Estimation of the Safety Benefits of a vehicle Replacement Program in Victoria

Penny Oxley[1] (Presenter); Stuart Newstead[1]; Max Cameron[1]
[1]Monash University Accident Research Centre

Biography
Penny Oxley has been working for almost 2 years as a Research Analyst at Monash University Accident Research Centre. She completed a BCom and BSc (Hons.) at the University of Auckland in the areas of economics and statistics, with specific interest in categorical data analysis techniques. Penny has a wide range of interests in road safety including road safety advertising, speed enforcement effects and older drivers licensing procedures.

Abstract
Australia is facing an ageing and polarising-market passenger vehicle fleet. Changes in the composition may have substantial road safety implications in terms of the fleet's overall crashworthiness. This study focuses on Victoria, and assesses the current and past passenger fleet composition in terms of vehicle age by market group. Based on current trends, such as population rates, new vehicle sales and market group trends, a scrappage function by age of vehicle is estimated to project the vehicle fleet to 2012. By manipulating key inputs and outputs to the system, deviations from this baseline projection are estimated from a range of scenarios, to examine changes in vehicle fleet composition from various external influences to the system. The overall purpose of this estimation procedure will be in estimating the crashworthiness, and intrinsically aggressivity, of those projected fleets to give an overall estimation of fleet crashworthiness under the various scenarios. This will help to determine the effect of a particular change to the system, for example a policy change, and to measure the effect on the overall safety of the vehicle fleet over time.

1. INTRODUCTION

This project ultimately seeks to estimate the benefits of a program of replacing older passenger vehicles in Victoria. Explicitly, the question posed is what programs would be suitable in Victoria to bring about a reduction in the vehicle fleet age, with the overall aim being to bring about a more crashworthy fleet.

In order to determine road safety benefits, market group and age profiles were used to project the passenger vehicle fleet over time from 2003 to 2012. This gives an indication of how the passenger vehicle fleet may look in the future, based on current trends such as population rates, new vehicle sales and market group trends. This will be considered as the base or business-as-usual scenario when projecting safety effects. Deviations of the base scenario will be carried out in two stages.

The first stage examines the inputs and outputs to a vehicle fleet, focusing particularly on new vehicle sales and vehicle scrappage. These scenarios will examine safety effects of modifying the age profile of the vehicle fleet over time. The second stage takes the projected vehicle fleet in a year, and considers the safety implications of a changing market group composition within a projected scenario. In these scenarios, the total number of passenger vehicles will remain fixed but the fleet market group composition will be altered.

Crash risks and crashworthiness estimates will be further applied to determine the safety benefits associated with each projected scenario and change in fleet profile. The final result

will be an indication of the direction that the current passenger vehicle fleet is plausibly heading and the road safety implications. Changes to this fleet will demonstrate possible safety benefits from an intervention which will redirect the fleet composition towards an overall more crashworthy fleet.

2. RECENT TRENDS

2.1 Average Vehicle Fleet Age

From the earliest census year available in 1971 through to 1993 there has been a steady increase in average age of vehicles across all states and Australia overall, from 6.1 years in 1971 to 10.4 years in 1993. This rate began to plateau and from 1998, there has been a slight decrease in average vehicle age. This trend was mirrored for all passenger vehicles but at a slightly lower average age.

2.2 Polarising Market Groups

Sales trends in new passenger vehicles over the past ten years have seen a polarisation of the Australian vehicle fleet into large and small vehicles, with sales in the medium segment showing a rapid decline. Sales of Sport Utility Vehicles (4WDs) have also increased greatly over the same period.

2.3 Population Trends

It has been suggested that Australia is reaching a plateau in terms of the number of passenger vehicles per 1000 population. However, further analysis into this suggestion found that the plateau as discussed in the literature may actually be an artefact of the census timing rather than a trend in the data itself. Therefore the total registration estimations will not be based on a plateau rate.

3. TRENDS IN EXISTING FLEET

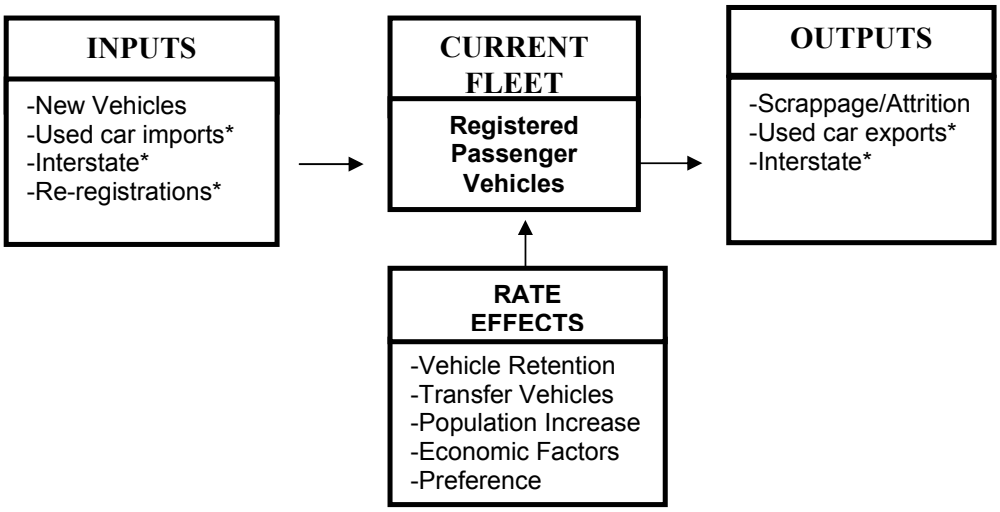
The existing and past passenger vehicle fleets were examined to provide a framework of the current composition and trends over recent years. This will provide a baseline from which the future projections will take place, while taking into account likely future trends. The vehicle composition in terms of age of vehicle and market group will initially be considered separately, and then estimated together.

4. AGE OF VEHICLE

The age of a vehicle is going to be represented by the year of manufacture of the vehicle. In order to determine the change in the vehicle fleet composition in terms of age, knowledge of the current situation and consideration of influences that may effect a change in vehicle age composition was needed. A changing vehicle fleet can be considered within a simple Input-Output type framework as demonstrated in Figure 1.

In this model, changes to the number of registered passenger vehicles will occur as a result of new vehicle inputs into the system, and the outputs due to the scrappage of vehicles. Other inputs and outputs will be assumed to have a negligible net impact. A range of factors will determine the rate of these inputs and outputs into the system, some of which are stated in Figure 1. These will be taken into account when examining the inputs and outputs of the system below, and in the future projections.

Figure 1: Passenger Vehicles on Register Input-Output Model



** For purpose of the model, the net impact is assumed to have a negligible effect*

4.1 Current Fleet

Registered Passenger Vehicles Numbers of passenger vehicles by year of manufacture over time was required, to give an indication of the current and past age distributional trends of registered vehicles in Victoria. The data was obtained from the ABS which produce a Motor Vehicle Census (Publication 9309.0) giving information about the general motor vehicle population broken down by various categories. The information used was the passenger vehicles by year of manufacture. The data needed to be adjusted to obtain individual year of manufacture estimates and consistent estimates projected to the end of December of each census year. This provided a matrix of passenger vehicle registrations for each census year from 1985 to 2002 by year of manufacture from pre 1979 through to 2002 where applicable.

Inputs: New Vehicle Sales VFacts is publication produced by the Federal Chamber of Automotive Industries. It gives a detailed break down of new vehicle sales by manufacturer and market share, available each month and by state or territory. For the purpose of this study, it gives an indication of the annual inputs into the system, new passenger vehicles. The VFacts data was adjusted to fit our working definition of a passenger vehicle. The VFacts data was also used in conjunction with the ABS New Vehicle Registrations (9301.0).

5. MARKET GROUPS

Given the estimates for each year of manufacture, each year needed to be broken down into the representative market group proportions. However, there was no information or data available in this form in Victoria. The New South Wales Roads and Traffic Authority (RTA) holds registration data which contains the required information, and was used as an approximation for the Victorian composition.

The NSW Registrations data consisted of 3 individual snapshots at 31st December of vehicles and vehicle accessories on register in 1996, 1998 and 2000 in NSW. The snapshot records information on a range of vehicle aspects including year of manufacture information and Vehicle Identification Numbers (VINs). The VINs were decoded using a sequence of programmes originally derived by Pappas for use in the Used Car Safety Ratings project (Newstead et al. 2003), which initially decodes the VINs into make and model. These are subsequently recoded into market groups from which the passenger vehicle market groups

are selected. The passenger vehicle market groups included in this breakdown were small, medium, large, luxury, sport and sport utility vehicles (4WDs), to match the Motor Vehicle Census passenger definition.

The final output provided a matrix of passenger vehicle market groups by Year of Manufacture for each of the 3 years. It was found that the market group proportions in each Year of Manufacture remained relatively consistent over the 3 time periods. Assuming the proportion of vehicles in each market group for passenger vehicles is the same in Victoria as it is in NSW, we were able to apply the average of these proportions to each year of manufacture in census years 1996 to 2002 for Victoria, to give an estimate of the relative market group frequencies within a given year of manufacture.

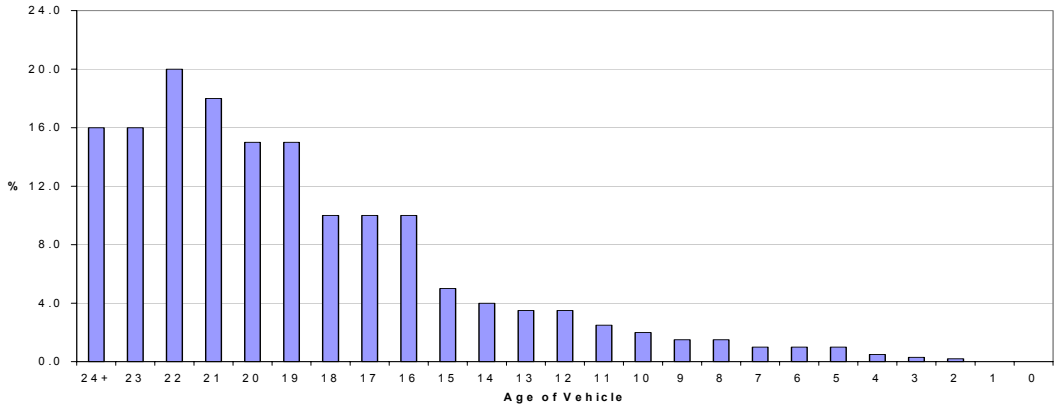
6. PASSENGER VEHICLE SCRAPPAGE FUNCTION

6.1 Estimation

The scrappage function was approximated by NSW biennial registration data from 1996 – 2000, and adjusted according to Victorian registration data from 1996 – 2002. The scrappage function gave an estimated rate of scrappage for each vehicle age. For example in year 0, the estimated scrappage was zero, that is, in its first year the cars were registered and not likely to be scrapped. As the cars got older, the scrappage rate increased until a maximum where it then decreased.

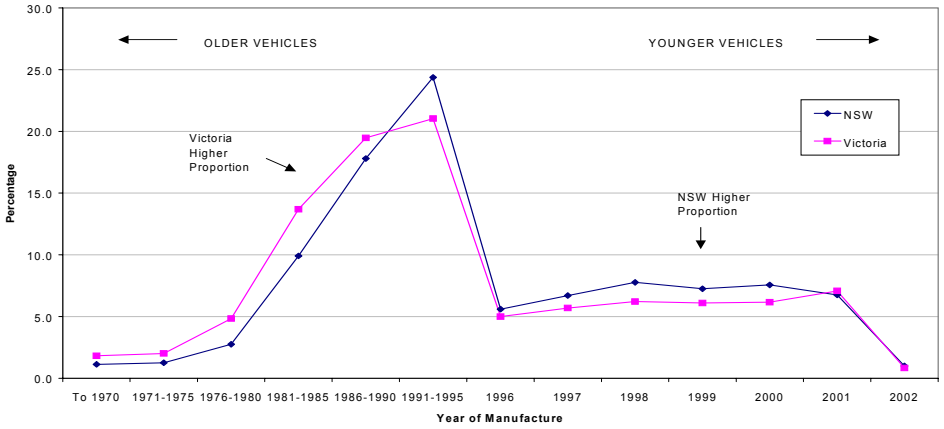
The scrappage function was estimated by examining the decrease in vehicles in each year of manufacture from NSW registration years 1996 to 1998 and from 1998 to 2000. These decreases were represented as a percentage decrease from the previous registration year and converted into decreases representing age of vehicle. They were adjusted to represent yearly figures. The final scrappage function is shown in Graph 1.

Graph 1: Scrappage as a function of Age of Vehicle



This scrappage function was then to be applied to the Victorian data. An adjustment was needed to represent the Victorian scrappage. The adjustment was made comparing the proportion that each year of manufacture represented of total passenger vehicles. This is depicted in Graph 2. We can see that the rates in NSW and Victoria are similar, but Victoria has a slightly higher proportion of older vehicles, whereas NSW has a higher proportion of younger vehicles, and hence a younger vehicle fleet. This needs to be accounted for in the scrappage function with an increase in the scrappage rate at the younger end of the function, and a decrease at the older end to represent a higher retention of older vehicles. However, we also need to take into account an adjustment to represent the decreasing average age of the vehicle fleet in recent years (actually getting younger), so would need to increase scrappage, particularly at older end to represent this.

Graph 2: Comparison of NSW and Victoria Year of manufacture Proportions.



Note: Peak is an artefact of the groupings, and dip at end is due to non-complete estimation for 2002.

The NSW data gave a good approximation for this scrappage function rather than directly from the Victorian data for a number of reasons. The NSW data by each year of manufacture was from actual data and therefore can be considered as actual trends, whereas single years for Victoria had been estimated from grouped years of manufacture. This meant that any trends identified in the scrappage may be a result of the systematic estimation process of single years. The NSW data also had registration breakdown by market group and therefore was able to estimate market group scrappage.

6.2 Application

The function was used within the following formula to give the estimated registration frequencies for each age of vehicle, v, in a given year, y.

$$R_{yv} = R_{y-1,\,v-1} - (S_{v-1} * R_{y-1,\,v-1}) \qquad v>0 \qquad \text{(Eq. 1a)}$$

$$= N_y \qquad v=0 \qquad \text{(Eq. 1b)}$$

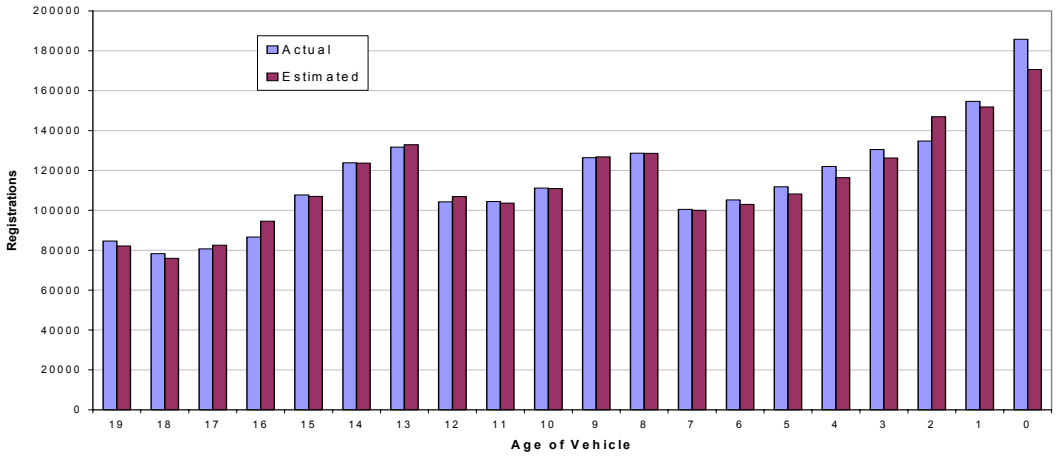
Where
R_{yv} = Registration at Year y and Age of vehicle v
$R_{y-1,\,v-1}$ = Registration in previous year y-1 and previous age v-1
S_{v-1} = Scrappage Rate for previous age v-1.
N_y = New vehicle sales for year y.

The first part of the equation, Equation 1a, states that the registration at year y and age v>0 is estimated by the previous years registrations at the previous age, minus scrappage for that age in that year. The second part of the equation, Equation 1b, states that the registration estimation for year y at age of vehicle v=0, are the new projected vehicle sales for that year.

6.3 Evaluation

Using 1996 as the base year, the registrations were estimated for the progressive years based on the above equation. This allowed a comparison of estimated values with actual. As the years projected progressed, the estimates were more variable yet fairly close estimate in terms of percentage difference. The estimates appeared to be less accurate at the older and younger end of the age spectrum. Graph 3 shows a comparison of actual and estimated values for 1998, using 1996 as the base year. The scrappage function by age of vehicle was adjusted to achieve an adequate representation of the actual scrappage and is used in the projection process for the baseline scenario.

Graph 3: 1998 Estimated vs. Actual Registered Passenger Vehicles, Base year 1996



7. PROJECTING PASSENGER VEHICLE REGISTRATIONS

The projection of registered passenger vehicles by Age of Vehicle and Market Group can be considered as a 2-step process. The first step estimated total registration by Age of Vehicle for each projected year. Age of vehicle was used instead of year of manufacture due to the consistency in the scrappage function by age, but not by year of manufacture. Once calculated, however, it would be very simple to revert back to Year of Manufacture. The second step took these totals by age of vehicle and further broke down the registrations by market group for each age of vehicle. This is further explained below.

Step 1: Overall Projection by Age of Vehicle

Step 1 projected registrations by age of vehicle for each year from 2003 - 2012. The projection was based on the estimated scrappage function by age of vehicle. The function used year 2002 as the base projection year. The annual total for each projected year was the sum of each projected age of vehicle frequency.

The projected vehicle sales were estimated on the basis of current trends per 1000 population and the early projections in 2003 and 2004. It was assumed that the new vehicle sales would plateau at a rate of 39 new vehicles per 1000 population. Alternatives to this assumption will be examined later. These new vehicle estimates are represented in Equation 1b, the estimated frequency at age of vehicle equals zero.

Step 2: Market Group Estimation

The second step in the projection process was a breakdown by market group. It was found that in NSW, the proportions that each of the market groups represented in a given year of manufacture was consistent in the 3 data snapshots 1996, 1998 and 2000.

These market group proportions were applied to the relative age in the future projections, to give a subsequent break down of frequencies by market groups. This was only required for ages of vehicles representative of pre 2001 vehicles. The proportions for 2001 to 2012 were not known. These were estimated using a linear regression over the last 6 known years, 1995-2000. The last 6 years from 1995 recognises the deceleration of the changing proportions over recent years. The use of all years, or more years, would not represent this, and would introduce substantially more variation into the model. The residuals were found to be non-systematic.

8. CRASH RISK AND CRASHWORTHINESS

The projected vehicle registrations provide a base to which safety measure estimates will be applied to establish the overall safety of a given passenger fleet. Vehicle safety measures typically fall into two classes: primary safety and secondary safety. Primary safety is measured by the risk crash involvement per unit of exposure. Various units of exposure have been considered in relation to primary safety, including distance based measures, such as kilometres travelled, and time based measures, such as years of registration. Secondary safety is measured by the risk of sustaining an injury of some type or severity given involvement in a crash. This study requires use of both a primary and secondary safety measure.

8.1 Primary Safety: Crash Risk

Good vehicle exposure data in terms of distance travelled is not generally available in Australia. Consequently crash risk ratings for Australian passenger vehicles on a per distance travelled basis have never been published. For this study, estimates of vehicle primary safety on a per registered year basis have been calculated for each market group. This has been achieved by dividing the number of vehicles crashing in NSW during a calendar year in each market group by the number appearing in the NSW registration data in the same year. The totals also had to be adjusted to match the census totals.

8.2 Secondary Safety: Crashworthiness

Each of the input secondary safety measures for this project is a crashworthiness estimate focusing on a different major crash configuration occurring on the road or on trends in crashworthiness by year of vehicle manufacture. The definition of crashworthiness used is that defined by MUARC in calculating the widely published Australian Used Car Safety Ratings and is the risk of death or serious injury (hospitalisation) given involvement in a crash where at least one vehicle was towed from the scene. It is a two-part measure, the first representing the risk of injury given crash involvement, the second representing the risk of death or serious injury given some level of injury was sustained. The product of the two measures gives the crashworthiness rating. Each rating component is estimated using logistic regression analysis methods with the ratings being adjusted for non-vehicle factors that affect injury outcome and are available in the crash data. These include driver age and sex, and speed zone of crash.

Estimates of vehicle secondary safety effects based on year of vehicle manufacture are produced regularly by MUARC as part of estimating the Used Car Safety Ratings. The most recent estimates, given by Newstead et al (2003), will be used as secondary safety input to this project.

To estimate fleet safety effects reflecting market group mix in the fleet, a number of new crashworthiness measures covering a range of crash configurations have been estimated. Together, the crash configurations considered cover the majority of crashes appearing in the available data. Each is estimated from police reported crash data in NSW, Victoria, Queensland and WA from 1987 to 2000 used to calculate the most recent Used Car Safety Ratings. The research here is primarily concerned with examining the effect of different mixes of vehicle market groups on total fleet safety. On this basis, the safety estimates that have been obtained represent averages across vehicle market group categories. No estimates specific to particular makes and models have been obtained. However, it is conceded that the market group averages will reflect the particular mix of makes and models that are found in the crash data and it is assumed that this gives estimates representative of the true average crashworthiness within each group.

To the crashworthiness ratings an additional adjustment will be made to reflect the year of manufacture profile of a given passenger fleet. For example, an older fleet will have a higher crashworthiness rating, to reflect an overall less safe fleet, and a younger fleet will have a lower rating to reflect an overall safer fleet.

The application of primary and secondary safety to the vehicle fleet projections will help to give an indication of the expected safety trends under different scenarios highlighting the changing vehicle fleet mix. It is hoped that this tool will help to identify and quantify areas that are of current safety concern, or appear to be increasing such that they may have a substantial impact in the near future. This identification and quantification of such areas has the potential to be of use in the policy setting in assessing the future impact of a decision on the safety of the passenger vehicle fleet as a whole. Currently the estimates apply to Victoria but the techniques could be extended to incorporate the Australian national vehicle fleet.

References

Australian Bureau of Statistics. (1995-1999, 2001-2002) *Motor Vehicle Census*. ABS Report 9309.0, Canberra.

Federal Chamber of Automotive Industries (1995-2002) *Vfacts*. FCAI, Canberra.

Newstead, S.V., Cameron, M., Watson, L..M., Delaney A.K. (2003). *Vehicle Crashworthiness and Aggresivity Ratings and Crashworthiness by Year of Vehicle Manufacture*. MUARC Report No. 196. Monash University Accident Research Centre, Clayton, VIC.

Acknowledgements

The authors would like to acknowledge TAC for their expressed interest in the topic and funding towards the project. The authors would also like to acknowledge James Holgate and his 1997 paper that identified issues concerning the ageing vehicle fleet and attempted to quantify the expected volume of the future fleet. This paper uses an initial similar approach, with added dimensions. Also from MUARC, the paper acknowledges Linda Watson and Amanda Delaney for their contribution with the crashworthiness estimation.

Keywords

vehicle fleet, ageing, scrappage, crash risk, crashworthiness