attributed to the fact that the women were already driving slower through the curves on the approach to the intersection in location 2, at location 3 the herringbone treatment resulted in men’s average speeds being slower than the women’s even though their approach speeds were equivalent.

As can be seen in Figures 6a and 6b, the participants’ ages also influenced their speeds and the magnitude of the perceptual and attentional treatments’ effects. The eight drivers aged 17 to 20 tended to drive faster through all three scenarios than the other drivers, particularly compared to the four drivers aged 65 or older who showed the slowest average speeds throughout all three scenarios. Of note though is the finding that the herringbone markings at location 1 slowed the older drivers’ speeds to a magnitude equivalent to the speed reduction signs at that location. It can also be seen that those older drivers also reduced their speeds at that location under the as-is scenario, although not to the degree afforded by the perceptual or attentional scenarios. At location 2, the herringbone markings had little or no differential effect on drivers of different ages, but at location 3, the herringbone markings once again produced the greatest reduction for the older drivers. At location 4, the older drivers tended to drive more slowly under the perceptual and attentional scenarios than the as-is scenario, through the approach as well as the treatment areas.
Figure 5. Average speeds for the men and women participants in the three driving scenarios.
Figure 6a. Average speeds at locations 1 and 2 shown for participants of different ages.
Figure 6b. Average speeds at locations 3 and 4 shown for participants of different ages.

Statistical analysis of the participants’ reduction in speed across the three scenarios using a repeated-measures analysis of variance revealed a significant main effect of treatment type $F_{(2, 28)} = 32.117$, $p < .001$, and a significant treatment by gender interaction $F_{(2, 28)} = 3.557$, $p < .05$. The analysis also showed a significant effect of location on the
participants’ reduction in speed $F_{(2, 28)} = 24.158, p < .001$, but did not indicate any significant higher-order interactions of location with treatment or gender. Pearson correlations computed on the data indicated a significant negative correlation between participants’ age and their speed in the driving simulator ($r = -.492, p < .01$) indicating that driving speeds declined with age. The analysis also indicated that the participants’ reported number of crashes in the past year was positively correlated with their reported kilometres driven per week ($r = .594, p < .001$). Analysis of the participants’ responses to the DBQ showed significant correlations between their reported crashes and their violations score ($r = .542, p < .01$), error score ($r = .484, p < .01$), lapse score ($r = .466, p < .01$) and aggressive violation score ($r = .375, p < .05$). Analysis of variance indicated significant differences between the men and women participants’ DBQ error scores, $F_{(1,29)} = 6.776, p < .01$, and lapse scores, $F_{(1,29)} = 4.567, p < .05$, with the women reporting more errors and lapses than the men.

**Discussion**

The principal aim of this research programme was to explore methods of identifying and modelling high-risk interactions between vehicles, roading situations, and drivers, culminating in the development of a modelling tool for road safety professionals. The work described in this paper represents the final phase of that programme, the use of high-resolution video analysis and computer simulation techniques to assess issues of vehicle performance, road configurations, and driver behaviour. As demonstrated in Phase 1 of the report, the programme has been successful in producing a modelling technique with which road transport solutions can be assessed safely and economically. The modelling tool was successfully implemented and tested with a panel of experienced road safety professionals exploring the issues and treatment alternatives associated with a specific section of the state highway system. The feedback from the panel of experts was uniformly positive as regards the tool’s capabilities, usability, and potential.

In the second phase of work described in the paper, candidate treatments identified by the expert panel were introduced into a simulation of the road and tested with a representative sample of drivers. The results of that test identified which treatment
alternatives may produce the greatest road safety benefits at specific locations. More specifically, speed reduction signage was found to produce significantly reduced vehicle speeds at intersections known to have a history of crashes. Further, the testing demonstrated that, at two of the locations, herringbone road markings also produced reductions in drivers’ average speeds. The comparison of these two treatment types, road markings designed to work at an implicit perceptual level and explicit speed reduction signage, was of particular current interest due to the hypothesised costs and benefits of the two types of approach.

The results of the testing also provided further information with which to understand and gauge the potential benefits of the approaches. For example, the relationship between the effectiveness of implicit perceptual and drivers’ perceptions of safety in a particular situation can be explicitly compared by examining the age differences observed for the perceptual driving scenarios. Older drivers, known to perceive the risk in driving situations as being greater than do other road user segments (Charlton, Newman, & Baas, 2003) showed the greatest caution in approaching intersections in the as-is scenario and also displayed the greatest effects of the perceptual treatments. On the other hand, the finding that the perceptual treatment had a greater effect on male drivers than female drivers (of all ages) is difficult to reconcile with males’ generally higher tolerance to driving risk. This latter finding is the first time this relationship has been reported and opens avenues for further research on the mechanisms behind perceptual countermeasures’ effectiveness. Finally, the differential effectiveness of the perceptual countermeasures at the four sites tested in this study also sets the stage for further research into the road characteristics and situations most appropriate for perceptual treatments.

As regards the specific road examined in the paper, the results provide some relatively clear-cut information regarding the potential effectiveness of two treatment options. These findings will be transmitted to the road safety agencies currently considering options for this road as well as made available to other road safety professionals who may be facing similar situations elsewhere. The modelling tool and methodology will also be made available for use in assessing other situations and potential treatments in New Zealand.
References


Appendix A

Phase 1 Expert Panel Workbook
Welcome to the
Driver-Vehicle Interaction Study

The purpose of the study is to develop a planning and evaluation tool for road safety and engineering professionals in NZ.

We are asking our expert panel of advisors to:

1) Try out the tool by using it to assess an actual road in the NZ state highway network,
2) Answer several multi-choice questions about the road and possible remedial treatments, and
3) Provide a short assessment of the usefulness and potential effectiveness of the tool.

Treatments recommended by the expert panel will be incorporated into the tool and a representative sample of drivers will be asked to “drive” the road in the simulator to gauge the effectiveness of the remedial treatments.

All information you provide will be treated in the strictest confidence and if you have any questions feel free to ask us. You can withdraw from the study at any time.

Thank you in advance for your participation.

Dr. Samuel G. Charlton, Project Supervisor
Background Demographics

How many years of experience do you have in the transport engineering or road safety sector? __________ yrs

How many kilometres do you drive in an average week? (approximately) _______________ km

What is your job title? ____________________________________________

What is your gender? M  F (circle one)

Road familiarity question.

Please rate your familiarity with this section of road (SH2 between Katikati & Bethlehem).

1 – Very, very familiar; driven and thought about frequently.
2 – Moderately familiar; drive road occasionally, some discussion.
3 – Slightly familiar; have driven and aware some problems exist.
4 – Somewhat unfamiliar; may have driven road, no discussion.
5 – Completely unfamiliar; never driven nor discussed this road.

Answer: ____________

Now we will try out the planning and engineering tool on five sections of the road.

You will be shown a video of each section of the road, the available crash data for each section, and be allowed drive and explore each section using a digital simulation.

After you have explored each section of the road we will ask you several questions about the characteristics of the road and what might be done to improve it.
Section 1: Walker Road to Dawson Road

5 Year crash history

19 reported crashes:

4 loss of control (1 S, 2 M, 1 NI)
4 overtaking (1 F, 3 M)
3 head-on (1 M, 2 NI)
2 turning vs same direction (1 S, 1 NI)
2 crossing turning (1 M, 1 NI)
1 right turn against (F)
1 rear-end (M)
1 crossing (NI)
1 load lost/object in roadway (NI)
Section 1: Walker Road to Dawson Road

Driving difficulty question.
Please rate the difficulty of driving this road (for a typical driver).

1 -- Easy; No difficulty at all.
2 -- Slightly difficult; No problems.
3 -- Moderately difficult; Easy to do.
4 -- Somewhat difficult; Challenging.
5 -- Very difficult; Hard to do.
6 -- Extremely difficult; Potentially hazardous.
7 -- Nearly impossible; Unsafe.

Answer: ____________

Mental workload question
Please rate the mental workload associated with this drive (for a typical driver).

1 -- No workload; Not demanding.
2 -- Little workload; Minimal demands.
3 -- Moderate workload; Easily managed.
4 -- Busy; Challenging but manageable.
5 -- Very busy; Demanding to manage.
6 -- Extremely busy; Very difficult to manage.
7 -- Overloaded; Unmanageable; Unsafe.

Answer: ____________

What are the most difficult (or unsafe) aspects of driving this section of road?
1. ___________________________________________________________________________
2. ___________________________________________________________________________
3. ___________________________________________________________________________

What specific aspects or features of the road would you change?
1. ___________________________________________________________________________
2. ___________________________________________________________________________
3. ___________________________________________________________________________

(Continue on the back of the page if necessary)
Section 2: Aongetete to south of Works Road

5 Year crash history

16 reported crashes:

9 loss of control (4 M, 5 NI)
3 head-on (1 F, 1S, 1 NI)
2 turning vs same direction (1 S, 1 M)
2 hit parked vehicle (2 NI)
Section 2: Aongetete to south of Works Road

Driving difficulty question.

Please rate the difficulty of driving this road (for a typical driver).

1 -- Easy; No difficulty at all.
2 -- Slightly difficult; No problems.
3 -- Moderately difficult; Easy to do.
4 -- Somewhat difficult; Challenging.
5 -- Very difficult; Hard to do.
6 -- Extremely difficult; Potentially hazardous.
7 -- Nearly impossible; Unsafe.

Answer: ____________

Mental workload question

Please rate the mental workload associated with this drive (for a typical driver).

1 -- No workload; Not demanding.
2 -- Little workload; Minimal demands.
3 -- Moderate workload; Easily managed.
4 -- Busy; Challenging but manageable.
5 -- Very busy; Demanding to manage.
6 -- Extremely busy; Very difficult to manage.
7 -- Overloaded; Unmanageable; Unsafe.

Answer: ____________

What are the most difficult (or unsafe) aspects of driving this section of road?

1. __________________________________________________________________________
2. __________________________________________________________________________
3. __________________________________________________________________________

What specific aspects or features of the road would you change?

1. __________________________________________________________________________
2. __________________________________________________________________________
3. __________________________________________________________________________

(Continue on the back of the page if necessary)
Section 3: Wainui South Road to south of Apata Station South

5 Year crash history

24 reported crashes:

- 13 loss of control (1F, 1 S, 5 M, 6 NI)
- 4 head-on (1 F, 2 S, 1 NI)
- 3 crossing turning (2 S, 1 M)
- 1 right turn against (S)
- 2 load lost/object in roadway (1 F, 1 M)
- 1 pedestrian (F)
Section 3: Wainui South Road to south of Apata Station South

Driving difficulty question.

Please rate the difficulty of driving this road (for a typical driver).

1 -- Easy; No difficulty at all.
2 -- Slightly difficult; No problems.
3 -- Moderately difficult; Easy to do.
4 -- Somewhat difficult; Challenging.
5 -- Very difficult; Hard to do.
6 -- Extremely difficult; Potentially hazardous.
7 -- Nearly impossible; Unsafe.

Answer: ____________

Mental workload question

Please rate the mental workload associated with this drive (for a typical driver).

1 -- No workload; Not demanding.
2 -- Little workload; Minimal demands.
3 -- Moderate workload; Easily managed.
4 -- Busy; Challenging but manageable.
5 -- Very busy; Demanding to manage.
6 -- Extremely busy; Very difficult to manage.
7 -- Overloaded; Unmanageable; Unsafe.

Answer: ____________

What are the most difficult (or unsafe) aspects of driving this section of road?
1. __________________________________________________________________________
2. __________________________________________________________________________
3. __________________________________________________________________________

What specific aspects or features of the road would you change?
1. __________________________________________________________________________
2. __________________________________________________________________________
3. __________________________________________________________________________

(Continue on the back of the page if necessary)
Section 4: Francis Road to South of Omokoroa

5 Year crash history

17 reported crashes:

6 loss of control (1 F, 2 S, 2 M, 1 ni)
2 overtaking (1 F, 1 M)
2 head-on (2 NI)
1 turning vs same direction (S)
3 crossing turning (3 NI)
2 right turn against (2 S)
1 crossing (NI)
Section 4: Francis Road to South of Omokoroa

Driving difficulty question. 
Please rate the difficulty of driving this road (for a typical driver).

1 -- Easy; No difficulty at all.
2 -- Slightly difficult; No problems.
3 -- Moderately difficult; Easy to do.
4 -- Somewhat difficult; Challenging.
5 -- Very difficult; Hard to do.
6 -- Extremely difficult; Potentially hazardous.
7 -- Nearly impossible; Unsafe.

Answer: ____________

Mental workload question
Please rate the mental workload associated with this drive (for a typical driver).

1 -- No workload; Not demanding.
2 -- Little workload; Minimal demands.
3 -- Moderate workload; Easily managed.
4 -- Busy; Challenging but manageable.
5 -- Very busy; Demanding to manage.
6 -- Extremely busy; Very difficult to manage.
7 -- Overloaded; Unmanageable; Unsafe.

Answer: ____________

What are the most difficult (or unsafe) aspects of driving this section of road?
1. __________________________________________________________________________
2. __________________________________________________________________________
3. __________________________________________________________________________

What specific aspects or features of the road would you change?
1. __________________________________________________________________________
2. __________________________________________________________________________
3. __________________________________________________________________________

(Continue on the back of the page if necessary)
Section 5: Loop Road to Clarke Road

5 Year crash history

27 reported crashes:

10 loss of control (1 M, 9 NI)
4 head-on (2 S, 1 M, 1 NI)
1 turning vs same direction (NI)
2 right turn against (2 NI)
2 rear-end (1 S, 1 NI)
4 crossing (1 S, 2 M, 1 NI)
2 load lost/object in roadway (2 NI)
1 manoeuvring (NI)
1 collision with obstruction (NI)
Driving difficulty question.

Please rate the difficulty of driving this road (for a typical driver).

1 -- Easy; No difficulty at all.
2 -- Slightly difficult; No problems.
3 -- Moderately difficult; Easy to do.
4 -- Somewhat difficult; Challenging.
5 -- Very difficult; Hard to do.
6 -- Extremely difficult; Potentially hazardous.
7 -- Nearly impossible; Unsafe.

Answer: ____________

Mental workload question

Please rate the mental workload associated with this drive (for a typical driver).

1 -- No workload; Not demanding.
2 -- Little workload; Minimal demands.
3 -- Moderate workload; Easily managed.
4 -- Busy; Challenging but manageable.
5 -- Very busy; Demanding to manage.
6 -- Extremely busy; Very difficult to manage.
7 -- Overloaded; Unmanageable; Unsafe.

Answer: ____________

What are the most difficult (or unsafe) aspects of driving this section of road?
1. ______________________________________
2. ______________________________________
3. ______________________________________

What specific aspects or features of the road would you change?
1. ______________________________________
2. ______________________________________
3. ______________________________________

(Continue on the back of the page if necessary)
Please rate the usability of the planning and evaluation tool you saw today in terms of each of the following areas:

<table>
<thead>
<tr>
<th></th>
<th>Strongly disagree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I think that I would like to use this system frequently</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>2</td>
<td>I found the system unnecessarily complex</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>3</td>
<td>I thought the system was easy to use</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>4</td>
<td>I think that I would need the support of a technical person to be able to use this system</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>5</td>
<td>I found the various functions in this system were well integrated</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>6</td>
<td>I thought there was too much inconsistency in this system</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>7</td>
<td>I would imagine that most people would learn to use this system very quickly</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>8</td>
<td>I found the system very cumbersome to use</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>9</td>
<td>I felt very confident using the system</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>10</td>
<td>I needed to learn a lot of things before I could get going with this system</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

Finally, please give us any comments or feedback about the tool or the exercise that you are willing to share with us.

_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

That’s it. Thank you very much for your help.
Appendix B

Phase 2 Participants’ Questionnaire
Welcome to the 

Driver-Vehicle Interaction Study

Instructions

The purpose of the study is to find out more about the attitudes and driving habits of road users in NZ.

We are asking participants in the study to

1) answer a set of multi-choice questions about your driving habits.
2) drive simulated roads on our driving simulator across three sessions. The roads are based on actual roads in the Waikato and you will be able to practise driving the simulator before you begin.

All information will be treated in the strictest confidence and if you have any questions feel free to ask us. You can withdraw from the experiment at any time.

If you are a first-year Psychology student you will receive participation points for 102 or 103. Otherwise, your club will receive a donation in your name at the end of your participation.

We would like to begin by having you complete an informed consent form and then give us some background information about your driving habits.

Thank you in advance for your participation.

Dr. Samuel G. Charlton, Project Supervisor
What kind of vehicle do you drive most often?
- Motorbike
- Compact car
- Midsize car or wagon
- Van or ute
- Taxi
- Truck
- Truck & trailer
- Other _____________

How many kilometres do you drive in an average week? _______________ km

What is your annual income (approximately)? $ _______________

What is your occupation?
- Sales
- Service
- Clerical
- Managerial
- Education
- Professional/technical
- Agricultural/fishing
- Manufacturing/building
- Transport
- In school/training
- Unemployed
- Retired
- Work at home
- Other _____________

In the past year, how many motor vehicle crashes have you been involved in? _______

In the past year, how many driving infringements (including speed camera fines) have you received? _____

What percent of your driving is:

<table>
<thead>
<tr>
<th>Activity</th>
<th>0%</th>
<th>10-20%</th>
<th>20-30%</th>
<th>40-50%</th>
<th>60-70%</th>
<th>80-90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>To and from work</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shopping</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Medical</td>
<td></td>
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<td></td>
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<tr>
<td>Education</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Driving as part of job</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transporting children</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social and recreation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other _____________</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What percent of your driving is between the hours of:

<table>
<thead>
<tr>
<th>Time</th>
<th>0%</th>
<th>10-20%</th>
<th>20-30%</th>
<th>40-50%</th>
<th>60-70%</th>
<th>80-90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>6am-10am</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10am-2pm</td>
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<td></td>
<td></td>
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<tr>
<td>2pm-6pm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6pm-10pm</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>10pm-2am</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2am-6am</td>
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</tr>
</tbody>
</table>

What is your age? _______________

Is your household Rural or Urban? (circle one)

What is your gender? M  F  (circle one)
This next part of the experiment contains several multi-choice questions about your driving habits.

For each question, you are asked to indicate how often a particular driving situation has happened to you, ranging from:

| 0 = never 1 = hardly ever 2 = occasionally 3 = quite often 4 = frequently 5 = all the time |

Base your judgements on what you remember of your driving over, say, the past year.

How often do you do each of the following?

| 0 = never 1 = hardly ever 2 = occasionally 3 = quite often 4 = frequently 5 = all the time |

<table>
<thead>
<tr>
<th>please tick the most appropriate column for EACH item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hit something when reversing that you had not previously seen</td>
</tr>
<tr>
<td>Intending to drive to destination A, you “wake up” to find yourself heading for destination B, maybe because the latter is a more usual destination</td>
</tr>
<tr>
<td>Drive when you suspect you might be over the legal blood alcohol limit</td>
</tr>
<tr>
<td>Get into the wrong lane approaching a roundabout or an intersection</td>
</tr>
<tr>
<td>Queuing to turn left onto a main road, you pay such close attention to the main stream of traffic that you nearly hit the car in front</td>
</tr>
<tr>
<td>Fail to notice that pedestrians are crossing when turning into a side street from a main road</td>
</tr>
<tr>
<td>Sound your horn to indicate your annoyance at another road user</td>
</tr>
<tr>
<td>Fail to check your rear-view mirror before pulling out, changing lanes, etc.</td>
</tr>
<tr>
<td>Brake too quickly on a slippery road, or steer the wrong way in a skid</td>
</tr>
<tr>
<td>Pull out of an intersection so far that the driver with right of way has to stop and let you out</td>
</tr>
<tr>
<td>Disregard the speed limit on a residential road</td>
</tr>
<tr>
<td>Switch on one thing, such as the headlights, when you meant to switch on something else, such as the wipers</td>
</tr>
<tr>
<td>On turning left, nearly hit a cyclist who has come up on your inside</td>
</tr>
<tr>
<td>Miss “Give Way” signs, and narrowly avoid colliding with traffic having right of way</td>
</tr>
</tbody>
</table>

Please continue on to the next page
How often do you do each of the following?

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attempt to drive away from the traffic lights in third gear</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attempt to overtake someone that you hadn’t noticed to be signalling a right turn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Become angered by another driver and give chase with the intention of giving him/her a piece of your mind</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stay in a motorway lane that you know will be closed ahead until the last minute before forcing yourself into another lane</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forget where you left your car in a car park</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Overtake a slow driver on the inside</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Race away from traffic lights with the intention of beating the driver next to you</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Misread the signs and exit from a roundabout on the wrong road</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Drive so close to the car in front that it would be difficult to stop in an emergency</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Cross an intersection knowing that the traffic lights have already turned against you</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Become angered by a certain type of driver and indicate your hostility by whatever means you can</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Realise that you have no clear recollection of the road along which you have just been travelling</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Underestimate the speed of an oncoming vehicle when overtaking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disregard the speed limit on the open road</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

That is the end of the survey – Thank you very much for your answers. Let the researcher know that you are finished and they show you how to begin your practise session on the driving simulator.

Be sure to ask if you have any questions whatsoever!