ARE RECENT AUSTRALIAN CARS SAFER OR ARE THEY JUST BIGGER?

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ABSTRACT

The Australian Design Rules (ADRs) have set standards for occupant protection in private and commercial vehicles since 1968. In order to measure the impact of these design changes, the crashworthiness of vehicles manufactured from 1970 to 1995 was estimated from records of crashes occurring in Western Australia between 1987 and 1996. These crash records included crash site and driver information as well as the year of manufacture and the make, model and mass of each vehicle involved.

The risk of serious injury (hospital admission or death) in tow away crashes was estimated using multiple logistic regression. Adjustments were made for driver age, gender, speed zone, vehicle mass and mass ratio. Admission to hospital or death was derived from police crash reports that were linked to hospital discharge or death records in the WA Road Injury Database.

The median mass of crashed vehicles decreased from 1300 kg in 1970 vehicles to 1100 kg in 1985 vehicles and increased again to 1300 kg in 1995 vehicles. There were reductions in the proportion of drivers with serious injury over vehicle manufacture years 1970 to 1980. The estimated risk of serious injury to drivers of 1980s passenger cars was approximately two-thirds the risk for 1970s vehicles in most crash situations. However, there was virtually no improvement in crashworthiness of vehicles manufactured after 1990, when corrected for vehicle mass.

SUBSTANTIAL CHANGES HAVE OCCURRED in the design of passenger vehicles over the past 30 years. In Australia this has been driven in part by the regulatory requirements of the Australian Design Rules (ADRs) introduced in 1968. Crash testing of new cars has been carried out in Australia since 1993 by the New Car Assessment Program to demonstrate the occupant protection capabilities of vehicles tested.

BACKGROUND

In Australia, Newstead & Cameron (1997) demonstrated that crash outcomes for drivers of particular makes and models of vehicles were consistent with test results from the New Car Assessment Program (NCAP). Specifically, reductions in the risk of head and chest injury in real crashes were of the same order as head and chest injury criterion scores obtained from NCAP results. In addition, despite significant differences between certain makes and models of vehicles, it was confirmed that on average a driver in a 1990s vehicle had a significantly lower risk of injury than that experienced by a similar driver in a 1970s vehicle. The Monash University Accident Research Centre has also measured the 'crashworthiness' and 'aggressivity' ratings for particular makes and models of passenger cars (Cameron et al, 1997).

A British index, developed by Broughton (1996), demonstrated a linear relationship with mass. The index was derived from two-car crashes where at least one driver was injured and was defined to be 'the proportion of vehicles with an injured driver compared to all such drivers'. Using information on two vehicle crashes from the US Fatal Accident Reporting System (FARS), Evans & Frick (1994) found a relative safety disadvantage of small compared to large cars that was less for post-1980 cars than for pre-1980 cars. This reduced mass effect for mid-1980s cars was attributed to improved safety features appearing in small cars earlier than in large cars.

In the present study we have examined the effect of mass and relative mass in single and multiple vehicle collisions after correcting for driver age, gender, crash type and speed zone. The information was derived from police crash reports linked to hospital and death records.

METHODS

In Western Australia road crashes resulting in injury or property damage exceeding $1000 should be reported to the police. The Traffic Accident System (TAS) contains details from these reports as well as vehicle licence details and additional road information. Records of all crashes occurring between 1st January 1987 and 31st December 1996 have been extracted and linked to hospital admission and death registration records to form the WA Road Injury Database (Ferrante AM, et al, 1993). Records of all drivers of standard passenger vehicles involved in road crashes requiring a vehicle to be towed from the scene were selected for this study. In the TAS, for collisions between two vehicles, one is defined as the 'colliding' vehicle and the other as the 'target' vehicle. The 'target' is usually the vehicle least likely to be 'at fault' ie, the vehicle in front in a rear impact; the vehicle hit on the side in a right angle collision; and the vehicle travelling on the correct side of the road in a front impact.

For this analysis a driver was defined as being 'seriously' injured if there was a matching hospital admission or death record. The speed zone at the crash location was a proxy for vehicle travelling speed and the vehicle mass was its 'tare weight'. The risk of serious injury was estimated by using multiple logistic regression models in which adjustments were made for time of day, speed zone, driver age and gender, vehicle mass and mass ratio. Driver injury only was used as the measure of crashworthiness since the presence of uninjured passengers was not recorded in the crash data.

RESULTS

In WA, during the 10-year period 1987-1996, 52,890 passenger vehicles were involved in single vehicle crashes reported to the police and 35,201 of these vehicles were towed from the scene. Over the same period, 496,396 passenger vehicles were involved in reported multi-vehicle crashes resulting in 113,447 vehicles being towed away. Complete vehicle and driver information was available for 28,344 vehicles in multi-vehicle tow-away crashes and for 13,218 single vehicle crashes.

PROPORTION OF DRIVERS INJURED 1872 (14.2%) drivers were seriously injured in single vehicle tow-away crashes, while 506 (3.6%) were seriously injured in multi-vehicle tow-away crashes. Figure 1 shows the proportion of drivers who were seriously injured for each vehicle model year. In single vehicle crashes the proportion of drivers with serious injury (17.3%) was highest in vehicles manufactured between 1970 and 1974, fell to a minimum of 12.6% in vehicles manufactured in the 1980-1984 period and rose to 14.4% in post-1995 vehicles. In multi-vehicle crashes, the proportion of drivers with serious injury in the 'target' vehicle fell from 5.4% in 1970-1974 models to 2.7% in vehicles manufactured after 1995. Similarly, the proportion of seriously injured drivers in the 'colliding' vehicle fell from 4.5% in 1970-1974 models to 2.1% in vehicles manufactured after 1995. The greatest reduction in all three groups occurred for vehicle model years 1970 to 1984.

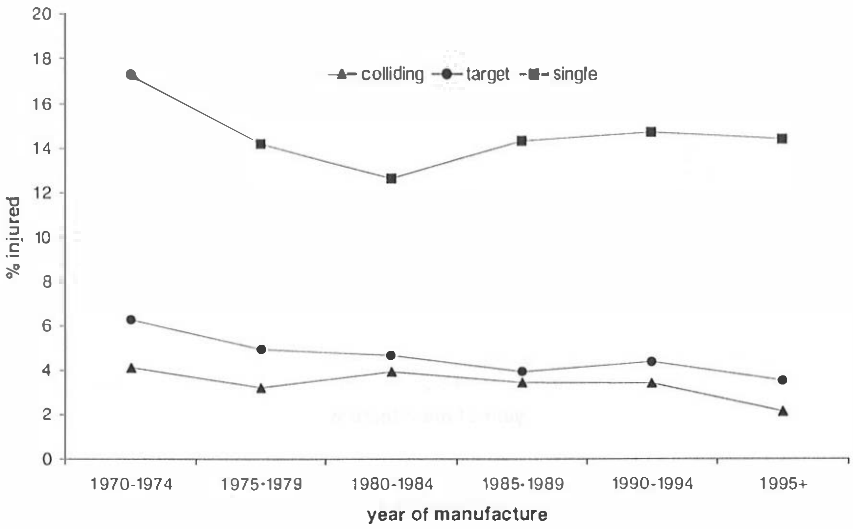

Figure 1 Serious injuries to drivers in tow-away crashes, Western Australia 1987-1996.

LOGISTIC REGRESSION MODELLING In the second part of the analysis, the risk of serious injury was estimated using logistic regression models. A simple model, using only year of vehicle manufacture to predict risk of injury was developed first. The effect of year of vehicle manufacture was initially measured as a 'class' variable with a separate coefficient for each year. Other models using linear, quadratic and cubic trends for the year of manufacture were fitted to the data. The quadratic trend fitted the crash data best for all situations and is displayed with the point estimates in Figures 2, 3 and 4 for single, colliding and target vehicles respectively.

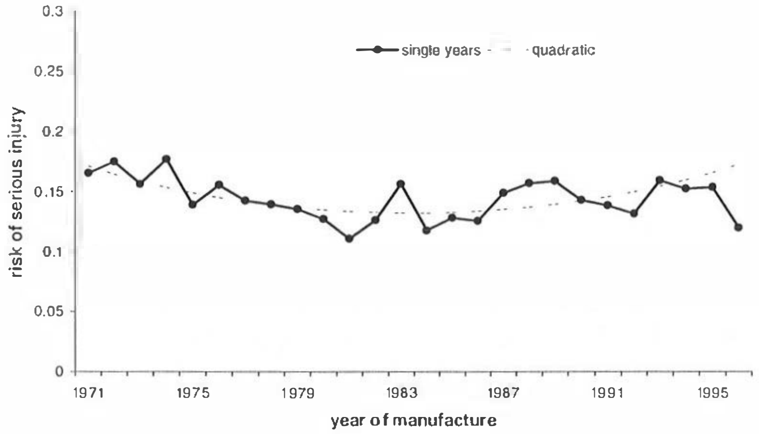

Figure 2. Estimated risk of serious injury to drivers in single vehicle tow away crashes, Western Australia 1987-1996

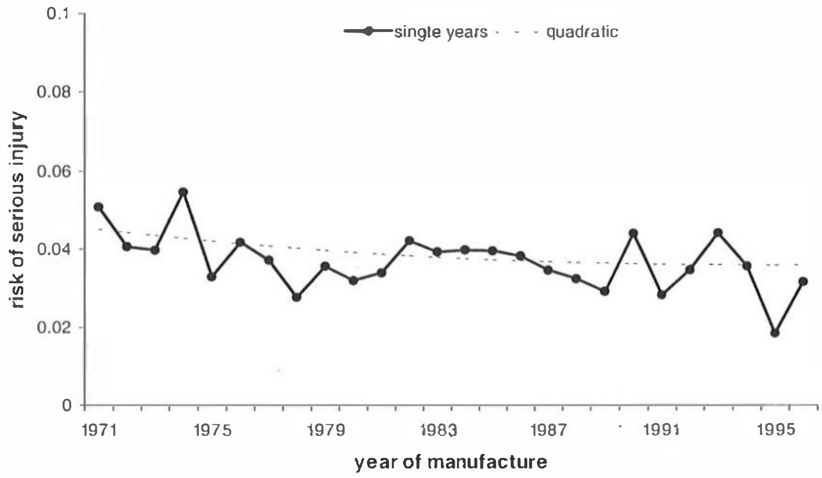

Figure 3 Estimated risk of serious injury to drivers of colliding vehicles in multi-vehicle tow away crashes, Western Australia 1987-1996.

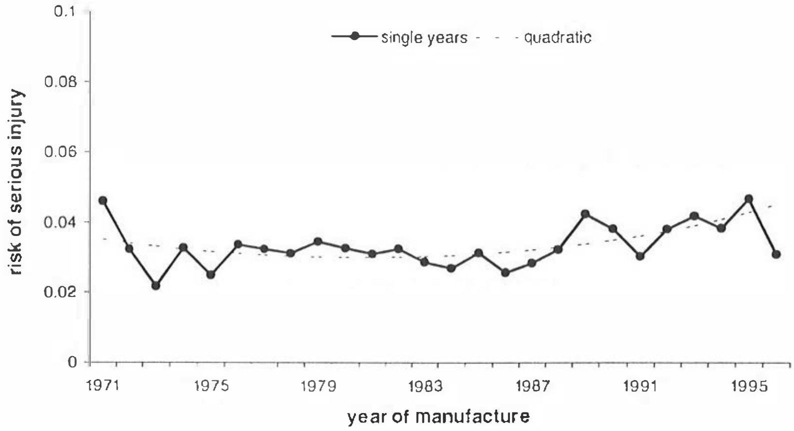

Figure 4 Estimated risk of serious injury to drivers of target vehicles in multi-vehicle tow away crashes. Western Australia 1987-1996.

The estimated risk of serious injury to drivers of 1980s passenger vehicles was approximately two-thirds that for drivers in similar 1970s vehicles in most crash situations. The models suggest an increase in risk for vehicles manufactured after 1985 involved in single vehicle crashes or as 'targets' in multi-vehicle crashes. The actual data for single vehicle crashes indicates an increase in risk between 1985 and 1990.

DRIVER AGE It is known that age is associated with increased risk of injury (eg, Ryan et al, 1998) and there is also a tendency for young drivers to drive older vehicles. In the 1987-1996 crash data, there was a significant relationship between driver age and vehicle year of manufacture for all crash types. Figure 5 shows the median driver age by vehicle model year for single, colliding and target vehicles. The median age of all drivers in vehicles manufactured in 1970 was 25, while drivers of vehicles manufactured in 1996 had a median age of 34 years. Overall, drivers in single vehicle crashes were younger than drivers in multi-vehicle crashes. For multi-vehicle crashes 'colliding' drivers were likely to be younger than 'target' vehicle drivers. The median age of drivers in single vehicle crashes ranged from 21 years (1970) to 29 years (1994); those in 'colliding' vehicles ranged from 25 years (1970) to 35 years (1993) and those in 'target' vehicles ranged from 27 years (1970) to 38 years (1993).

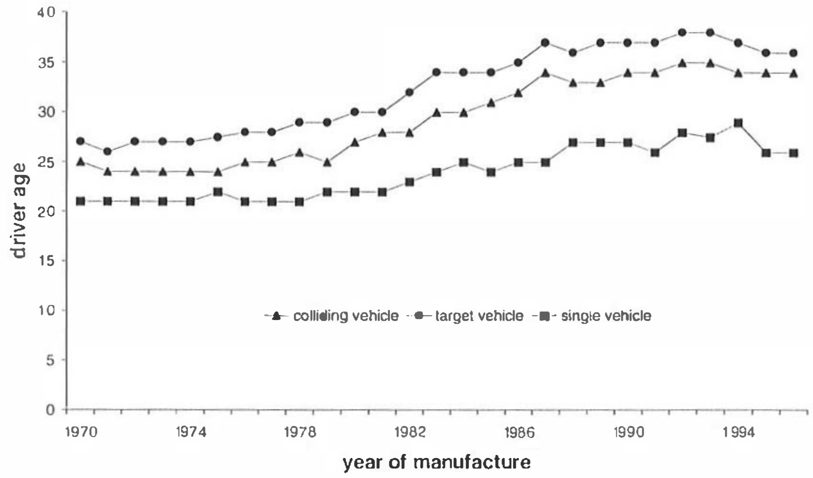

Figure 5 Median driver age by vehicle role and year of manufacture. Western Australia 1987-1996.

Models of relative crashworthiness developed by Cameron et al, 1994 included crash type, time of day and speed zone. These variables are known to have a significant independent association with risk of driver injury. Consequently, crash type, time of day and speed zone were included in all our logistic regression models after the initial investigation of the trend with vehicle model year. The model displayed in Figure 6 included driver age and gender and shows the estimated risk of serious injury for each vehicle year for 20-year old male drivers in right angle crashes, during daytime in a 70km/h zone. These values for crash type, speed zone and time of day have been used throughout to show the independent effect of vehicle model year.

After adjusting for driver age and other factors, the trend in the estimated risk of serious injury was markedly different for 'colliding' and 'target' vehicle drivers. The risk for drivers of 'target' vehicles improved most between model years 1970 and 1985, whereas the improvement for 'colliding' vehicles was greatest for vehicles manufactured after 1985.

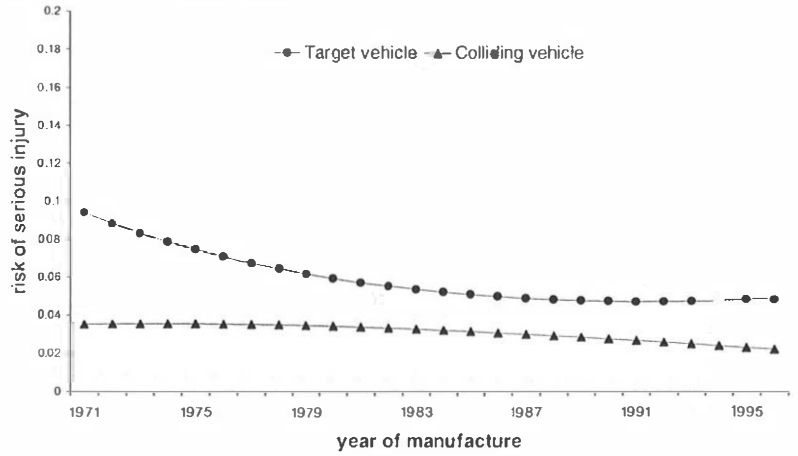

Figure 6 Estimated risk of serious injury to drivers in right angle tow away crashes adjusted for driver age. Western Australia 1987-1996.

VEHICLE MASS. The median vehicle mass for single, 'colliding' and 'target' vehicles involved in crashes between 1987 and 1996 is displayed in Figure 7. Vehicles in single vehicle crashes were marginally heavier than 'colliding' vehicles or 'target' vehicles. The median mass of 'target' vehicles manufactured before 1985 was about 1100 kg rising to more than 1200 kg after 1985. Overall, the median mass of vehicles decreased from 1300 kg for those manufactured in 1970 to 1100 kg in 1980 then increased to 1300kg in 1995.

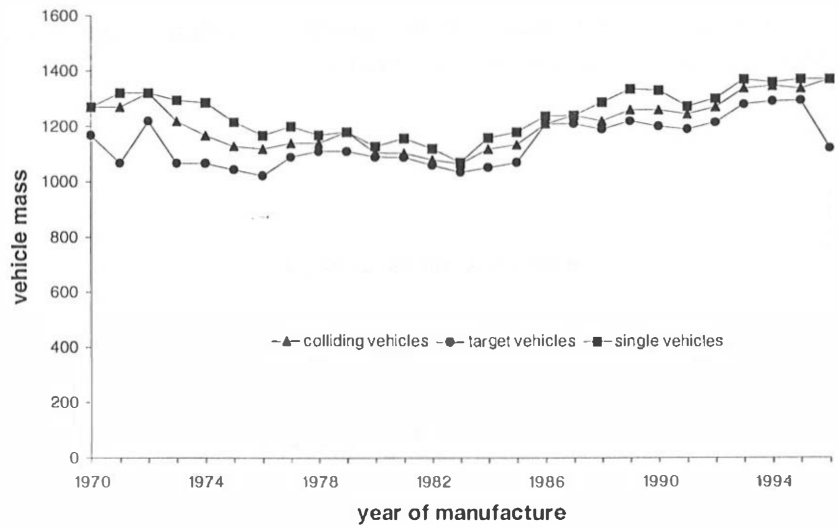

Figure 7 Median mass by vehicle role and year of manufacture. Western Australia 1987-1996.

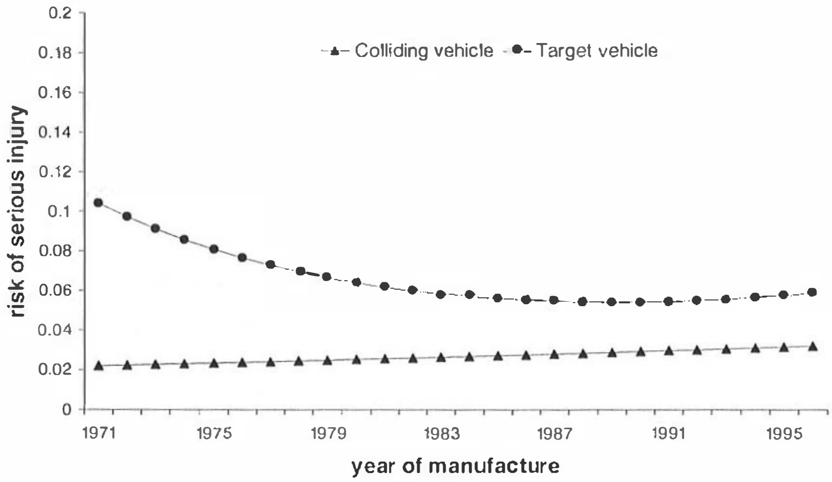

Figure 8 Estimated risk of serious injury to drivers in right angle tow away crashes, adjusted for driver age and vehicle mass. Western Australia 1987-1996.

Vehicle mass was introduced in the next set of logistic models to account for the relationship between vehicle mass and model year. The trend in risk of serious injury for right angle crashes in a 70km/h speed zone, during the day, for vehicles of mass 1000kg, with male drivers aged 20 years is shown in Figure 8. The risk for drivers of target vehicles manufactured between 1985 and 1995 was about two-thirds that of drivers in 1970s vehicles. For drivers of colliding vehicles, however, the greater risk of 1990s vehicles is a reversal of the trend shown before adjusting for vehicle mass.

MASS RATIO Another important factor in two-vehicle crashes is the relative mass of each vehicle. The ratio (MR) between the mass of the colliding vehicle and the mass of the target vehicle was used here to represent this factor.

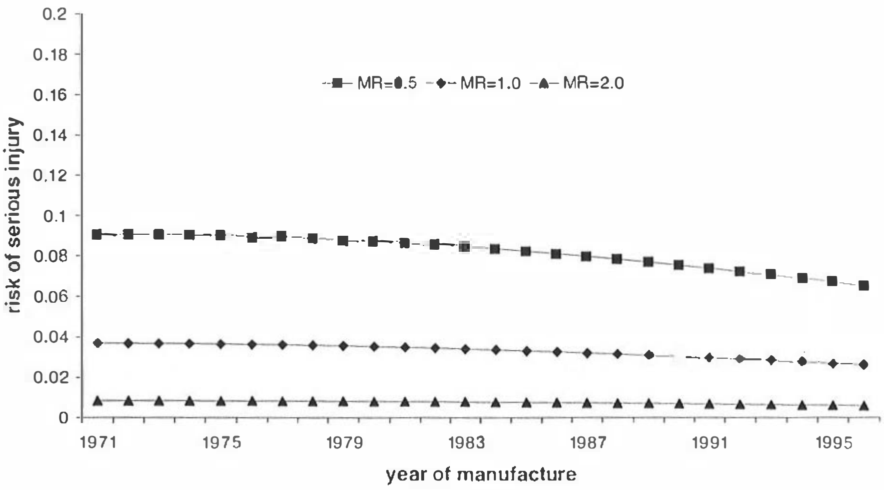

Figure 9 Estimated risk of serious injury to drivers of colliding vehicles in right angle tow away crashes by mass ratio. Western Australia 1987-1996.

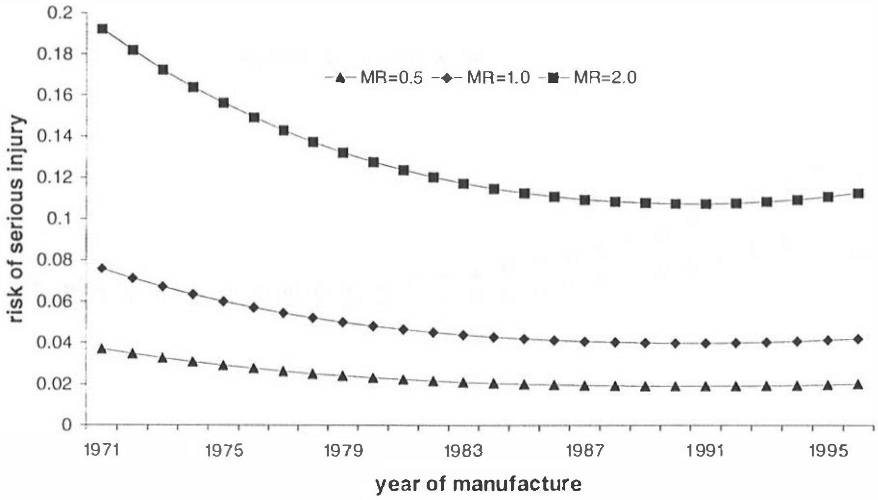

Figure 10 Estimated risk of serious injury to drivers of target vehicles in right angle tow away crashes by mass ratio. Western Australia 1987-1996.

Figures 9 and 10 illustrate the effect of the mass ratio on the risk of serious injury in two car collisions. As an example, in a right angle crash a driver was at greatest risk when colliding with another vehicle that was much bigger. An extreme situation is when MR=0.5 for a colliding vehicle or when MR=2.0 for the target vehicle. As shown in Figure 9, the driver of a 'colliding' vehicle was at greatest risk of serious injury (10%) in a tow-away crash when MR=0.5 and the vehicle was manufactured in 1970. Similarly, the driver of a 'target' vehicle was at the greatest risk (20%) when driving a 1970 vehicle colliding with a much heavier vehicle (MR=2.0). For similar crash conditions, the estimated risk of serious injury for a driver in a target vehicle, hit by a much larger vehicle, fell from 20% if the vehicle was manufactured in 1970 to 12% if the vehicle was manufactured in 1985 (Figure 10).

CRASH TYPE Figures 11 and 12 illustrate the effect of crash type if all other factors, including the mass ratio, are held constant. In single vehicle crashes, drivers were more likely to be injured in hit object crashes than roll-overs irrespective of their gender, age, the model year of their vehicle, the vehicle mass, the speed zone or the time of day. The improvement in 'crashworthiness' over model years 1970 to 1985 was greater in hit object crashes than in roll-overs (Figure 11). Similarly, in two-vehicle collisions a driver was much more likely to be seriously injured in a front impact than a side or rear impact whatever his/her age, the model year of the vehicle, the vehicle mass, mass ratio, the speed zone or the time of day. As for single vehicle crashes, the 'crashworthiness' of 1980-1985 target vehicles was significantly better than 1970 models, with the greatest improvement for front impacts (Figure 12).

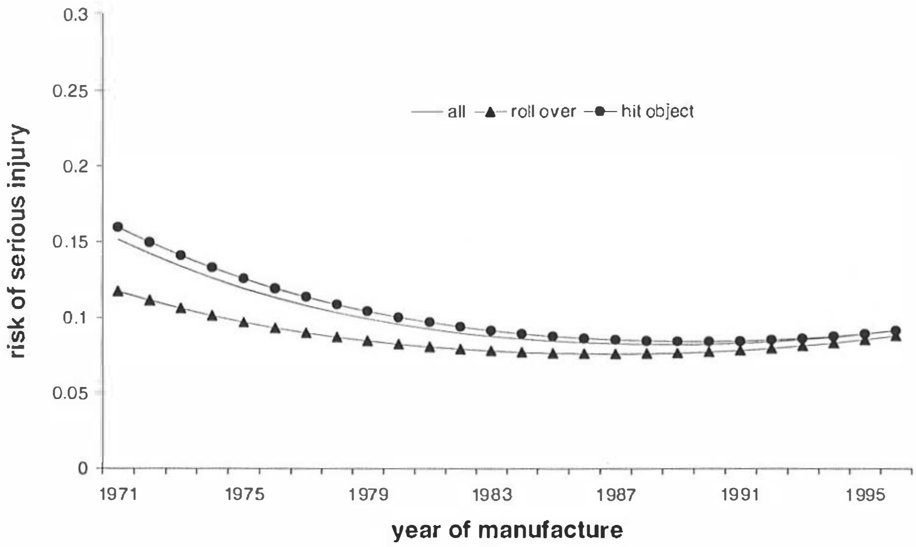

Figure 11 Estimated risk of serious injury to drivers in single vehicle tow away crashes by crash type. Western Australia 1987-1996.

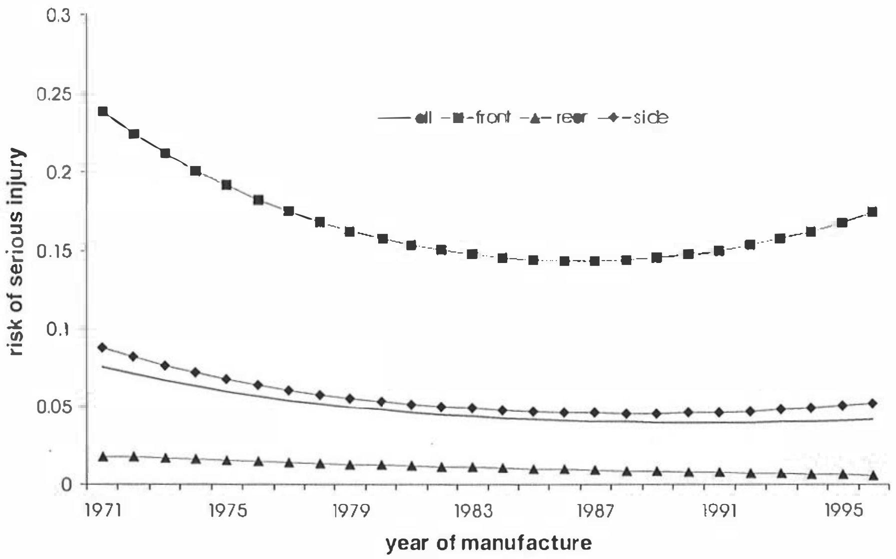

Figure 12 Estimated risk of serious injury to drivers of target vehicles in tow away crashes between vehicles of equal mass. Western Australia 1987-1996.

It is interesting to note that the increase in the adjusted risk of serious injury since 1985 has occurred for frontal impacts (head-on two-vehicle crashes and hit-object crashes) whereas the situation in side and rear impacts has been steadily improving.

DISCUSSION

The objective of this analysis was to determine whether changes in the risk of serious injury to drivers of cars involved in tow-away crashes in Western Australia from 1987 to 1996 were due to changes in vehicle design. The analysis was based on 13,218 vehicles involved in single vehicle crashes and 14,172 vehicles involved in multi-vehicle crashes. In the single vehicle crashes 14.2% of drivers sustained serious injury, ie, were admitted to hospital or died, compared to 3.6% for multi-vehicle crashes. The risk of driver injury was highest in vehicles manufactured in 1970-1974 for both types of crashes. For single vehicle crashes the risk was at a minimum for vehicles manufactured in 1980-1984. The risk for the driver in the 'target' vehicle in multi-vehicle crashes was slightly higher than for the colliding vehicle, with a steady decline in risk for the years to 1995 and after.

In order to determine the factors influencing these changes a series of logistic models were constructed in a systematic way. A simple model, using only year of manufacture showed that there was a quadratic trend fitted the data for the single, colliding and target vehicles indicating that after an initial decrease there was a slight increase in the risk of serious injury in vehicles manufactured after 1980. In fact when vehicles were divided into 5-year groups there was a significantly greater injury risk for drivers of vehicles manufactured between 1970-1974 and 1975-1979 and those manufactured in 1995 or later.

Since post-1980 cars tended to have older drivers, and age is associated with risk of injury, driver age was added to the model. This second model included crash type, speed zone and time of day as well as driver age and gender. These were all factors known to have an influence on risk of injury. Using this model, the risk for drivers of target vehicles decreased in post-1980 vehicles, compared to the previous model. For colliding vehicles, the shape of the trend line inverted compared to the previous model, with the risk being highest for 1980-1985 vehicles.

Finally, the mass of vehicles was taken into account in the model by adding first the mass of the driver's vehicle then the ratio of the masses of the two vehicles in the collision. There was considerable variation in the distribution of vehicles in the vehicle fleet between 1970 and 1995, with the median mass being at a minimum between 1980 and 1984 and being very similar in 1970 and 1995. Th effect of including mass was to increase the estimated risk of serious injury for drivers of cars manufactured after 1985, for both target and colliding vehicles. When mass, mass ratio, driver age, driver sex and all other factors were held constant there were no significant differences in risk of driver injury by year of manufacture for front, side or rear impacts in multi-vehicle collisions. However, for hit object and roll-over single vehicle crashes there were significant improvements between 1970 and 1985. In each case, however, after a decline from 1970, there was a minimum in the late 1980s and early 1990s and a rise thereafter.

In summary, this analysis has shown that there were correlations between year of manufacture, driver age and vehicle mass. The analysis also demonstrated the strong effect of mass ratio and crash type on risk of injury. When adjustments were made for these factors in a series of logistic regression models, the risk of serious injury to the driver decreased from 1970 to about 1980, remained constant to about 1985 and then appeared to rise for vehicles manufactured subsequently. The differences observed between the risk of injury in vehicles designated as colliding or target could not be explained by the data available.

The final model of the risk of serious injury to drivers included the mass ratio for multi-vehicle collisions, as well as crash type, time of day, speed zone, driver age and gender, and vehicle mass. By including all these factors, we could be more confident that any improvement in injury risk attributable to the year of manufacture of the vehicle was associated with changes in vehicle design. Although for two-car collisions the trend in the risk of serious injury to drivers with vehicle year of manufacture, was not significant after adjusting for all other factors, the reduction between 1970 and 1980 for single vehicle crashes was consistent with the introduction of the ADRs.

It seems intuitive that recent model passenger vehicles should be 'safer' than those manufactured more than ten years ago. There may be several reasons for the logistic regression analyses failing to detect the expected effect. The improvement between 1970 and 1980 in injury risk may have been overestimated if lighter vehicles had a relatively better crash performance than heavier vehicles in the 1980s, as suggested by Evans & Frick (1997). Alternatively, it is possible that recent model passenger vehicles, rather than earlier ones, were more likely to be travelling above the speed limit at the time of the crash, thereby increasing the risk to occupants. The impact velocity needed to cause sufficient damage for a vehicle to be towed from the crash scene could have been greater for recent model vehicles thus exposing drivers to a greater risk of injury. In fact, 40% of vehicles manufactured in 1971 were towed compared to 34% of those manufactured in 1996. Another possibility is that the mass and driver age effects were not linear as modelled in this study, but had a more complex relationship with injury risk.

Finally, the changes in the mass distribution of the vehicle fleet over the ten-year crash period could have contributed to the reduced effect for vehicle model year. In 1989 crashes 35% of vehicles had a mass of 1500kg or greater compared to 40% of vehicles in 1996 crashes. Therefore the probability of a later model car colliding with a larger vehicle was increased.

CONCLUSION

This paper has explored changes in the risk of serious injury to drivers of standard passenger vehicles (ie cars, utilities, station wagons and panel vans) manufactured between 1970 and 1995, that were involved in single and multi-vehicle crashes between 1987 and 1996. In Australia, over this 10-year period, seat belts were worn by about 95% of drivers, while very few vehicles were equipped with air bags. The injury risk in newer compared to older vehicles was confounded by differences in vehicle mass and driver age associated with year of manufacture. Multiple logistic regression modelling was used to take account of all confounding factors including the ratio of vehicle masses in two-car collisions. A non-significant improvement in modelled injury risk with year of manufacture remained.

For single vehicle crashes there were significant improvements in the risk of serious injury to drivers of vehicles manufactured between 1970 and 1980. However, based on ten years of crash data, it must be concluded that in two-car collisions recent Australian cars are not significantly safer than those manufactured up to 25 years ago, if the ratio of the vehicle masses is taken into account.

REFERENCES

Broughton J. "The British index for comparing the accident record of car models" Accid Anal and Prev. 28(1): 1996 101-109.

Cameron MH, Finch C & Le T. "Vehicle Crashworthiness Ratings: Victoria and NSW Crashes during 1987-1992. Monash University Accident Research Centre Technical Report, June 1994.

Cameron MH, Newstead SV & Le CM. "The development and estimation of vehicle aggressivity ratings for Australian passenger vehicles." Road Safety Researchers Conference, Hobart, November 1997.

Evans L & Frick MC. "Car Mass and fatality risk: has the relationship changed?" Am J Pub Health. 84(1): 1994 33-36.

Ferrante AM, Rosman DL & Knuiman MW "The construction of a Road Injury Database" Accid Anal & Prev 25(6): 1993 659-666.

Newstead S & Cameron M "Correlation of the New Car Assessment Program with Real Crash Data" Monash University Accident Research Centre. Report 115 June 1997.

Ryan GA, Legge M & Rosman DL "Age related changes in driver crash risk and crash type. Accid Anal & Prev, 30(3): 1998 379-387.