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OLDER DRIVER CRASH RATES IN RELATION TO TYPE AND QUANTITY OF TRAVEL

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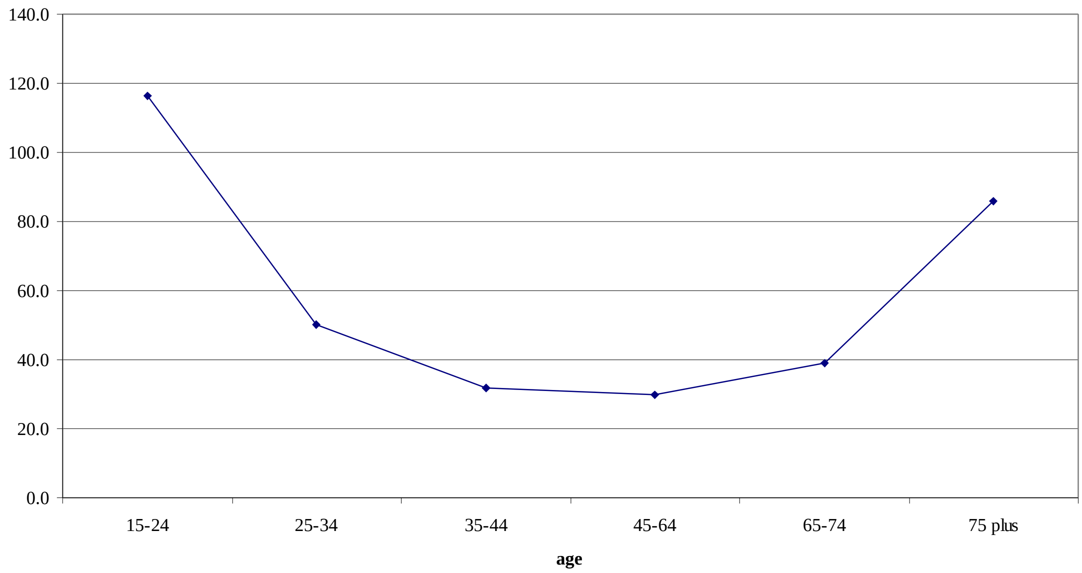
1. ABSTRACT

It is a well-established phenomenon that, notwithstanding their overall good crash record, older drivers have a higher than average rate of involvement in injury crashes when the rate is calculated by dividing crash numbers by distance driven. It has been hypothesised that at least some of this higher crash rate is an artefact of the different nature of driving undertaken by many older drivers. For example, driving in congested urban environments provides more opportunities for collisions than driving the same distance on a motorway. However, there have been few opportunities to investigate this theory, as relevant data are difficult to acquire. High-quality data from the New Zealand Travel Survey (1997/98) was combined with crash data to enable a statistical model to estimate the risk of driver groups under various driving conditions characterised by the type of road used, time of day, day of week and season of year. Despite elevated crash risks per distance driven for most road types, older drivers were as safe as any other age group when driving on motorways. The driving patterns of older drivers (in terms of when and where they drive) appear to minimise their risks in comparison with the driving patterns of other age groups. These results are of interest to both policy makers and transportation planners working against the background of inevitable increases in the number of older drivers as the population ages.

2. INTRODUCTION

Only 1.3% of drivers involved in injury crashes in the year 2000 were aged 80 and over. However, in terms of crashes per kilometre driven, older drivers' crash rates are second only to young drivers (LTSA, 2000a). The relationship between driver age and risk of crash involvement appears almost universally as a U-shaped curve, with higher risk for older and younger drivers and relatively low risk for ages in between. Such a curve is shown by Figure 1 (adapted from LTSA, 2000a). The curve represents risk of injury crash involvement, calculated from the (average annual) number of drivers involved in injury crashes in 1997/98, divided by the average annual distance driven by each age group in 1997/98, recorded in units of 100 million km.

Figure 1: Risk of involvement in injury crashes per 100 million km driven



This increased risk for older drivers can be assumed to arise from multiple causes. As drivers age, both age-related physiological changes and health problems, leading to slower reaction times and impaired cognitive functioning, become more likely to affect their ability to drive safely. These include: (i) deterioration in vision (Sivak, 1995), including slower recovery from glare, slower eye movements, reductions in visual field, visual acuity and contrast sensitivity; (ii) reduced ability to move quickly with control over the movement (Stelmach et al., 1992); (iii) medical conditions and associated medications (Ray et al., 1992); (iv) conditions such as Alzheimer's disease (Hunt et al., 1993). Crash patterns of older drivers are consistent with the effects of these age-related problems. Table 1 shows crash data from 1997 and 1998 with the causes of the crashes, as recorded by the Police Officer in attendance at the crash. This shows that older drivers are involved in a larger proportion of their crashes as a result of failing to give way (40% of their crashes compared to 17% of all injury crashes), failing to see another road user (19% vs. 8% overall) and medical/health reasons (22% vs. 2% overall). On the other hand, their crashes are less likely than average to involve speed, alcohol, losing control, overtaking, inexperience, vehicle problems or road factors. Eberhard (1996), in his analysis of U.S. data found a similar pattern, with causes of older driver crashes more related to inattention or slowed perception than to the sort of deliberate unsafe behaviours that are characteristic of younger drivers' crashes, such as speeding and drinking and driving. There is strong evidence, however, that older drivers who are not cognitively impaired recognise their limitations as drivers and avoid driving situations that present them with difficulties (Hakamies-Blomqvist, 1998).

Table 1: Percentage of all drivers of light 4-wheeled vehicles involved in injury crashes 1997, 1998, with specified cause code, by age of driver

Age group	n drivers	Alcohol	Speeding	Fail to give way	Fail to keep left	Too far left	Lost control	Over-taking	Too close	Sudden	No see	Inexp-erience	Tired	Inattent-ion	Medical	Vehicle	Road
14-24	7540	15%	19%	16%	2%	1%	6%	2%	3%	3%	7%	8%	4%	12%	0%	3%	9%
25-34	5740	14%	11%	14%	2%	1%	3%	2%	3%	3%	7%	2%	4%	9%	1%	2%	9%
35-44	4391	11%	7%	15%	2%	1%	3%	1%	3%	2%	7%	1%	3%	9%	1%	2%	9%
45-64	4400	5%	5%	18%	2%	1%	3%	1%	3%	2%	8%	1%	3%	8%	2%	1%	9%
65-74	1091	2%	3%	28%	3%	1%	3%	1%	3%	2%	12%	1%	3%	12%	5%	1%	10%
75 plus	750	2%	3%	40%	2%	3%	2%	1%	2%	1%	19%	1%	3%	11%	22%	1%	6%
TOTAL	23912	11%	11%	17%	2%	1%	4%	2%	3%	3%	8%	4%	4%	10%	2%	2%	9%

Travel patterns of older drivers differ considerably from those of younger drivers. Older drivers are less likely to commute and they have more flexibility as to when and where they travel. On average, they drive less overall and tend to make shorter trips, although the actual number of driving trips made per drivers aged 80 plus is similar to the number made by drivers aged under 25, for example (LTSA, 2000a; LTSA, 2000b). Older drivers choose to travel less at night (and correspondingly more during the day). This may be related to less demand for night-time travel for older people as well as to deliberate avoidance of situations that present more problems for older drivers than for younger ones (Hakamies-Blomqvist, 1998), such as driving in darkness and coping with the glare of headlights (Sivak, 1995).

There are arguments that risk curves such as that shown in Figure 1 give an unfair impression that older drivers are “poor” drivers. Compared to young drivers, drivers aged 80 and over are more prone to suffering injuries in crashes (Evans, 2001), increasing their injury crash involvement rate. Thus, a crash that may cause little harm to a younger person can injure a more fragile older person. Further, a measure of risk that does not take into account the nature of driving undertaken may misrepresent the actual risks (Janke, 1991). For example, an older person driving a kilometre on local urban roads may have more opportunities of collision involvement than a person who drives the same distance on a motorway or freeway.

The current study makes use of a rare opportunity to model driver risk according to driving on different types of road. This enables the risk estimates to be relatively unconfounded by differences in the travel behaviour of different age groups, which has long been suspected as a major contributor to older driver elevated crash risks per distance driven. As noted by Janke (1991), there should be a whole family of accident per distance curves, depending on the driving conditions. This paper describes a model that allows for the existence of a number of such curves. These can be expected to vary according to the parameters considered, which include age and gender of driver, time of night, time of year, weekend/weekday, and type of road.

3. METHOD

3.1 STUDY DESIGN

The study was a case-control design of driver-kilometres (a kilometre of travel by a particular driver). The driver-kilometre was defined as a case if the driver had been involved in a crash on that road section. A control driver-kilometre consisted of a kilometre of road travel not involving a crash driven by a representative sample of New Zealand drivers over the period of a year (from mid-1997 to mid-1998). Dimensions of risk evaluated included driver characteristics, road characteristics and time of travel characteristics. The study was restricted to light four-wheeled vehicles (cars, vans and utility vehicles) as trucks and motorcycles involve a substantially different driving task and have very different risks (LTSA, 2000b).

3.2 ANALYSIS METHOD

As the data were clustered according to the primary sampling units (for the controls) or according to the particular crash in which more than one driver was involved (for the cases), it was appropriate that the method for forming risk estimates took into account this clustering. Case-control data of the type studied here are well suited to logistic regression analysis, of which the generalised estimation equation method is an extension that is valid for clustered data (Zeger and Liang, 1992). This method was put into effect using the SAS procedure GENMOD (SAS Institute, 1998) using the REPEATED statement and an exchangeable correlation structure, which appears most suitable for modelling crash risk (Hutchings et al., 2003). It is not unusual for data of this type to be overdispersed (to have higher variability than expected for binomial data). To account for this, a multiplicative overdispersion factor was calculated to be the deviance divided by the degrees of freedom, which had a value of slightly less than two. As risk was expected to vary smoothly with age, it was decided to model age as a continuous variable. To find the most appropriate functional form (a form that fitted the data well but was nevertheless not too specific to the particular data), the method of fractional polynomials (Royston and Altman, 1994) was used. This involved fitting a number of possible polynomials to the data to find the functional form of age that gave the best fit from a small but reasonable selection of polynomial expressions, and a significantly better fit than less complex functional forms of the variable. The resultant functions were found using STATA (StataCorp, 2001). Age was represented by a two-term function that expresses risk against age as a U-shape. The two functions (scaled and centred) used to represent the effect of individual driver age were:

$$AGE1 = \left(\frac{age+1}{10}\right) - 4.298 \quad (1)$$

$$AGE2 = \left(\frac{age+1}{10}\right)^2 - 18.47 \quad (2)$$

The other variables included in the model, together with their estimated coefficients, empirical standard error estimates and confidence intervals are listed in the appendix. The variables include driver gender (SEX), night (DARK=1 for 8pm to 6am, =0 otherwise), season ("WINTER", June to August; "HOLS" - summer holidays, December and January; "OTHER" – all other times of year), weekend/weekday (WEEKEND=1 from Friday 4pm to Monday 6am, =0 otherwise), ROAD (Major Urban, Minor Urban - where "urban" means that the speed limit is less than or equal to 70 km/h - and rural speed limit road types: Motorway, Divided State Highway[1], Undivided State Highway and Other rural roads). Only terms that were significant at the 5% level were retained in the model. No third-order interactions were significant.

3.3 CONTROL DATA (DERIVED FROM TRAVEL SURVEY DATA)

Over a period of a year – from mid-1997 to mid-1998 - approximately 14,000 people were surveyed from 7,000 randomly sampled households (LTSA, 2000a). The survey was designed to produce national estimates of travel and travel-related information. Interviewed in person at their homes, people were asked to describe all of their travel for two particular days (called "travel days"). As these days were spread out over a whole year, information could be scaled up to represent a year's travel by all New Zealanders. There was a very high response rate with 75% of households providing full information from all household members, each of whom was personally interviewed. At least one valid interview was completed for 79% of households. The distance of each driving trip was computer-calculated by locating the trip origin map co-ordinates, the destination map co-ordinates, and by measuring the road distance between the two. This last calculation was done by Critchlow Associates, who used an algorithm that calculated the shortest route (in terms of driving time) from the trip origin to the destination. Where a respondent took a route that was not the shortest (for example, a scenic drive), an intermediate address or road was specified so that the route generated passed through this intermediate point. The routes were then

[1] State Highways are state-administered roads that link most New Zealand towns and cities.

matched to a digitised map of all NZ roads to enable distances to be calculated, classified by the six types of road listed in section 3.2.

3.4 CASE DATA

Information about motor vehicle crashes was extracted from the Land Transport Safety Authority's database of coded information derived from Traffic Crash Reports. As the travel survey began and ended in the middle of consecutive calendar years, it was appropriate to form risk estimates that combined crash data from both years spanned by the survey. Thus, numbers of crashes were averaged over the two calendar years 1997/98, to form estimates of average annual crashes or crash involvement. There were 23,912 crash-involved drivers in 1997 and 1998. The crashes were also classified according to their location into the six road types listed in section 3.2.

3.5 CRUDE RISKS AND DRIVING PATTERNS

Crude risks (crash involvements per 100 million km driven) were calculated by combining case and control data for the common variables age, gender, time of travel/crash, day of travel/crash and location of travel/crash. Using these estimates, it was possible to estimate crash rates of given driver age groups supposing that they adopted another driver group's driving patterns. For this calculation, the risks per driving situation (where a situation is defined by driving time and location) for a given age group were multiplied by the corresponding proportion of driving done in this situation by another age group to estimate a crash rate for the given age group as though they drove their total distance distributed across the various driving situations proportionately like the second age group. This can be represented mathematically as follows:

Let $\hat{r}_{bi}$ be the crude estimated risk of crash involvement for driver group β in driving situation *i* (*i=1, …, n*). Such a driving situation may be driving at night on a motorway on a weekend night. Let d_{bi} be the distance driven by driver group β in driving situation *i,* then $d_b = \sum_{i=1}^{n} d_{bi}$ is total distance driven by group β. The estimated relative crash rate of group β driving with the driving patterns of another driver group, α, is estimated to be:

$$\left(\sum_{i=1}^{n}(d_{ai} \times \hat{r}_{bi} / d_a)\right) \Bigg/ \left(\sum_{i=1}^{n}(d_{bi} \times \hat{r}_{bi} / d_b)\right) \qquad (3)$$

4. RESULTS

4.1 DRIVING PATTERNS IN RELATION TO RISK

Table 2 shows the different driving patterns of different age groups derived from New Zealand Travel Survey data. Older drivers drive very little at night. Young drivers drive more at night (15% of driving distance) compared to 9% of total distance for 45-64-year-old drivers and only 4% of total distance for drivers aged 75 and over. When this oldest group do drive at night, they tend to use motorways (at a time of low congestion) proportionately more than during the day.

Table 2: Driving patterns of different age groups by day/night and road type, with percentage of total age group's driving (SH=State Highway).

Age	Day / night	Percentage of total age group's driving by road type						TOTAL
		Minor Urban	Major Urban	Divided SH Rural	Undivided SH Rural	Other Rural	Motorway	
14-24	day	13	24	1	17	15	15	85
14-24	night	2	4	0	2	3	3	15
25-34	day	14	23	1	24	15	13	90
25-34	night	2	3	0	2	2	2	10
35-44	day	13	21	1	23	20	12	90
35-44	night	1	2	0	2	2	2	10
45-64	day	13	22	1	24	20	11	91
45-64	night	1	2	0	2	2	2	9
65-74	day	14	20	0	30	21	9	94
65-74	night	1	1	0	1	1	1	6
75+	day	18	26	0	23	18	10	96
75+	night	1	2	0	0	0	2	4

Table 3 shows the change in crash involvement that would be expected if a given age group adopted the driving patterns of another age group (but drove the same total distance and had the same risk per driving situation - e.g., a situation may be driving at night on an urban road). Each age group's existing crash involvement is set to 1 (the diagonal of the table – see also equation 3). So, for example, if the youngest driver group (14-24) were to drive at the same times and road types as drivers aged 75 plus, their crash involvement rate would be only 91% of their current rate. For the two oldest age groups featured, it is apparent that their existing driving patterns are the safest (of all age groups' patterns) for them (but not always the safest for other driver groups). If an average driver aged 75 plus were to behave like an average young driver (in terms of driving patterns), there would be an 18% predicted increase in that driver's risk of injury crash involvement per kilometre travelled.

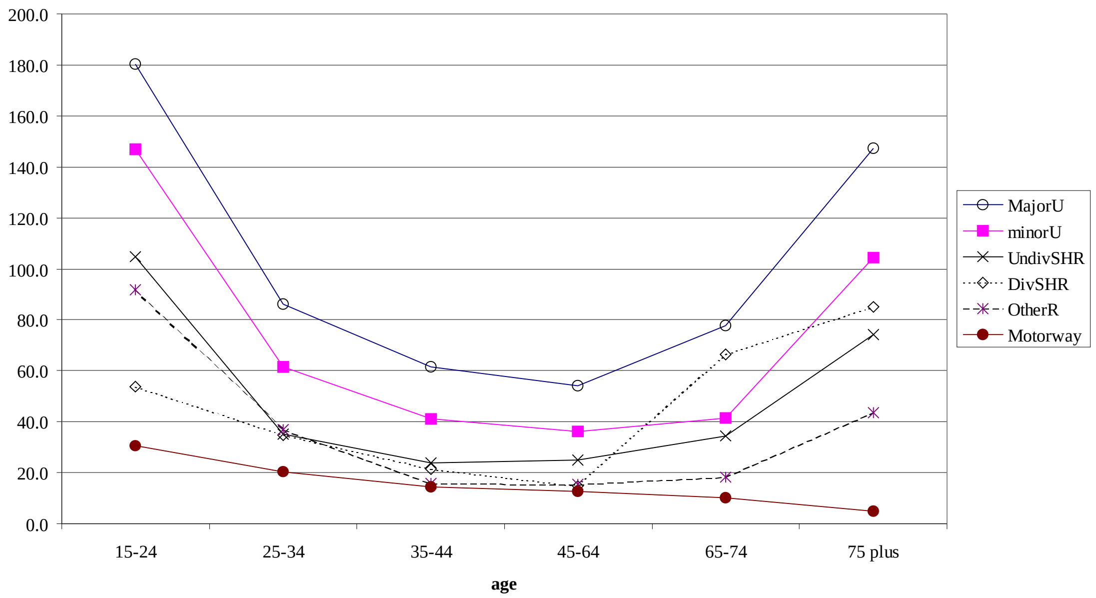
Table 3: Relative crash involvement rate per driver age group (rows) if that age group were to adopt another age group's (columns) driving patterns, but retain their own risk per driving situation and total distance driven.

	Age group whose driving pattern is adopted					
Age group	14-24	25-34	35-44	45-64	65-74	75plus
14-24	1.00	0.94	0.92	0.92	0.88	0.91
25-34	1.12	1.00	0.97	0.98	0.91	0.98
35-44	1.17	1.06	1.00	1.01	0.96	1.06
45-64	1.09	1.03	0.99	1.00	0.97	1.05
65-74	1.07	1.04	1.01	1.03	1.00	1.08
75 plus	1.18	1.20	1.13	1.14	1.08	1.00

4.2 CRUDE RISK ESTIMATES

Numbers of case road sections were divided by the numbers of control road sections to form crude risk estimates of injury crash involvements per 100 million km driven, shown in Figure 2. This indicates that driving on motorways is the safest form of travel per km driven for all age groups according to the crude risk estimates. The most risky roads (in terms of injury crash involvement per distance driven) are the urban speed limit roads, Minor Urban and Major Urban. Only Motorways do not show increasing risk for older drivers. For all other road types, there is a distinctive U-shape, as is also evident in the overall risk curve for all roads combined (Figure 1).

Figure 2: Crude risks of injury crash involvement per 100 million km driven by road type



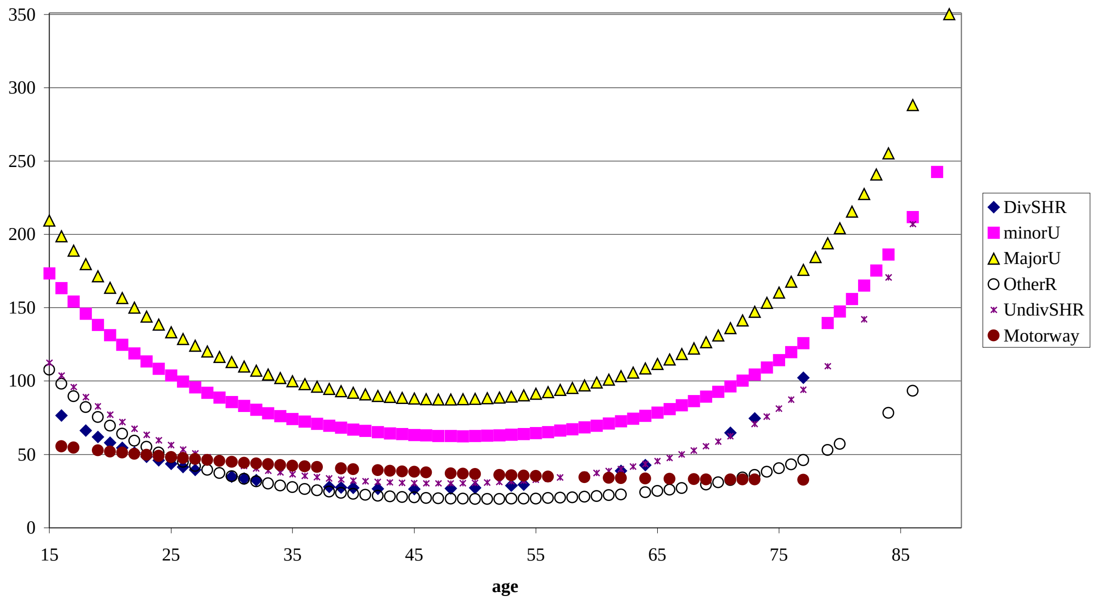
4.3 ADJUSTED RISKS

The coefficients estimated by the logistic model fitted to the data are shown in the Appendix. The model is a complex one, involving interactions between several factors so that any given dimension of risk is always represented by the combined effects of several factors.

4.3.1 Age by road type

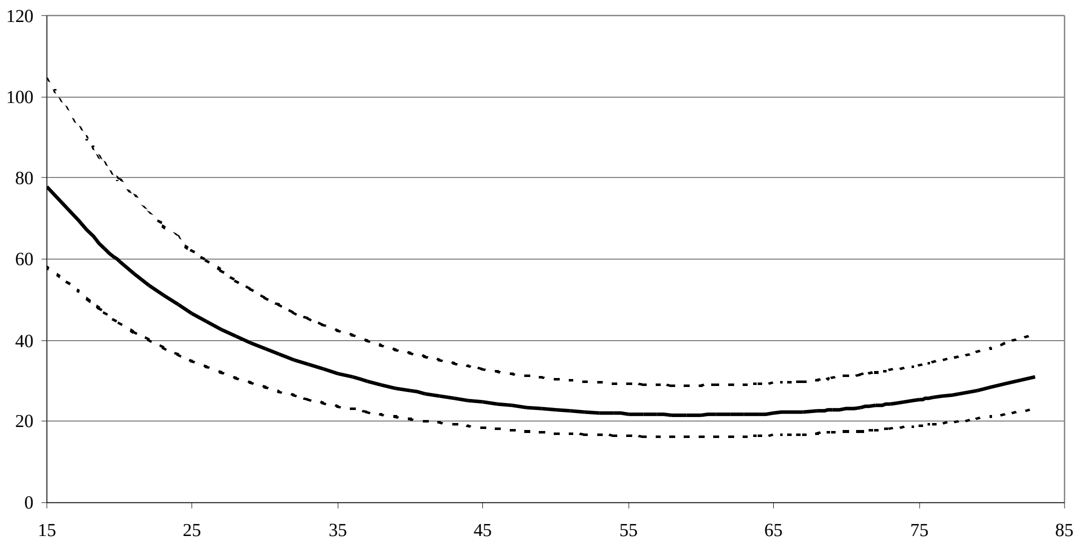
Figure 3 shows the model-based risk estimates by age and road type for female drivers during the day on weekdays during the summer holiday period. In common with most of the graphs shown hereon, only age groups with either case or control data for the configuration represented generate a point on the graph. For example, Figure 3 shows that there were neither crashes nor travel recorded for drivers aged over 77 on Motorways for the times represented. As the six curves for the six road types are all for the same driver/time-of-day/season configuration, the graph shows the way that risk changes differentially by the single dimension of age for different road types. The steeper upward slope of the curves for Divided SH (State Highway) Rural roads and Undivided SH Rural roads for older drivers indicates that risk increases proportionately more quickly with older age for these roads than for other road types. Further investigation was required to determine whether the apparently diminishing risk with age on Motorways shown in Figures 2 and 3 was statistically significant.

Figure 3: Model-based risk estimates for female drivers during the day on weekdays during summer holiday period, by age and road type



To address this question, Figure 4 shows how risk changes with age (for male drivers during the day on weekdays during winter) on Motorways with 95% confidence intervals for the risk estimate. It is clear that risk is relatively high for young drivers, but decreases to a fairly low level from about age 35 and there is no statistically significant increase in risk for older drivers from that of middle-aged drivers. In fact, for female drivers, the slight non-significant upturn in risk for older drivers on Motorways does not occur in the model-based estimates. This is discussed further in 4.3.2. A potential limitation of the data used in this analysis is that the distance by road type values were generated by an algorithm that connected trip origin and destination via a shortest route. If older drivers are more likely than other drivers to elect slower routes that avoid motorways, there is the possibility that some urban road travel could have been misclassified as motorway travel, resulting in a misleading drop in estimated risk for older drivers on motorways. To check this possibility, non-rush-hour driving trips involving motorway travel were analysed by age group, by proportion of trip distance that was on the motorway and by trip length using travel survey data (i.e., the control sample data). The average trip speed (being the total trip length divided by trip duration, calculated from self-reported trip departure and arrival times) of older drivers was slightly slower than trip speeds of younger age groups. This was expected as older drivers generally drive more slowly (Hakamies-Blomqvist, 1998). As alternative routes to travelling by motorway in New Zealand take much longer to drive (in non-congested conditions), it can be concluded that, for trips that were quickest via motorway, older drivers were not more likely to avoid motorways than other age groups (or there would have been larger differences in their trip speeds).

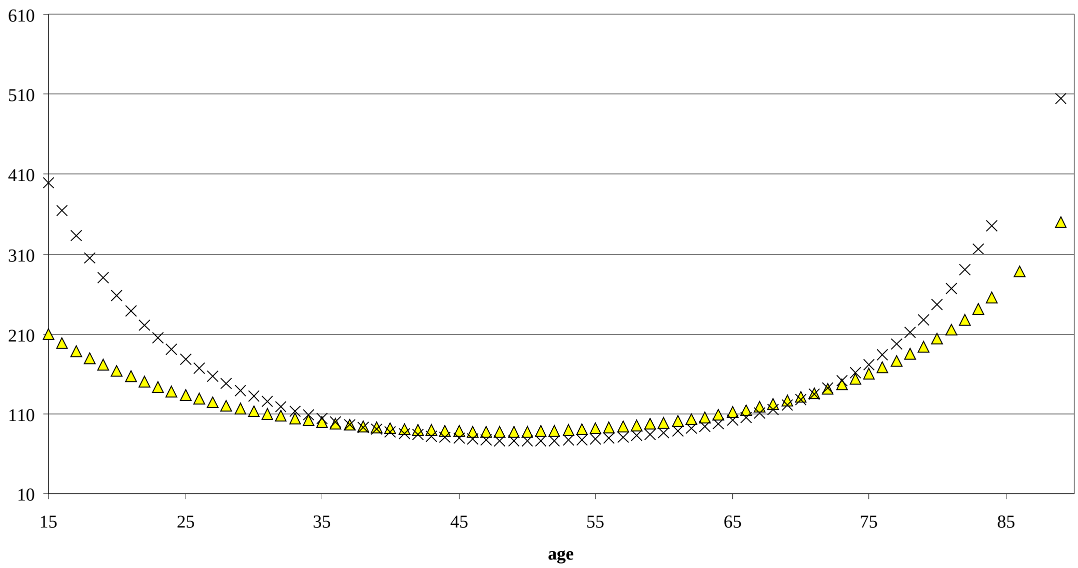
Figure 4: Risk of male drivers during the day on weekdays during winter on Motorways with 95% confidence intervals for the risk estimate (dotted lines)



4.3.2 Age and gender

Figure 5 shows a comparison of male and female risks by age for Major Urban roads. Other dimensions of risk have been held constant to enable comparison of these risks by gender. In the middle of the age range, risks are almost identical. For drivers aged over 75, risk for males relative to females starts increasing quite steeply. The gender comparison of daytime risks for other road types results in a similar pattern. This relative increase in risk at each end of the driving age scale for males is the reason why the risks for female drivers on Motorways is represented by model-based estimates that decrease monotonically with age (Figure 3), whereas there is a small (non-significant) increase for males (Figure 4).

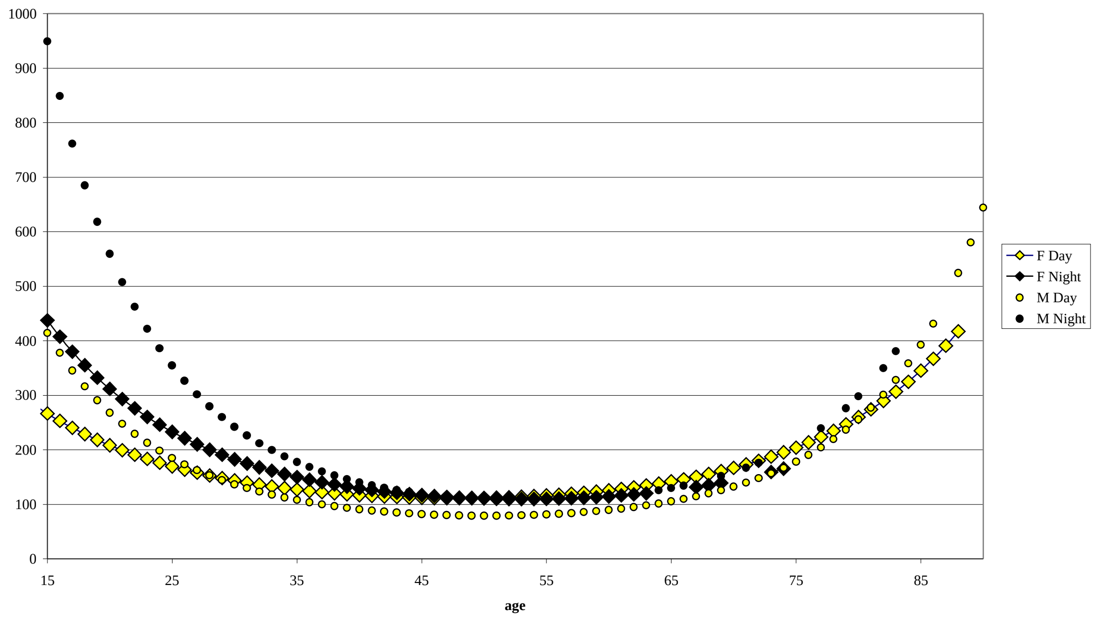
Figure 5: Model-based risk estimates for male (crosses) and female (triangles) drivers on Major Urban roads during the day on weekdays during summer holiday period, by age.



4.3.3 Night driving

Figure 6 shows that there is estimated to be a strong gender effect for night-time risk at. At night, the risks for males over 75 increase more steeply than for females and the overall risk is higher for males. There is little estimated difference in risk for older females driving at night compared to daytime, however. (In fact, there were few crashes and little recorded travel for female drivers aged over 75 at night). The most striking feature of Figure 6 is the high night-time risk for young males that dwarfs the older driver risks. This is discussed in another paper that analyses these data (Keall and Frith, 2003).

Figure 6: Comparison of risk curves for Male and Female driving at night and day on Major Urban roads (winter during the week)



5. DISCUSSION

This study has several limitations. As pointed out by Hakamies-Blomqvist (1998), an approach to evaluating older driver risk that uses risks averaged over driver groups presents a potentially misleading impression that all drivers in a group have a similar degree of risk. Older drivers exhibit more variability in their ability to undertake complex tasks such as driving than do younger driver groups (Rabbit, 1993). Therefore, the group average as a measure of their risk is more liable to be affected by a few drivers with severe deficiencies. As noted by Janke (1991), drivers who ration their driving because they know they may be at high risk per distance driven should not be penalised as a result of the sort of risk curves shown above. Per licensed driver, older drivers are a very safe group and present little risk to other road users (Evans, 2000). These estimates may also not be readily generalisable to other countries. In New Zealand, the older drivers involved in this study were subject to an older driver licensing system that included medical screening and on-road driving tests. This means that the older driver sample may differ in some ways from older driver populations in countries without specific older driver licensing systems. Further, New Zealand is a mountainous country, which means that the rural road network (particularly the Undivided SH Rural and Other Rural roads) includes many relatively narrow and winding roads, so the risks imposed on drivers may also differ from those of other countries.

The result that urban roads presented the highest risk was expected. It is outside the scope of this paper to model separately the risk of serious crash involvement, which is usually higher for rural roads largely owing to higher speeds travelled by the colliding vehicle or vehicles (Kloeden et al., 1997). Greibe (2003) formed models for the crash risk of urban roads, finding that most variability in risk was explained by AADT (average annual daily traffic), followed by land use, number of minor junctions and the presence of parking facilities. All these factors indicate that roads with more complex interactions of vehicles are more risky in terms of crash involvement. It is not surprising that older drivers have a disproportionately higher crash rate on roads that present more complex traffic situations such as urban roads. Older people are less able to perform in multiple-task situations than are younger people (Korteling, 1994) and their higher crash involvement in complex traffic environments has often been noted (e.g., Fildes et al., 1994). Shorter trips undertaken by older drivers may also be inherently more risky as they involve greater frequency of entering and leaving the traffic stream per distance driven. The different risk curves for age by road type show that older drivers become more challenged by the rural speed limit roads with increasing age, but do not appear to have higher risk with increasing age when travelling on motorways, which are also 100km/h speed limit roads but with limited access and a high grade of design, lighting and signage. This steeper increase in risk with age for rural roads may purely reflect the greater fragility of older drivers when subjected to the greater impact forces that accompany higher speed crashes (Evans, 2001). It may also reflect failure to deal with the cognitive challenges of a relatively congested road environment (in the case of the State Highways) at higher speeds. The relative safety of older drivers on motorways, as shown in Figure 3, may indicate the way forward for road design to cater for an ageing population: high grade, well-signalised, well-illuminated road design may prevent some of the anticipated increase in road injury that may come with an older population.

The greater safety of motorways for older drivers does not necessarily imply that older drivers should elect to travel by motorway in preference to alternative routes on other road types. Older drivers who are not cognitively impaired have been shown to choose low risk driving situations over higher risk ones (Hakamies-Blomqvist, 1998).

The results of the current paper (especially Table 3) show that older drivers as a group may choose safe times and environments for their driving. Those drivers currently using motorways may do so because they know they can cope with that traffic environment. The fact that the oldest driver group makes relatively high use of (well-lighted) motorways at night (when congestion is low) may be an example of this.

Both Chipman et al. (1993) and Lefrançois and D'Amours (1997) noted that older women had a higher crash rate than older men per distance driven. This phenomenon was also apparent in the risk curves based on crude estimates of risk per distance travelled produced from the data used in the current study (LTSA, 2000b). Chipman and colleagues considered that this difference in risk for their Canadian data was related to factors such as driving speed, differences in driving environment, risk tolerance and possibly driving experience. When factors such as time of day and road type were controlled for in the model-based risk estimates of the current study, male and female older drivers were quite similar in their risks for daytime driving, but male older drivers were more risky at night. Thus differences in driving environment explain much of the gender difference in risk for older drivers. Reasons for the higher night-time risk for older males are unclear, but they could include driver alcohol use, which is the subject of another study based on these data (Keall et al., 2003).

The fact that there were very few crash involvements at night for drivers aged over 75, particularly female drivers, is consistent with the minimal amount of night driving undertaken by this age group. This may be a consequence of deliberate avoidance of night driving or of the lack of night-time activities involving older people that require transportation. The greater avoidance of night driving by older females than older males is also noted by Hakamies-Blomqvist and Wahlström (1998).

6. CONCLUSIONS

This study has shown that some of the differences noted between the risks of older driver groups in previous studies may be explained by different travel patterns. For example, the phenomenon of higher older female crash rate than male crash rate for the same aged drivers was found to disappear when risk was disaggregated by type of road. Further, the risk differential was reversed for night-time driving, with older males estimated to be at more risk than older female drivers. A significant finding of this study was the relative safety of motorways for older drivers. For such roads, there was no significant upturn in risk with increasing age. This indicates that road networks of the future should include features of motorway design that protect older drivers from harm. It is clear that older drivers generally avoid driving in the dark, an environment in which the deterioration of vision that often accompanies ageing can increase crash risk. Whether this reflects deliberate avoidance of night driving or simply lack of transportation demand cannot be determined from the present study. When the driving patterns of various age groups are compared, it is apparent that older drivers have selected (whether deliberately or as a consequence of lifestyle) driving patterns that minimise their risk.

7. ACKNOWLEDGEMENTS AND DISCLAIMER

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Appendix: GEE parameter estimates with empirical standard error estimates

Parameter	Level1	Level2	Description	Estimate	Stderr	LowerCL	UpperCL
Intercept				-15.151	0.1868	-15.5169	-14.7845
age1			See formula (1)	-0.7868	0.1867	-1.1528	-0.4209
age2			See formula (2)	0.0651	0.0204	0.0251	0.1052
SEX	F			0.3206	0.1157	0.0938	0.5474
SEX	M			0	0	0	0
dark			8pm to 6am	0.3328	0.133	0.0721	0.5934
ROAD	Div SH R			0.1029	0.2807	-0.4473	0.6532
ROAD	Minor U			0.8188	0.1648	0.4958	1.1419
ROAD	Major U			1.1914	0.1519	0.8937	1.4891
ROAD	Other R			-0.4492	0.2086	-0.8581	-0.0403
ROAD	Undiv SH R			-0.3082	0.2034	-0.7069	0.0906
ROAD	M'way			0	0	0	0
weekend			4pm Fri - 6am Mon	0.0429	0.06	-0.0748	0.1606
SEASON	Hols		Dec - Jan	0.2805	0.3122	-0.3315	0.8925
SEASON	Other		Feb-May, Sep-Nov	-0.6488	0.2088	-1.0581	-0.2395
SEASON	Winter		Jun - Aug	0	0	0	0
age1*SEX	F			0.5711	0.1341	0.3083	0.834
age1*SEX	M			0	0	0	0
age1*dark				-0.2347	0.1487	-0.5262	0.0568
age1*ROAD	Div SH R			-0.9721	0.3508	-1.6597	-0.2845
age1*ROAD	Minor U			-0.6714	0.1708	-1.0062	-0.3365
age1*ROAD	Major U			-0.5779	0.1608	-0.893	-0.2628
age1*ROAD	Other R			-1.1409	0.2062	-1.545	-0.7368
age1*ROAD	Undiv SH R			-1.0106	0.2255	-1.4526	-0.5686
age1*ROAD	M'way			0	0	0	0
age1*weekend				0.015	0.1252	-0.2304	0.2604
age2*SEX	F			-0.0516	0.0145	-0.08	-0.0233
age2*SEX	M			0	0	0	0
age2*dark				0.0135	0.0166	-0.0191	0.0461
age2*ROAD	Div SH R			0.1165	0.0385	0.041	0.192
age2*ROAD	Minor U			0.0753	0.0188	0.0385	0.1122
age2*ROAD	Major U			0.0679	0.0178	0.033	0.1028
age2*ROAD	Other R			0.1162	0.0226	0.0718	0.1606
age2*ROAD	Undiv SH R			0.1139	0.0237	0.0674	0.1604
age2*ROAD	M'way			0	0	0	0
age2*weekend				-0.0043	0.0134	-0.0305	0.022
dark*SEX	F			-0.333	0.0865	-0.5026	-0.1633
dark*SEX	M			0	0	0	0
SEX*ROAD	F	Div SH R		-0.1044	0.1918	-0.4804	0.2716
SEX*ROAD	F	Minor U		-0.101	0.0921	-0.2815	0.0795
SEX*ROAD	F	Major U		-0.042	0.0846	-0.2078	0.1239
SEX*ROAD	F	Other R		-0.1072	0.1076	-0.318	0.1037
SEX*ROAD	F	Undiv SH R		0.1957	0.1123	-0.0244	0.4159
SEX*ROAD	F	M'way		0	0	0	0

Appendix: GEE parameter estimates with empirical standard error estimates (continued)

Parameter	Level1	Level2	Estimate	Stderr	LowerCL	UpperCL
SEX*ROAD	M	Div SH R	0	0	0	0
SEX*ROAD	M	Minor U	0	0	0	0
SEX*ROAD	M	Major U	0	0	0	0
SEX*ROAD	M	Other R	0	0	0	0
SEX*ROAD	M	Undiv SH R	0	0	0	0
SEX*ROAD	M	M'way	0	0	0	0
SEX*SEASON	F	Hols	-0.2048	0.1318	-0.4632	0.0536
SEX*SEASON	F	Other	-0.13	0.0836	-0.2939	0.0339
SEX*SEASON	F	Winter	0	0	0	0
SEX*SEASON	M	Hols	0	0	0	0
SEX*SEASON	M	Other	0	0	0	0
SEX*SEASON	M	Winter	0	0	0	0
dark*ROAD	Div SH R		-0.0454	0.3204	-0.6735	0.5826
dark*ROAD	Minor U		0.0866	0.1307	-0.1697	0.3428
dark*ROAD	Major U		0.0769	0.1174	-0.1533	0.3071
dark*ROAD	Other R		0.257	0.1353	-0.0081	0.5221
dark*ROAD	Undiv SH R		0.3942	0.1496	0.101	0.6873
dark*ROAD	M'way		0	0	0	0
dark*weekend			0.3826	0.0882	0.2097	0.5554
ROAD*season	Div SH R	Hols	-0.3871	0.5696	-1.5034	0.7293
ROAD*season	Div SH R	Other	0.3409	0.353	-0.3509	1.0327
ROAD*season	Div SH R	Winter	0	0	0	0
ROAD*season	Minor U	Hols	-0.2079	0.2771	-0.751	0.3352
ROAD*season	Minor U	Other	0.4096	0.1817	0.0536	0.7657
ROAD*season	Minor U	Winter	0	0	0	0
ROAD*season	Major U	Hols	-0.3174	0.2617	-0.8303	0.1955
ROAD*season	Major U	Other	0.2493	0.1673	-0.0786	0.5771
ROAD*season	Major U	Winter	0	0	0	0
ROAD*season	Other R	Hols	-0.0262	0.3295	-0.6721	0.6196
ROAD*season	Other R	Other	0.7316	0.2301	0.2806	1.1826
ROAD*season	Other R	Winter	0	0	0	0
ROAD*season	Undiv SH R	Hols	-0.1131	0.3223	-0.7447	0.5185
ROAD*season	Undiv SH R	Other	0.6601	0.2288	0.2117	1.1086
ROAD*season	Undiv SH R	Winter	0	0	0	0
ROAD*season	M'way	Hols	0	0	0	0
ROAD*season	M'way	Other	0	0	0	0
ROAD*season	M'way	Winter	0	0	0	0