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ROAD SAFETY BENEFITS OF VEHICLE ROADWORTHINESS INSPECTIONS IN NEW ZEALAND AND VICTORIA

by

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Abstract:

Although previous research has identified some safety benefits accruing from periodic vehicle inspection programmes, such benefits may not be sufficient to justify the costs of such schemes. This study conducted analysis of merged crash and licensing data from two jurisdictions, Victoria and New Zealand, where periodic vehicle inspections are conducted to certify roadworthiness at the point of sale of a vehicle (Victoria and New Zealand) or at 12-montly or 6-monthly intervals (just in New Zealand).

New Zealand crash data, licensing data and inspection data from the warrant of fitness (WoF) scheme were merged together to evaluate the safety benefits in terms of reduced crash risk and the reductions in safety-related vehicle faults associated with the increase from annual to biannual inspections that occur six years after the car's manufacture date. These were estimated to be respectively 8% (with 95% confidence interval 15% to 0.4%) and 13.5% (with 95% CI 12.8%-14.2%). The proportion of vehicle faults prevented is likely to be at least maintained over the vehicle age range 7-20 years, suggesting that the resultant safety benefits should also be maintained. The confidence interval for the drop in crash rate was wide, showing considerable statistical uncertainty about the precise size of the drop although indicating the likely drop is less than 15%. Despite these safety benefits, the costs to the motorist of the 6-monthly inspections over and above the annual inspections were estimated to be considerable, valued at $250 million annually, excuding the overall costs of administering the scheme. This means that the 6-monthly inspections are very unlikely to be cost-effective. The WoF scheme as a whole cannot be robustly evaluated using the analysis approach used here, but the safety benefits would need to be substantial – yielding at least a 12% reduction in injury crashes – for it to be cost-effective.

The Victorian analysis of potential periodic roadwothiness certification safety benefits was not entirely conclusive. It suggested the maximum annual crash savings associated with moving to annual vehicle roadworthiness inspections for vehicles over 5 years old to be around 4%, which is likely to be much less than required to make an annual periodic scheme cost effective.

Key Words:

Vehicle roadworthiness
Vehicle defects
Vehicle safety
Crash risk
Statistics
Data analysis

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Preface

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Contributorship Statement

Assoc. Prof. Stuart Newstead	Project concept, analysis design, manuscript preparation and review
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Ms Linda Watson	Data preparation and manuscript review

Ethics Statement

Ethics approval was not required for this project.

Contents

EXECUTIVE SUMMARY VI

BACKGROUND 8

New Zealand warrant of fitness (WoF) scheme 9

Roadworthiness regulation in Victoria 9

DATA AND METHODS 10

New Zealand data and analysis 10

Victorian data and methods 11

RESULTS 13

New Zealand analysis 13

Victorian results 24

DISCUSSION 32

CONCLUSIONS 35

EXECUTIVE SUMMARY

Previous research has identified some safety benefits accruing from periodic vehicle inspection programmes, but such benefits may not be sufficient to justify the costs of such schemes. Analyses in this study were conducted of merged crash and vehicle licensing data from two jurisdictions, Victoria and New Zealand, where periodic vehicle inspections are conducted to certify roadworthiness at the time of sale of a vehicle (Victoria and New Zealand) or at 12-montly or 6-monthly intervals (just in New Zealand).

The periodic vehicle inspection regime in New Zealand is referred to as the warrant of fitness (WoF) scheme. Vehicles are required to be inspected every year when they are under six years old and every 6 months subsequently. The WoF inspection checks the following aspects of the vehicle and the WoF is failed if one or more aspect fails to reach the specified standard: tyre condition (including tread depth); brake operation; structural condition (rust is not allowed in certain areas); lights; glazing; windscreen washers and wipers; doors; safety belts (must not be damaged or overly faded; buckles must work properly); airbags (if fitted); speedometer (must be working); steering and suspension (must be safe and secure); exhaust (there must be no leaks and the exhaust must not be smoky or louder than the original exhaust system); fuel system (there must be no leaks).

A roadworthiness certificate is required in Victoria to sell a registered vehicle or to re-register a used vehicle. A licensed vehicle tester will issue a certificate if the vehicle passes an inspection test, focusing on safety related aspects, including: wheels and tyres; steering, suspension and braking systems; seats and seat belts; lamps and reflectors; windscreen, and windows including front windscreen wipers and washers; the structure of the vehicle itself; other safety related items on the body, chassis or engine. Otherwise, regular roadworthiness inspections are not required. Police, however, can inspect a vehicle and issue a defect notice that specifies required repairs and a roadworthy certificate to be obtained or else registration can be cancelled.

In the current analysis, crash data, licensing data and inspection data from New Zealand warrant of fitness (WoF) scheme were merged together to evaluate the cost-effectiveness of 6-monthly inspections compared to annual inspections. An analysis was made of the safety benefits in terms of the reduction in casualty crash risk and of the reductions in the numbers of safety-related vehicle faults associated with the increase from annual to biannual inspections that occurs six years after the car's manufacture date. These were estimated to be respectively 8% (with 95% confidence interval 0.4% to 15%) and 13.5% (with 95% CI 12.8%-14.2%) associated with the switch from annual to 6-monthly inspections. The proportion of vehicle faults prevented is likely to be at least maintained over the vehicle age range 7-20 years, suggesting that the resultant safety benefits should also be maintained. The confidence interval for the drop in crash rate was wide, showing considerably statistical uncertainty about the precise size of the drop although indicating that the actual crash rate reduction likely was less than 15%.

Despite these safety benefits, the costs to the motorist of the 6-monthly inspections over and above an annual inspection were estimated to be considerable, valued at $250 million annually for vehicles less than 20 years old. Such large costs meant that the 6-monthly inspections were not estimated to be cost-effective.

The New Zealand WoF scheme as a whole cannot be robustly evaluated using the analysis approach used here, but the safety benefits would need to be substantial – yielding at least a 12% reduction in injury crashes – for it to be cost-effective.

The Victorian analysis of potential periodic roadwothiness certification safety benefits was not entirely conclusive. It suggested the maximum annual crash savings associated with moving to annual vehicle roadworthiness inspections for vehicles over 5 years old to be around 4%, which is likely to be much less than required to make an annual periodic scheme cost effective.

BACKGROUND

The fact that vehicle defects contribute to crash occurrence is undisputed, but the importance of the role of vehicle defects is difficult to determine. Estimates of their causal role in traffic crashes range widely from as low as 3% (van Schoor et al, 2001) to 27% (Tanaboriboon et al, 2005) in a developing country. The proportion of crashes in which vehicle defects play any role is also not easy to estimate, and will be underestimated by a significant degree in official crash statistics, as police attending a crash normally do not have the time, training, or motivation to examine a vehicle thoroughly (Rechnitzer et al, 2000). Even if in-depth crash investigation were available, assessing the importance of defects is not straightforward. In a notional case-control study in which the cases are crash-involved vehicles and the controls are non-crash-involved, the relevant exposures being evaluated (mechanical defects) would necessarily be evaluated differently, invalidating aspects of the study. For example, a vehicle involved in a night-time frontal crash will have probable damage to headlights that prevent any adequate assessment of their pre-crash condition. The damage of the crash will also prevent many other features from being adequately assessed, an important exception being tyre condition. A complicating factor can also be that a given individual driver may have a low level of risk-averseness together with a high tolerance of vehicle faults, or may compensate for known vehicle faults by driving conservatively. Thus behavioural and attitudinal factors can confound estimates of crash risk associated with vehicle faults, as suggested by Christensen and Elvik (2006).

As an alternative, a prospective study using administrative data could be used to estimate whether inspections are associated with changes in accident rate, such as whether the crash rate after inspections differs from the crash rate before inspections, as investigated by Christensen and Elvik (2006). Although this approach is intuitively attractive, there will be strong biases in studies of crash rates from databases such as used in New Zealand, in which only injury crashes (those from which at least one medically treated injury resulted) are recorded. This is because many vehicles will be written off in a crash and therefore will not undergo a subsequent inspection. Analysis of property damage only crashes, the types of crashes that would have dominated the crash data analysed in the aforementioned study, may not be as affected by such a bias.

Rechnitzer et al. (2000) reviewed studies evaluating periodic vehicle inspection schemes that were conducted before 1999. Of the ten studies reviewed, eight studies found that periodic inspections reduced crash rates and defects, one study found an increase, and one study found no difference (Fosser, 1992). The fact that the vast majority of these studies were in the grey literature rather than in peer-reviewed journals may be symptomatic of the methodological difficulties in evaluating periodic inspection schemes. A New Zealand case-control study (Blows et al, 2003) did find an association between decreased safety and the lack of a current warrant of fitness (indicating the vehicle had not been recently tested and found roadworthy). But the study has been criticised as their inference of a causal association may not be valid because of potential confounding attitudinal and behavioural factors that may lead to both lack of compliance with such regulations and unsafe driving practices (Hockey, 2003).

Many countries attempt to regulate the mechanical condition of vehicles licensed to drive on the road, mainly related to the safety of the vehicle. These regulations are most commonly enforced in an ad-hoc manner when the vehicle – or more particularly the driver – comes to the attention of the police. Some jurisdictions, such as the Australian state of Victoria, require that the vehicle has a form of certification of roadworthiness when it changes ownership. A few countries, including New Zealand, have periodic vehicle inspections that determine a certain level of roadworthiness that is a condition of licensing. The safety benefits of such schemes are difficult to determine as such benefits are likely to be modest and therefore cannot be examined in prospective controlled studies, particularly as the small proportion of vehicles that are crash-involved demand a very large population of vehicles to be studied at the outset. The safety effects are also difficult to evaluate because the condition of a vehicle is theoretically known at the time of the inspection, but is not known at the time of the crash.

New Zealand warrant of fitness (WoF) scheme

The periodic vehicle inspection regime in New Zealand is referred to as the warrant of fitness (WoF) scheme. Vehicles are required to be inspected every year when they are under six years old and every 6 months when they are over six years old. There are about 3,200 authorised WoF inspection agents nationwide to cover 2.8 million passenger cars and vans. The penalty for not displaying a sticker on the windscreen indicating that the vehicle has a WoF is a NZ$200 fine. The WoF inspection checks the following aspects of the vehicle and the WoF is failed if one or more aspect fails to reach the specified standard: tyre condition (including tread depth); brake operation; structural condition (rust is not allowed in certain areas); lights; glazing; windscreen washers and wipers; doors; safety belts (must not be damaged or overly faded; buckles must work properly); airbags (if fitted); speedometer (must be working); steering and suspension (must be safe and secure); exhaust (there must be no leaks and the exhaust must not be smoky or louder than the original exhaust system); fuel system (there must be no leaks) (NZ Transport Agency, 2012).

In theory, if the date of the WoF is known and the date of the subsequent crash is known, some form of survival analysis can be conducted to see whether crash risk increases with increasing elapsed time since the inspection (at which point the vehicle was in a theoretically "safe" state mechanically). However, this approach assumes that there is no temporal relation between the timing of the inspection and the intensity of exposure to risk of the vehicle. Such relationships can confound any attempt to measure the safety effects. Another approach involves assessing the change in safety that accompanies the change in frequency of inspections for vehicles more than six years after manufacture. Although this may not provide an adequate means of assessing the safety effects of the scheme as a whole, the safety benefits of increased frequency can be assessed.

Roadworthiness regulation in Victoria

A roadworthiness certificate is required in Victoria to sell a registered vehicle or to re-register a used vehicle. A licensed vehicle tester will issue a certificate if the vehicle passes an inspection test, focusing on safety related items to ensure the vehicle is safe for normal use on the road (http://www.vicroads.vic.gov.au/Home/Registration/BuySellTransferVehicles/CertificateOfRoadworthiness/). Otherwise, regular roadworthiness inspections are not required. Police, however, can inspect a vehicle and issue a defect notice that specifies required repairs and a roadworthy certificate to be obtained or else registration can be cancelled. Other Australian States, however, require regular roadworthiness inspections of vehicles (for example NSW requires a safety inspection for vehicles over 5 years of age). This report documents a survival analysis conducted to determine how the probability of a crash occurring changes as a function of time since vehicle acquisition, a surrogate for time since roadworthy inspection. The results are expected to shed light on whether or not regular roadworthy inspections would be of benefit in reducing crashes in Victoria. Consideration is also given to how vehicle age at acquisition and vehicle type impact on the probability of a crash as a function of time since acquisition.

DATA AND METHODS

The Data and Methods section describes firstly the New Zealand data and analysis, and then the Victorian data and analysis.

New Zealand data and analysis

There were three data sets analysed, provided by the New Zealand Ministry of Transport and the New Zealand Transport Agency:

- **Crash data** 2004 to 2009. Reported crash data involving an injury for one of the involved road users for the years 2004 to 2009 were provided by the New Zealand Ministry of Transport. Only records for drivers of light passenger vehicles (cars and vans) were analysed, consisting of 85,773 crashed driver/vehicle combinations.
- **Licensing data** 2003-2008. Each of the six years of crash data was matched to a snapshot of registration data as at the beginning of the crash year, which was necessary for the analysis as owner data, and occasionally plate numbers, can change for a given vehicle. The registration data provided some information on the owner of each vehicle, including the general geographic area, age and sex. When the vehicle was owned by a company or a collective, age and sex were not relevant or available. About 15% of the crashed vehicles analysed were either company vehicles or had missing data on age and sex of the owner. Geographic areas were coded according to levels of urbanisation to provide a measure of different types of exposure to risk (different types and conditions of roads and different traffic volumes).
- **WoF inspection data** 2003-2009. These data consisted of odometer readings, whether the vehicle passed or failed, date of inspection, all faults identified.

Each make and model of crash-involved passenger vehicle was classified into one of 10 market groups for analysis: Light (passenger car, hatch, sedan, coupe or convertible 3 or 4 cylinder engine, generally <1100kg); Small (passenger car, hatch, sedan, wagon, coupe or convertible 4 cylinder engine, generally 1100-1300kg tare mass); Medium (passenger car, hatch, sedan, wagon, coupe or convertible generally 4 cylinder engine, generally 1300-1550kg tare mass); Large (passenger car, hatch, sedan, wagon, coupe or convertible generally 6 or 8 cylinder engine, generally >1550kg tare mass); People Movers (seating capacity > 5 people); SUV Compact (<1700kg tare mass), SUV Medium (1700kg-2000kg tare mass) and SUV Large (>2000kg tare mass); Van; and Utility vehicles (known as pickup trucks in the US).

An analysis that uses the number of faults in the vehicle as an explanatory factor for crash risk would have been ideal. The Police officer attending the crash does consider whether mechanical defects may have been a contributing factor in the crash. However, apart from an examination of the condition of the tyres and interviewing the driver (where the injuries are mild enough to allow such an interview), most of the vehicle defects within the scope of the WoF are not identified. Therefore two regressions were carried out to look at associations between faults and crash risk. The first regression analysed the way that crash risk changed with the age of the vehicle; the second the way that vehicle condition (faults identified) changed with the age of the vehicle. As the WoF inspections change in frequency from once per year for vehicles less than 6 years since the date of manufacture to six-monthly for vehicles more than 6 years since the data of manufacture, analyses by vehicle age show how both the mechanical condition of the vehicle and the rates of crash involvement change associated with this change in WoF inspection frequency.

Victorian data and methods

Victorian vehicle register snapshots

Data from snapshots of the Victorian vehicle register for the period 2000 to 2009, consisting of June and December snapshots for each of the years 2000 to 2001, 2003 and 2006 and June, August and December snapshots for 2002, March, June and December snapshots for 2004, February and December snapshots for 2005 and June snapshots for each year from 2007 to 2009 were used.

Decoding into vehicle make and model

The Victoria vehicle register provides vehicle make and year of manufacture but not detailed model information. The vehicle register also includes Vehicle Identification Numbers (VINs) for most light passenger vehicles from 1989 year of manufacture onwards. Where a VIN was available, the light passenger vehicle make and model information were decoded from the VIN using the same process utilised in the Used Car Safety Ratings (UCSR) project (Newstead et al, 2006).

Vehicle market groups

For each VIN decoded vehicle make and model, the vehicle was further categorised into a market group. The market groups defined are based on those used by the Federal Chamber of Automotive Industries (FCAI) for reporting Australian vehicle sales as part of their VFACTS publication (see www.fcai.com.au for further details). The 10 market groups are defined as described above for the New Zealand analysis.

The classification of SUV vehicles is based on an index developed by VFACTS that considers gross vehicle mass, maximum engine torque and the availability of a dual range transmission. The index typically classifies the vehicles roughly by tare mass as indicated on the classifications above. Some departures from the VFACTS classification have been made in this study. VFACTS defines a luxury SUV category based on vehicle price as well as classifying sports cars priced above the luxury car tax threshold as luxury vehicles. Here, the luxury SUVs have been distributed amongst the three defined SUV categories based on tare mass, as the information for computing the classification index used by VFACTS was not available at the time of the study.

There have also been some departures from the classification principles defined above for certain vehicle models that have a range of engine sizes and hence fall across two different defined categories. These are typically passenger vehicles and include, for example, the Toyota Camry comes fitted with a large 4 cylinder engine in some variants and a 6 cylinder engine in other variants. In these cases, a judgement has been made for each vehicle model individually based on the other vehicle models with which each typically competes in the market place.

Combining snapshots

Vehicles that were not light passenger vehicles were identified and excluded from the analysis, as were any duplicates in the register, retaining only the most recent record where two records were otherwise identical. Registrations where the vehicle was first registered and cancelled on the same date were also removed. Records where the date of acquisition was prior to January 1st, 2000 were also excluded as crash data from before this date were not used. This process was repeated until ultimately a single registration file consisted of unique registration periods for each plate from 2000 until 2009 inclusive.

Victorian crash data

Victorian crash data from January 2000 to December 2010 involving drivers of light passenger vehicles was combined with the registration data. To ensure consistency of vehicle make descriptor in the crash data, a make formatting process was applied to ensure the make field consisted of standard makes for comparison with make in the Victorian vehicle register. The final file consisted of 277,230 drivers of light passenger vehicles, manufactured during 1982-2010 and involved in crashes covering the period 2000 to 2010.

Crash record merging

The registration file was divided into registration plates with multiple registrations and those with a single registration over the period 2000 to 2009 inclusive. Crash data were matched to the singly registered plates by vehicle registration number. A check comparison was made of crash make with vehicle register make and crash year of manufacture with vehicle register year of manufacture. A further check confirmed the crash date fell within the matched vehicle register plate registration dates including cancellation and acquisition dates, first registration and expiry dates. This information was stored for each initial match.

Matches were retained for subsequent analysis if: the crash date fell within the matched vehicle register plate registration dates including cancellation and acquisition dates; first registration and expiry dates and the crash make was either the same as the vehicle register make or missing; and, when the crash make agreed with the vehicle register make.

All other crash vehicles not matched to single registrations were matched to multiple registrations by first determining those with plates having had multiple registrations. The final vehicle register file with matched crashes consisted of in total 13,146,467 records. These consisted of 5,539,126 singly registered plates not matched to a crash vehicle, 7,370,075 plates with multiple registrations not matched to a crash vehicle, 117,671 singly registered plates matched to a crash vehicle and 119,595 plates with multiple registrations matched to one or more crash vehicle events, a total of 237,266 Victorian vehicle register plates matched to one or more crash records for a plate. Crashes that occurred after June 2009 were excluded because the vehicle could have changed hands after that time and but the registration data were not available to indicate this change.

In preparation for the analysis, the following records were excluded: vehicles that were missing data for market group; pre-1989 vehicles; vehicles with missing data for first registration date; vehicles with a first registration date prior to 1988; vehicles with missing expiry date; multiple records with the same VIN but different dates of first registration; records where acquisition date was within 6 months of the acquisition date for the next ownership of that vehicle. The final file consisted of 5,045,538 records from 2000 to 2009 inclusive.

Definition of event

An event was defined as the first crash that occurred prior to the registration expiry date, cancellation date, next acquisition date for that vehicle, and June 30, 2009. Crashes that occurred after registration expiry or cancellation were not included.

Time to event/censor

The time to event, or censoring, for each record was defined as the shortest number of days between acquisition of the vehicle and:

1. First crash date, or
2. Registration expiry date ,or
3. Registration cancellation date, or
4. Next acquisition date for that vehicle, or
5. June 30, 2009

Time to event/censor was then converted into years, for ease of interpretation.

RESULTS

New Zealand analysis

The results section firstly describes the types and distributions of faults identified in the WoF inspections, particularly looking at the way these vary by the age of the vehicle. Then the mean rate of crash involvement per vehicle is analysed, firstly by the number of elapsed days since the WoF inspection and secondly by the age of the vehicle.

Figure 1 shows the proportion of all faults identified in WoF inspections of the light passenger fleet 2003-2009 according to the type of faults found. This shows that faults with the headlights and taillights, the tyres, steering and suspension and the brakes were the main ones identified. The prevalence of these faults according to the age of the vehicle and the age of the owner is analysed further below.

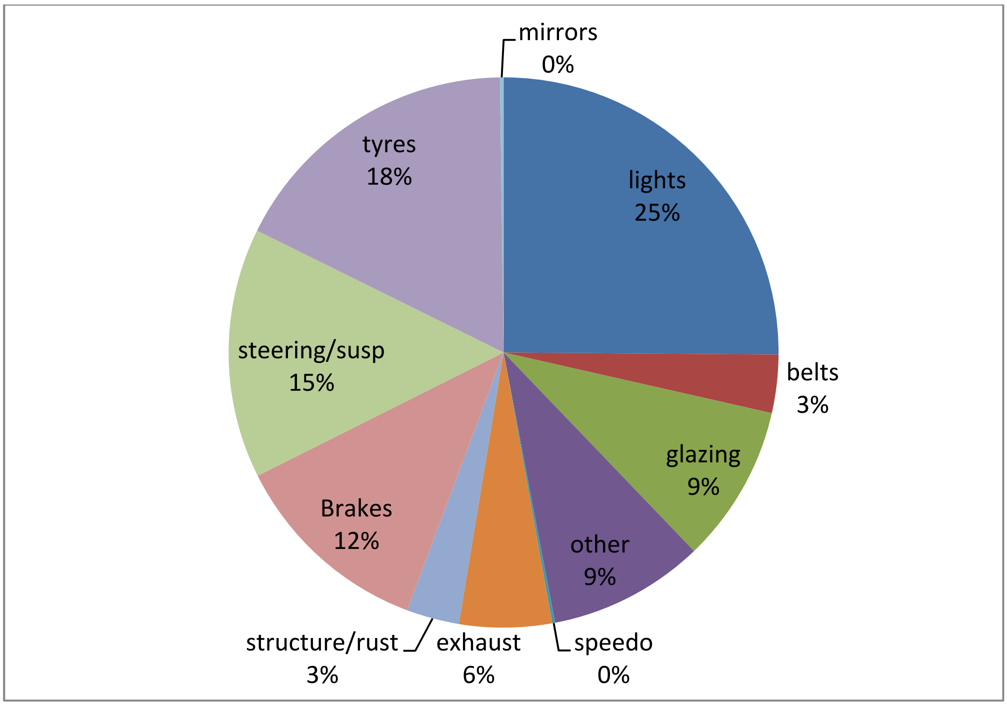

Figure 1: Distribution of faults identified in WoF inspections 2003-2009

Figure 2 indicates when the WoF inspection changes frequency from annual to six-monthly according to the age of the vehicle (the year of licensing minus the year of manufacture). This shows that the largest change occurs from a 6-year-old to a 7-year-old vehicle, although about a third of the 7-year-old vehicles were evidently still subject to the annual inspection.

Figure 3 shows the percentage of WoF inspections in which the vehicle failed and the mean number of faults identified per WoF inspection by the age of the vehicle. Only vehicles sold new in NZ are analysed here to avoid distortions to the time series associated with vehicles introduced into the fleet from other countries (mainly Japan) where different schedules of mechanical maintenance and different degrees of wear and tear associated with road conditions may apply. A failure occurs when at least one fault is identified. This shows that the failure rate generally increases with increasing vehicle age, with a small decrease in the failure rate for 7-year-old vehicles compared to 6-year-old vehicles, the point where most vehicles are inspected at 6-monthly intervals rather than annually, and the rate increases more slowly subsequently for the vehicles inspected 6-monthly. This is logically a consequence of the more frequent inspection that allows less time between inspection for faults to arise.

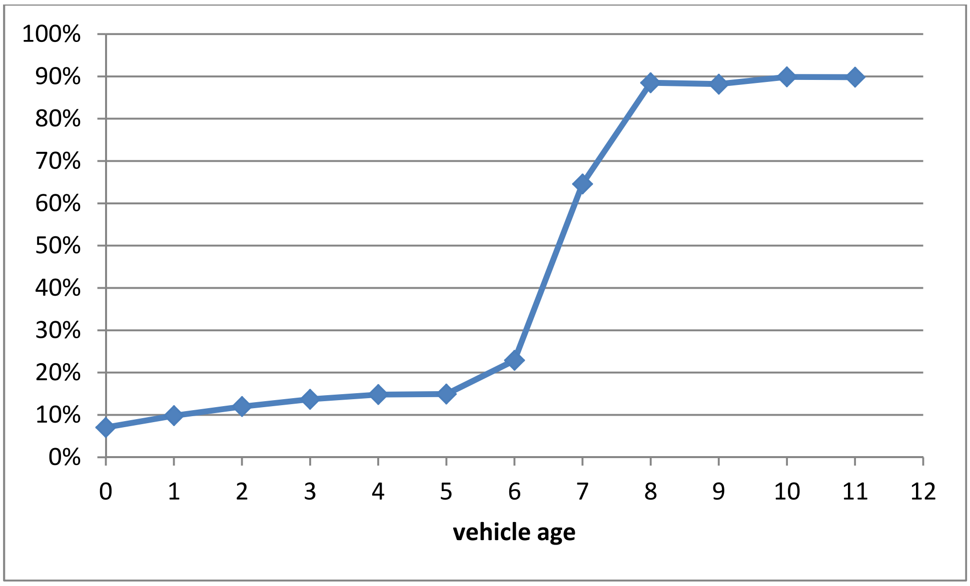

Figure 2: Percentage of WoF inspections (excluding multiple inspections on the same day) occurring between 90 and 210 days since the previous inspection date, by the age of the vehicle

Similarly to Figure 3, Figure 4 shows the mean number of faults identified per WoF inspection but this time according to the type of fault for the four more common fault types: brakes, tyres, steering/suspension and lights. Similarly to the pattern shown in the previous graph, all fault types show a marked flattening of the curve for vehicles inspected at 6-monthly intervals, with a marked drop in faults for vehicles aged 7 years old compared to 6 for tyres.

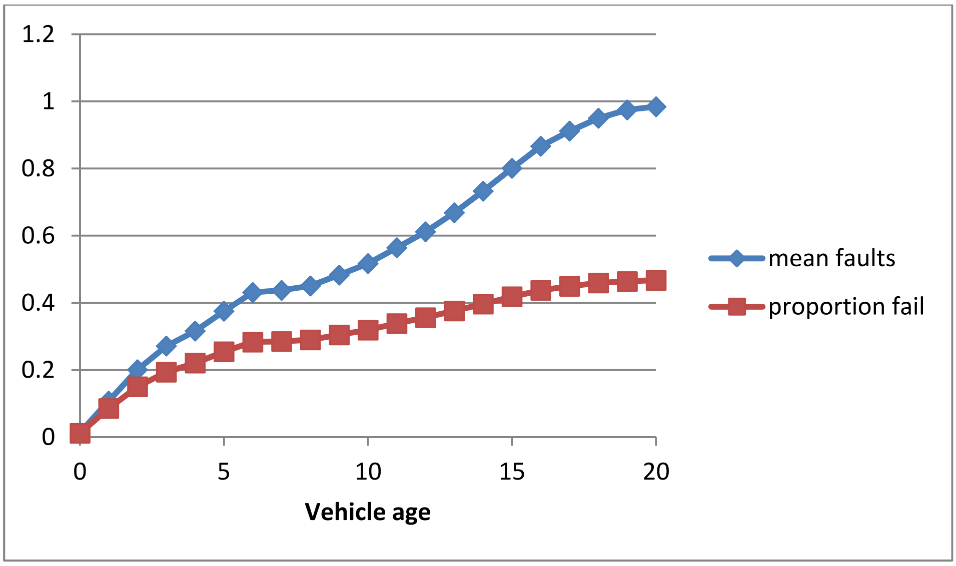

Figure 3: Percentage of WoF inspections where the vehicle failed by the age of the vehicle: only vehicles sold new in NZ (excludes used imports)

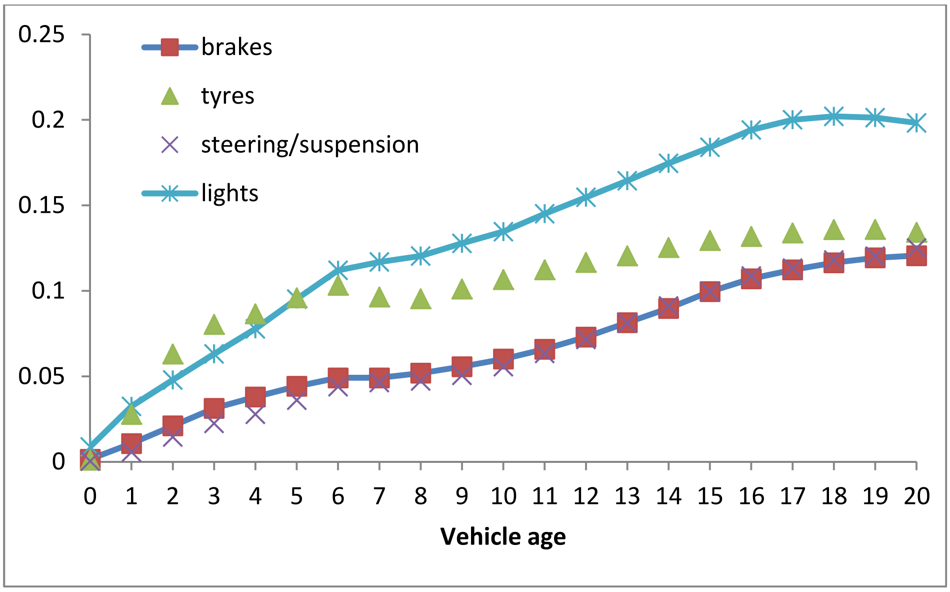

Figure 4: Mean number of faults identified per WoF inspection by the age of the vehicle and class of fault identified: only vehicles sold new in NZ (excludes used imports)

Figure 5 shows how the mean number of faults varies according to the age of the owner. The greatest number of faults is found for younger owners – those aged less than 30. Middle-aged owners have the next lowest average rate of faults, followed finally by vehicles owned by older people, aged 60 plus. Note that many faults arise from wear and tear on the vehicle that depends on the amount of use the vehicle gets. This, together with the amount of maintenance the vehicle receives, will explain some of the differences shown in this figure between owner age groups. When the numbers of faults within the specific defect classes were analysed (graphs not shown), all showed similar patterns to Figure 5.

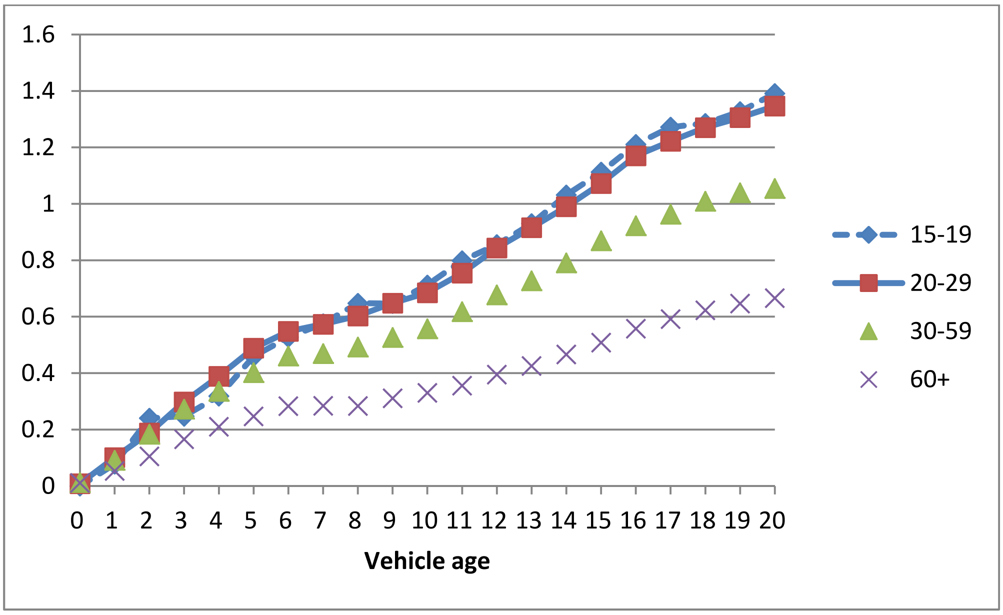

Figure 5: Mean number of faults identified per WoF inspection by the age of the vehicle and age group of owner: only vehicles sold new in NZ (excludes used imports)

To obtain an approximate estimate of the effect on the numbers of faults identified of the switch from annual inspections (for vehicles aged 6 and under) to six-monthly inspections, a

Poisson Generalised Linear Model was fitted to the vehicle inspection data to estimate the number of faults identified. Explanatory variables included:

- the age group of the owner
- the level of urbanisation of the owner's home address
- the market group of the vehicle
- the age of the vehicle (in logged form so that the model could estimate a linear increase in faults)
- a dummy variable to indicate when the vehicles switch from annual to six-monthly inspections

Only vehicles aged between two and ten years old were analysed to avoid fitting an overly steep trend line associated with vehicle age. It is likely that the more intensive maintenance regime that usually accompanies new car sales will make the number of faults detected at vehicle ages 0 and 1 atypical, so it was thought justified to exclude these vehicles from the analysis, which focuses on the change in the rate of faults at age 7. Only NZ new vehicles or imported vehicles sold near-new (less than three years old) were included for reasons discussed above: used vehicles introduced into the cohort analysed can confound the time series analysis. There were data from 2,115,086 inspections analysed with valid data for all the variables used in the model. Over-dispersion was allowed for by using quasi-likelihood estimation and multiplying the covariance matrix by a scale parameter estimated by the square root of Pearson's Chi-Square divided by the degrees of freedom, which was estimated to be 1.22. The model estimated that there was a 13.5% drop in the number of faults detected in the WoF inspection (with 95% CI 12.8%-14.2%) associated with the switch from annual to 6-monthly inspections.

Figure 6 shows the overall mean number of faults per inspection by vehicle age, with the slope of the increase estimated from data for years 2-6 shown as a solid line. This has been extended to 20-year-old vehicles even though it is likely to represent the continued increase in faults found if inspections continued to be annual only for a limited range of values beyond the data on which it is modelled. This extrapolation of the expected rate of faults suggests that the proportion of faults prevented by the 6-monthly inspections (compared to the annual inspections) is at least maintained up to vehicles aged 20 years old. Beyond this, the levelling out of the actual number of faults found suggests that a linear fit is not appropriate. Using this extrapolation, the average percentage of faults prevented over the vehicle age range 7-20 years was estimated to be 16% compared to the 13.5% drop in the number of faults (with 95% CI 12.8%-14.2%) found for 7-year-old vehicles.

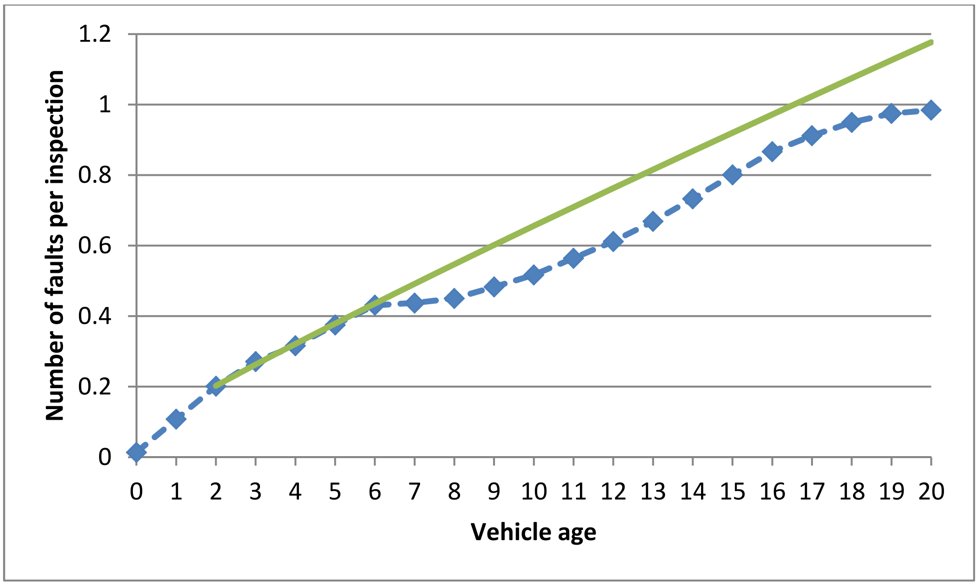

Figure 6: Overall mean number of faults identified per WoF inspection (dotted blue line) by the age of the vehicle along with the trend line (solid green line) estimated from years 2-6: only vehicles sold new in NZ (excludes used imports)

Figure 7 shows the crash rate per distance driven of vehicles owned by people aged 30-59, restricted to passenger vehicles newer than 7 years since manufacture. Shown in the figure are both the daily rate, represented as 400 points, which have a high degree of variability, and the 20-day mean (averaged across days 0-19, 20-39, etc.), which smoothes out the random fluctuations to show a decreasing crash rate from about 140 days onwards. Note that vehicles of this age are generally required to be inspected annually. The data extending more than a year from the date of the WoF inspection show even lower crash rates after a year has elapsed, most likely a result of these vehicles not being used as much.

Figure 7 shows that many of the daily crash rates beyond a year from the WoF inspection are zero as no vehicles had crashed in the population of vehicles studied for the particular number of days since inspection. Note that the distance driven used as a denominator of these rates is the distance driven in the *previous* year, so a vehicle with an elapsed WoF (and consequently abruptly reduced VKT) will be represented by a lower per-km crash rate than it should be.

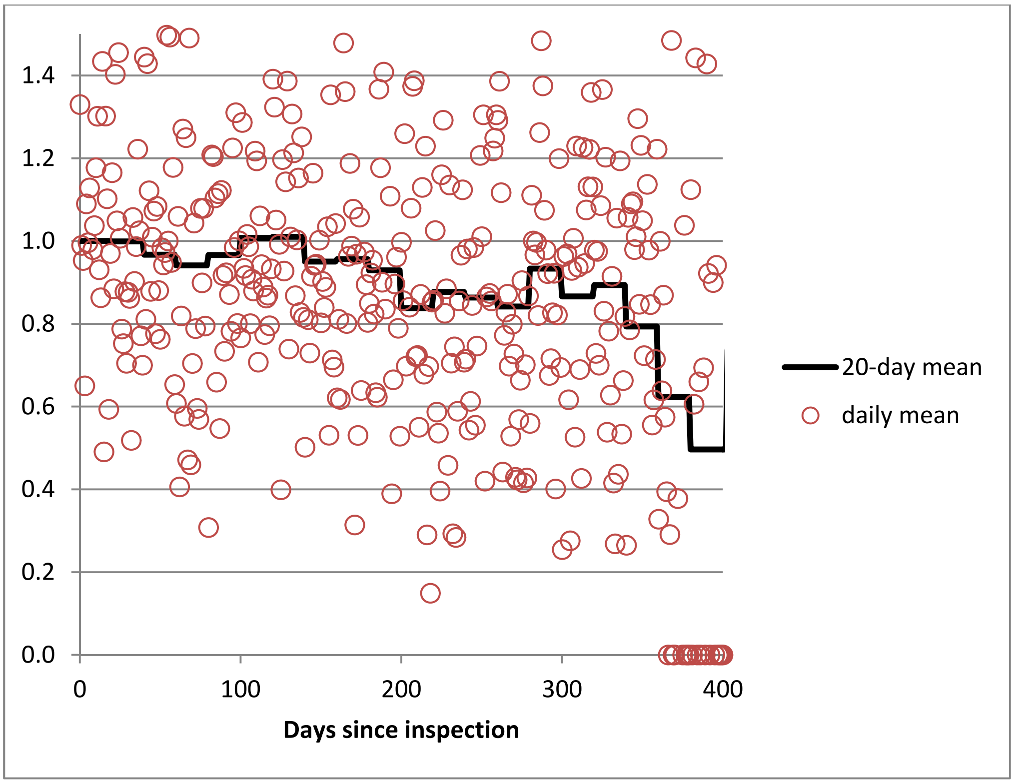

Figure 7: Per distance driven relative crash rate (daily rate and 20-day average rate) of vehicles aged 6 years and newer owned by people aged 30-59 according to number of days since inspection, relative to zero days

To estimate the change in crash risk associated with the change in inspection frequency from annual to 6-monthly, a logistic regression model was fitted to data for a total of 2,710,797 vehicle-years where there were complete data for all the covariates. This included vehicles aged 0 to 10 inclusive. There was no evidence of a poor fit, with a non-significant Hosmer-Lemeshow Goodness-of-fit test (P=0.19 with 8 degrees of freedom).

Figure 8 shows the outputs of two models fitted to the merged crash and licensing data. One model estimated risk per vehicle age, estimated discretely per year of age, with 95% confidence intervals shown. Two lines have been superimposed on these estimates, each with a slope estimated for a linear change in the logit of the vehicle crash risk, together with a step change estimated between the ages of 6 and 7. This step change provides an estimate of the change in risk associated with the change in WoF inspection frequency from annual (6 years old and younger) to mainly 6-monthly (7 years old and older). This was estimated to be an 8% reduction in risk with 95% confidence interval 15% to 0.4%, controlling for all the other factors included in the model, including the expected increase in risk with increasing vehicle age represented by the slope of the lines in the figure. This increase in risk with each added year of vehicle age was estimated to be 7.8% with a 95% confidence interval of 6.0% to 9.7%. For simplicity of presentation, the overall crash risk is presented in the figure along with an average increase in risk per year of vehicle age. In the models fitted, different sloped lines were allowed to be fitted for different years and for different vehicle market groups.

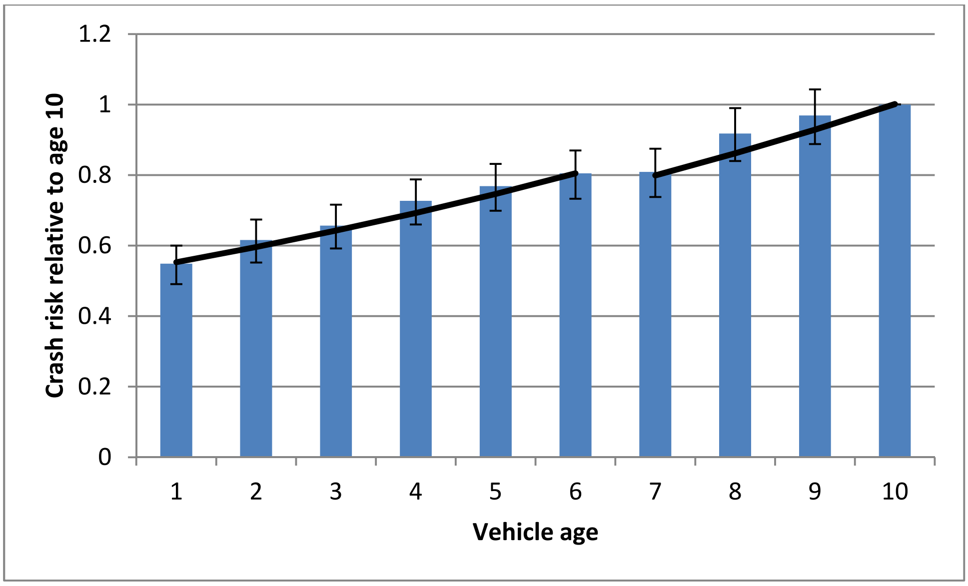

Figure 8: Crash risk of vehicles by age of vehicle relative to vehicles aged 10 (columns with 95% error bars). Also estimated linear trend in crash risk by vehicle age with step change estimated between vehicles aged 6 and 7.

Economic analysis of the WoF inspection

The following are some estimates of costs of the WoF scheme to the motorist (Uprichard, 2012):

Table 1: Approximate costs for motorists of WoF scheme: per inspection costs and aggregated costs using 2011 NZ dollars

Item		Cost estimate
Time commitment per vehicle owner per inspection	1.5 hours at $25 per hour	$37.50
distance travelled to a testing station	15 km (30 km round trip)	$21
Total per inspection (excluding fee)		$58.50
Average fail rate on first inspection	30%	
WoF inspection fee		$50
Cost per inspection	weighted by fail rate and including inspection fee	$126
Aggregate costs for six-monthly tests over and above annual tests for vehicles aged 7-20	1,970,000 inspections annually	$250 million
Aggregate costs for entire fleet if inspection annually	2,774,000 inspections annually	$350 million

The costs of the scheme to administer (excluding the costs to the motorist) are difficult to estimate as they are intertwined with other costs associated with vehicle licensing, although the aggregate costs to the motorist stated in Table 1 will dwarf such administrative costs.

Table 2: Estimated social costs associated with crashes using 2011 NZ dollars

Item		Cost estimate
Per injury crash		$324,000
Crashes involving vehicles aged 7-20 years	7,396 crashes in 2010	$2.4 billion

Benefits vs costs of the 6-monthly WoF inspection

The benefits of the scheme can be considered to be the safety benefits, calculated as the social cost of injuries potentially prevented by the scheme. Associated with the change from annual to 6-monthly inspections, it was estimated that the crash rate fell by 8% with 95% confidence interval 15% to 0.4% and the rate of vehicle faults fell by 13.5% (with 95% CI 12.8%-14.2%). Figure 6 suggests that the safety benefits are likely to be approximately maintained over the vehicle age range 7-20 years. The confidence interval for the drop in crash rate is wide, showing considerably statistical uncertainty about the precise size of the drop.

Figure 9 shows the implication of any given drop in crash rate. At the middle of the graph (for a notional 8% reduction in crash rates) the analysis predicts a 50% probability that the true reduction in crash rates would be at least of this size. An analysis of the preventive fraction implied by a given reduction in crash rates can help decide on potential values to use in the cost-benefit analysis, given the wide confidence interval found in our analysis. The middle of the confidence interval, the point above which the analysis suggests that there is a 50% chance that safety benefits exceed this level, also corresponds to the point at which Figure 9 represents the preventive fraction as about 60% (interpreted as the repair of a single fault would reduce the crash risk of vehicles with at least one fault by 60%). Given the range of other factors (principally driver behaviour) that are important in crash risk, this preventive fraction appears unrealistically high, suggesting that lower values within the confidence interval would present more realistic scenarios to use in a benefit-cost analysis.

As shown in Table 2, the social cost per injury crash was estimated to be $324,000 in $NZ 2011 values (Ministry of Transport, 2011b). There were 9,097 injury crashes involving cars and vans in 2010, of which 7,396 involved cars and vans aged between 7 and 20-years-old, a total social cost of $2.4 billion. If there were a 10% drop in crash rate associated with the 6-monthly inspections, the benefit-cost ratio would therefore be just below 1 (see Figure 9), indicating that the benefits in terms of social costs saved would be expected to approximately equal the costs estimated to be incurred by the motorist (as shown in Table 1) over and above any costs of an annual inspection. A 10% drop in the crash rate is unlikely from the distribution of the estimated drop: the probability that the drop is greater or equal to 10% is about 0.3 (Figure 9). More importantly, the the estimated preventive fraction resulting from this size of a drop in crash rate was estimated to be 74%, implying that just under three quarters of crashes could be prevented in vehicles with a single safety-related defect by repairs to this defect. Such a large preventive fraction is clearly improbable. Therefore a 10% drop is not consistent with the analysis and the safety benefits are extremely unlikely to equal or exceed the costs.

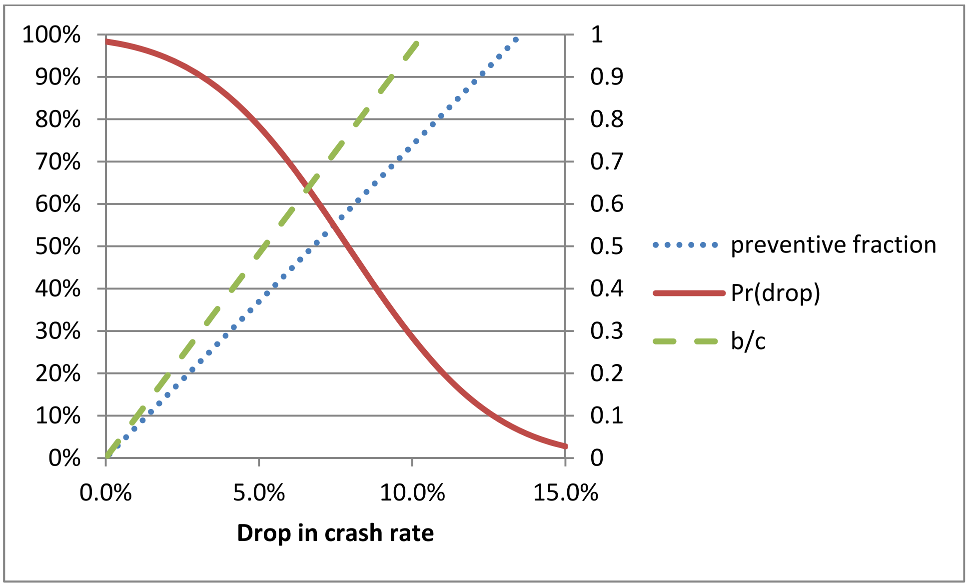

Figure 9: For given drop in crash risk associated with increased inspection frequency, probability that the drop was at least of this size (solid red line), preventive fraction (dotted blue line) of repairs of faults and benefit/cost ratio.

Level of benefits to justify costs of annual inspections

Although (with some caveats) the lack of safety benefits over costs associated with the change in inspection frequency from yearly to biannually has been established robustly above, it is difficult to estimate the safety benefits of the scheme as a whole. The reasons for this are: (i) the scheme affects motorists' behaviours around maintenance of their vehicles in ways that cannot be assessed; for example, it is likely that many people repair faults at the time of the scheduled inspection, but not normally at other times; (ii) the change in the mechanical condition of the fleet cannot be imputed from available data. However, it is possible to use the known costs of the scheme to the motorist as one side of the cost-benefit equation and estimate the necessary benefits to equal these costs, shown in Figure 10.

The benefits start to exceed the costs only when the drop in crash rate associated with the scheme is postulated to be at least 12%. This is evidently quite a demandingly high level of injury reduction. It is unlikely from the literature that 12% of crashes can even be considered to be caused by mechanical defects. Further, it is unlikely that any periodic inspection scheme could realistically produce a fleet that is free of mechanical defects. As indicated by the analysis above and shown in Figure 6: doubling the frequency of inspections from annual to twice annually was only estimated to reduce the frequency of faults by 13.5%. Thus mechanical defects continue to occur in the fleet despite the relatively high frequency of inspection and resultant repairs to defects found.

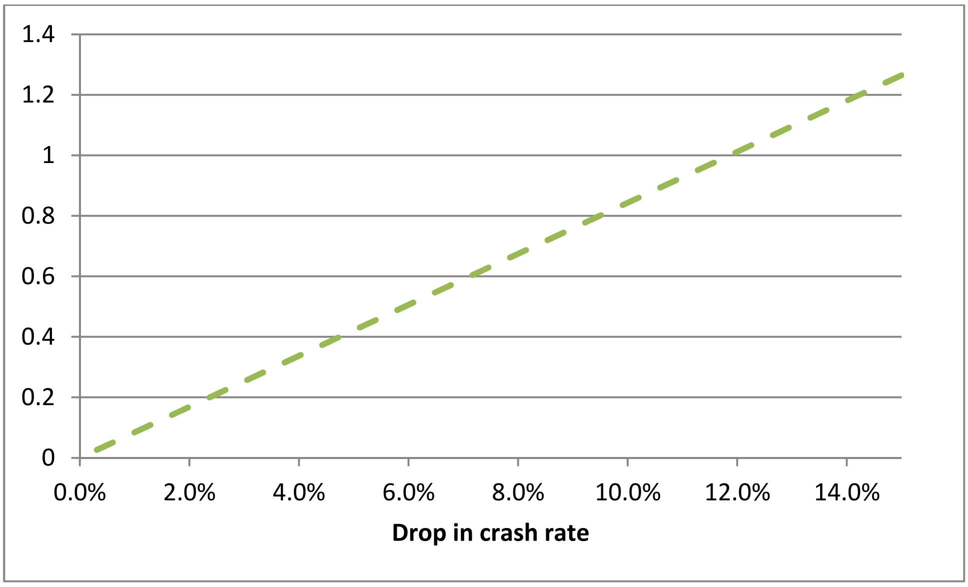

Figure 10: For given drop in crash risk postulated to be associated with the WoF scheme as a whole, estimated benefit/cost ratio.

Victorian results

There were 5,045,538 unique ownership records, with 57,574 eligible crashes that occurred prior to expiry, cancellation, next acquisition or June 30, 2009 (1.14% of all owner-year combinations). The overall incidence rate was 7.7 crashes per 1,000 ownerships per year. The survival analysis, which estimates the survival probability (where survival means there was no crash for that ownership up to a nominated time point) over time since acquisition for the vehicle fleet estimated a mean 9-year survival probability of approximately 91.9% (95% CI 91.6-92.1). That is, after 9 years since acquisition 91.9% of vehicles had not been involved in a police reported crash.

Figure 11 shows the hazard over time since acquisition, where the hazard reflects the rate of change in instantaneous risk of a police reported crash at a particular time, given that there was no crash during that ownership up to that point. It is related to the rate of change of the survival function. Figure 11 indicates a steep increase in hazard over the first 2 to 3 years, after which time the hazard becomes relatively uniform until approximately eight years after acquisition when the hazard increases again. The 95% confidence intervals show that the right-hand side of the graph is subject to much greater uncertainty as the data are much sparser.

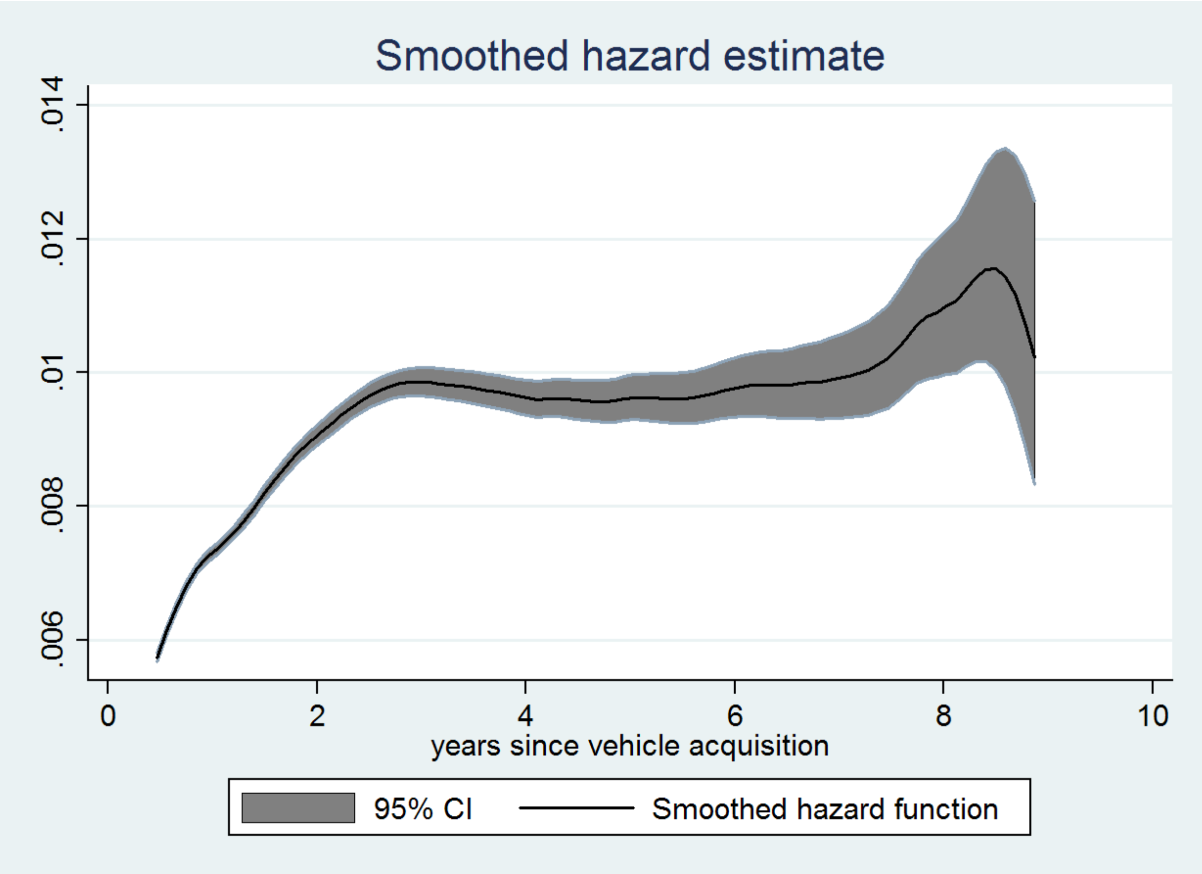

Figure 11: Smoothed hazard estimate (hazard function), indicating risk of crash involvement at each point in time since vehicle acquisition (whether purchased new or second-hand), with shaded 95% confidence interval.

By vehicle age at time of acquisition

Vehicle age at time of acquisition was derived for each record by calculating the difference between the date the vehicle was first registered and the date the vehicle was acquired. Figure 12 and Table 3 indicate that the vast majority of registration records in the dataset involved acquisition of new or near new vehicles (approximately half were acquired when less than one year old). The crash incidence rate increased with the age of the vehicle at time of acquisition (Table 3), with a crash incidence rate of 6.4 per 1,000 ownerships per year for vehicles less than one year old at time of acquisition compared to 10.6 per 1,000 ownerships per year for vehicles that were at least 10 years old at time of acquisition. It should be noted that the measured differences in crash incidence rates between different age vehicle is not necessarily a characteristic of the vehicle but more likely will represent the crash risk of the driver cohort of each vehicle group which will vary by age and gender profile. Age and gender of vehicle owner were not available in the Victorian registration data.

Table 3: Vehicle age at time of acquisition and crash incidence rates

Vehicle age at time of acquisition	n [%]	Incidence rate (per 1000 ownerships per year)
< 1 year	2,549,282 [51%]	6.4
1 year to < 5 years	1,068,562 [21%]	7.7
5 years to <10 years	824,911 [16%]	9.4
10+ years	602,783 [12%]	10.6

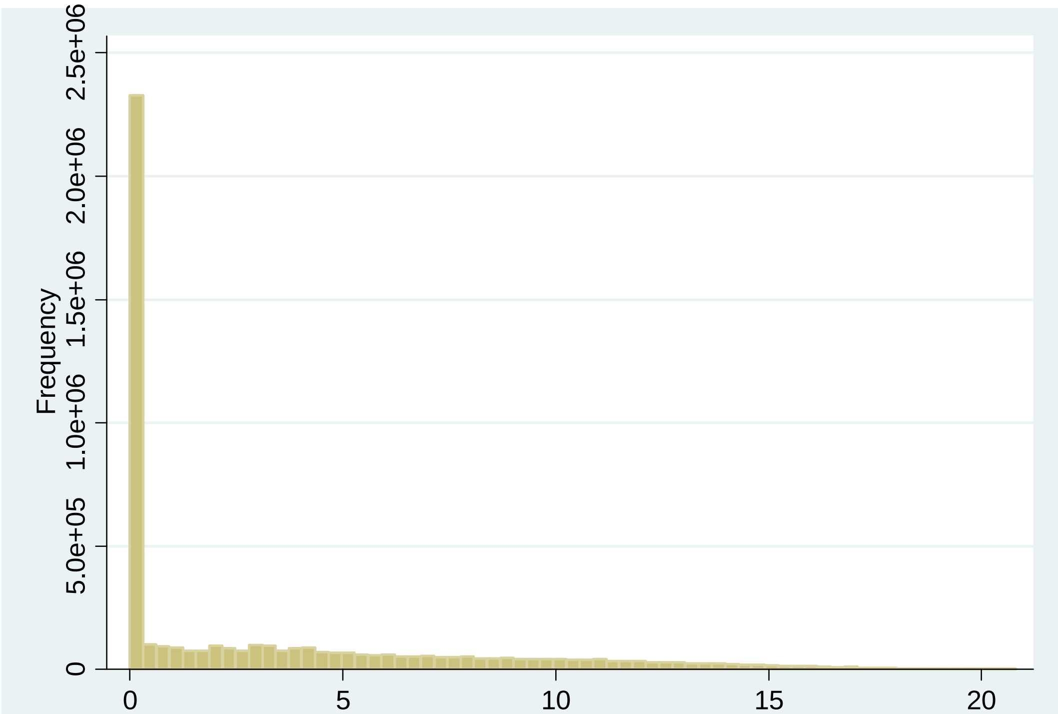

Figure 12: Frequency histogram of vehicle age at time of acquisition (years)

Table 4 shows the survival probability (where survival means no crash occurred) over time for vehicles of differing ages at time of acquisition. At any time point, the survival probability is generally lower as vehicle age at acquisition increases. An exception is for the survival probability at 9 years for vehicles aged 10+ years, which goes against that trend.

Table 4: Survival probabilities at various time points, by vehicle age at time of acquisition

Vehicle age at time of acquisition	% Survival probability [95% CI] at:			
	1 year	2 years	5 years	9 years
< 1 year	0.9946 [0.9945-0.9947]	0.9876 [0.9874-0.9879]	0.9612 [0.9604-0.9620]	0.9241 [0.9213-0.9269]
1 year to < 5 years	0.9934 [0.9932-0.9936]	0.9856 [0.9853-0.9860]	0.9568 [0.9556-0.9578]	0.9150 [0.9105-0.9192]
5 years to <10 years	0.9913 [0.9911-0.9915]	0.9819 [0.9815-0.9823]	0.9508 [0.9495-0.9520]	0.9103 [0.9045-0.9158]
10+ years	0.9894 [0.9891-0.9897]	0.9791 [0.9786-0.9796]	0.9504 [0.9488-0.9520]	0.9241 [0.9187-0.9291]

Figure 13 displays the hazard (the rate of change in instantaneous risk of a crash) over time, by vehicle age at time of acquisition. For all vehicles, there is an increasing instantaneous risk of crash for approximately the first two years after acquisition. For vehicles less than 10 years old at time of acquisition, after this time, there appears to be a constant hazard until approximately six to eight years, after which time the hazard increases again. The pattern is different for vehicles more than 10 years old at time of acquisition, as after the initial increase, the hazard appears to decrease over time. A decrease in risk can occur for a number of reasons, including a likely reduction in the driving exposure of older vehicles.

At most points in time after acquisition vehicles aged less than one year at acquisition were estimated to have an average hazard that is slightly lower than the average hazard of vehicles aged from 1 year to less than 5 years at the time of acquisition. Comparing each subsequent line at the first available point after acquisition, the point at which the vehicle is nominally "roadworthy", similarly shows an increase in hazard. As discussed, vehicles of different age at acquisition are likely to be driven by cohorts with different age and gender characteristics, which could explain some of the difference in risk in the period immediately after acquisition.

The important attribute of Figure 13 is that the hazard estimates to not vary significantly over time, particularly for older vehicles where they do not vary at any time since acquisition of the vehicle. The curves give no particular indication of a point where deterioration in roadworthiness appears to become a significant issue hence potentially justifying the introduction of mandatory roadworthiness inspections.

Table 4 does provide an indication of a maximum safety benefit that could be envisaged to be associated with annual roadworthiness certification for vehicles over 5 years old. Such benefits are likely to be overestimated as newly acquired vehicles are likely to be driven differently for a variety of reasons. Imputation of benefits from these data should probably exclude new vehicles as they are likely to be covered by warranties that include regular servicing and hence roadworthiness inspection is of limited value. The focus then is on vehicles 5-10 years old which have the steepest hazard in the first few years of ownership and hence the greatest potential safety benefits from annual inspection. The maximum benefit of annual inspections can be inferred from comparing the actual 2 year crash rate (1 – survival probability) with that expected if the first year survival probability was observed in both years 1 and 2 due to the survival curve being 'reset' to year 1 levels through an annual roadworthiness inspection process. This calculation shows a 3.9% drop in crash risk in the second year. This is considered to be a maximum crash reduction that could be achieved assuming all the increase in crash rate in the second year of ownership is due to vehicle roadworthiness deterioration which may not be the case.

Cox proportion hazards regression was not conducted on the data by age at acquisition because there was strong evidence that the hazard was not proportional between groups ($\chi^2(3)=396.61$, p=0.0000).

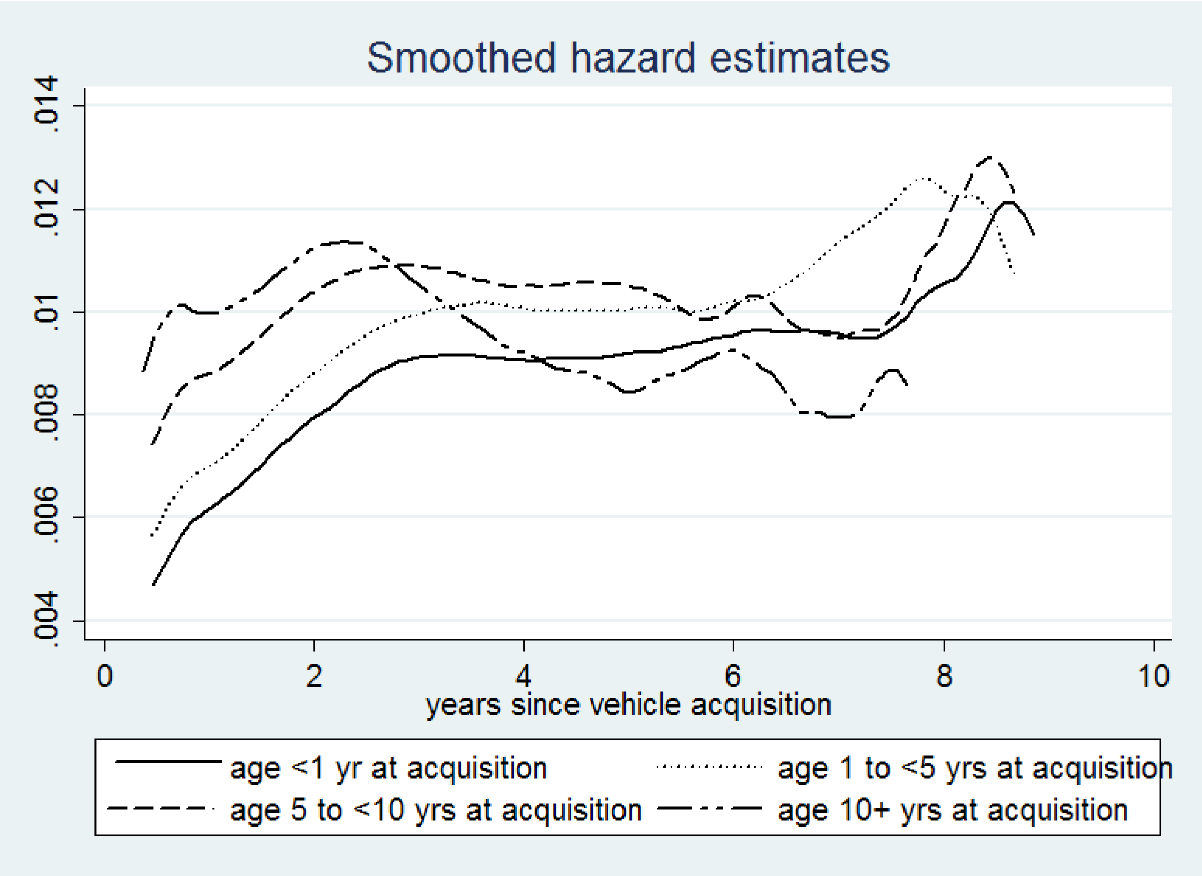

Figure 13: Smoothed hazard estimate (hazard function) over years since acquisition, by vehicle age at time of acquisition

By vehicle market group

The market group of the vehicle was decoded using the VIN and the frequency and proportion of each type is shown in Table 5. Large (34.6%) and small (22.57%) passenger vehicles were the most common while commercial vans (2.06%) and people movers (1.5%) were least common. The highest crash incidence rates (per 1000 vehicle ownerships per year) were for light (9.01) and large (8.52) vehicles, while medium sports utility vehicles (SUVs) had the lowest incidence rate (4.78). Again, this is likely to be largely a reflection of differences in the specific cohorts that drive these vehicle rather than reflecting characteristics of the vehicles themselves.

Table 5: Frequency of vehicle market group, and incidence rates

Market group	Frequency in terms of vehicle-years [%]	Crash incidence rate (per 1000 vehicle ownerships per year)
Large	1745725 [34.60]	8.52
Medium	582076 [11.54]	7.42
Small	1138914 [22.57]	8.33
Light	306904 [6.08]	9.01
SUV compact	239898 [4.75]	5.90
SUV medium	207607 [4.11]	4.78
SUV large	205775 [4.08]	5.17
People mover	75439 [1.50]	6.30
Commercial ute	439508 [8.71]	6.11
Commercial van	103692 [2.06]	7.42

Figure 14, Figure 15 and Figure 16 show the estimated hazard functions over time since acquisition for the different vehicle market groups. There were some differences in the hazards between categories, which are likely to be related to differences in the way the vehicles are used, and to random variation, particularly for vehicles that had been acquired 9 years or more previously.

Passenger cars (Figure 14) appear to have an increase in hazard over the first 2 to 3 years, and then again after about 7 years (similar to the results for the overall sample, not surprisingly, considering these make up approximately three-quarters of the sample). Commercial utes, by contrast, do not appear to have a substantial increase in hazard at any time point, and for commercial vans, the hazard gradually doubles by about three years after acquisition and then decreases after approximately five years (Figure 16). Across SUVs and people movers, the patterns were not consistent (Figure 15). Compact SUVs appear to have a steadily rising hazard over time, whereas medium SUVs display a consistent hazard for the first 7 years followed by a decrease in hazard to 8 years and a rather eye-catching increase following that. With all the curves shown, the data are scarcest at the far right-hand side, which means that little can be inferred from the apparent patterns. Again, Cox proportional hazards regression was not conducted because there was evidence that the hazard was not proportional across market group (χ^2 (9)=157.16, p=0.0000).

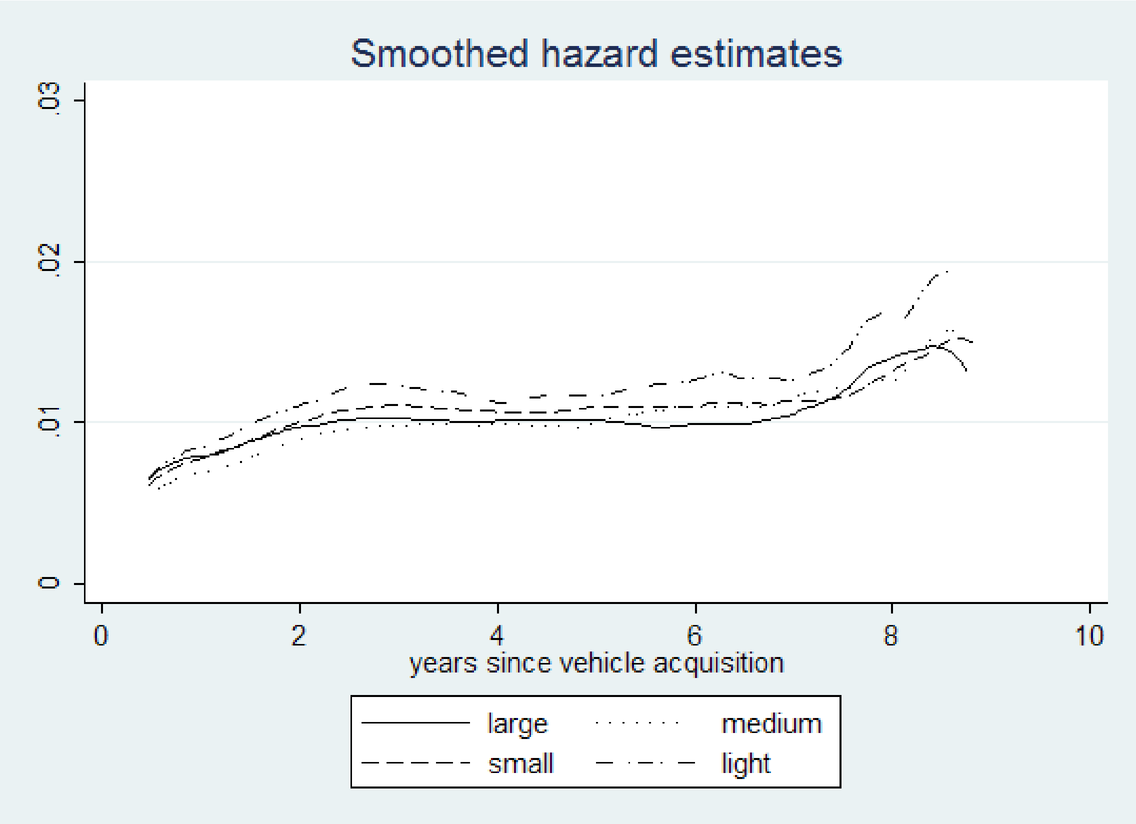

Figure 14: Smoothed hazard estimate (hazard function) over years since acquisition, by car market group

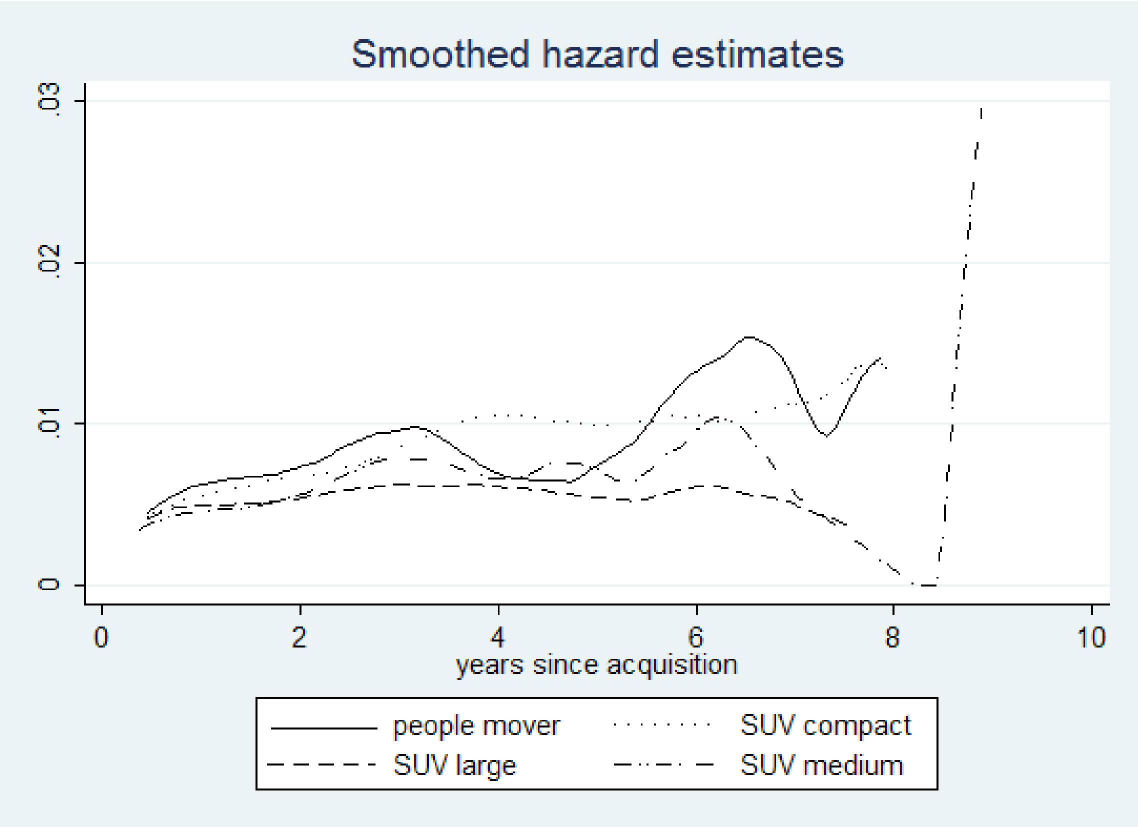

Figure 15: Smoothed hazard estimate (hazard function) over years since acquisition, by SUV and people mover market groups

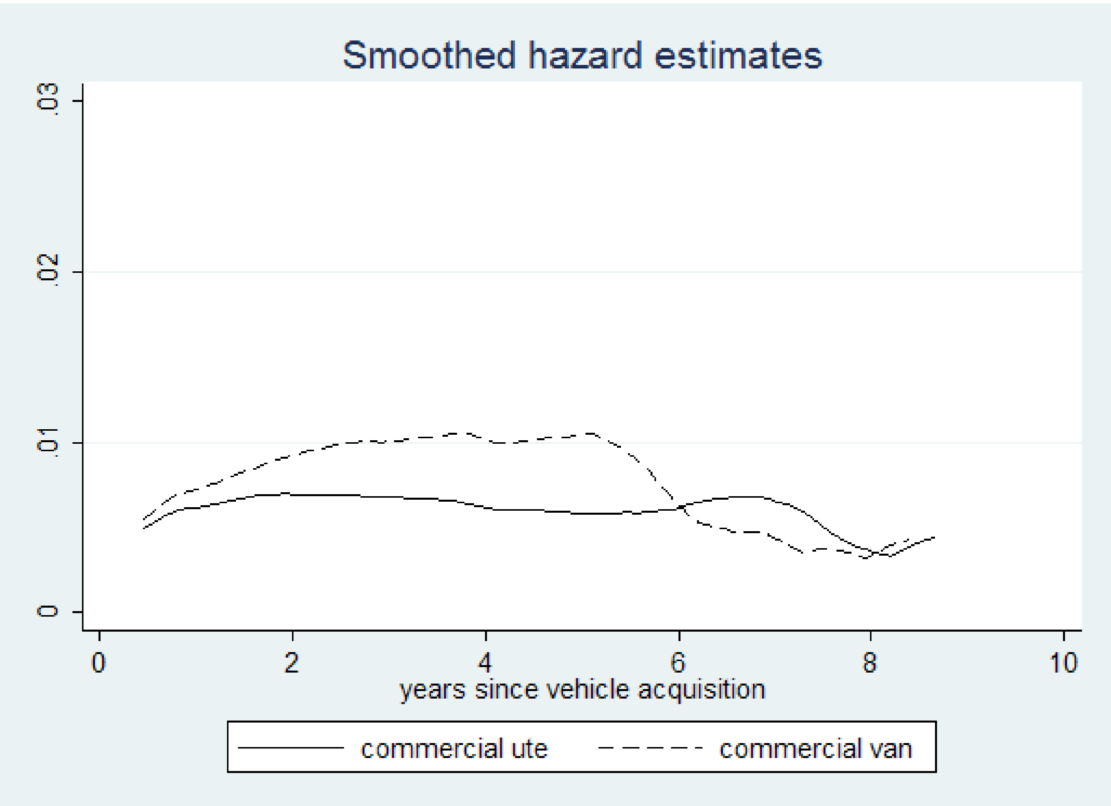

Figure 16: Smoothed hazard estimate (hazard function) for commercial vans and utes over years since acquisition

DISCUSSION

Overview of findings

It is difficult to conduct good analyses of the safety effects of vehicle inspection regimes as safety effects, based on defect rates, are likely to be small and confounding factors complicate the interpretation of any safety effects inferred. The New Zealand analysis could not evaluate the scheme as a whole, but could quantify the effects of the natural experiment provided by the change in inspection frequency of the scheme. An analysis was made of the safety benefits and the reductions in safety-related vehicle faults associated with the increase from annual to biannual inspections that occur six years after the car's manufacture date. The Victorian analysis found some patterns in common with the New Zealand analysis, most notably the increase in crash risk with older vehicles. The Victorian analysis potentially provided a contrasting view of vehicle safety in the absence of regular roadworthiness inspections, but the differences between the fleets and likely differences in the way older vehicles are used tend to obscure any potential inferences about safety differences due to regular inspections (such as the New Zealand WoF scheme). Although some previous analyses of periodic inspection regimes have used the increase in risk for older vehicles as a measure of increased crash risk due to mechanical defects, both the Victorian and New Zealand analyses shown here have shown that the higher risk for older vehicles occurs even for vehicles immediately after they are certified as roadworthy, which suggests that other factors, likely to be related to the way the vehicle is used and by who, lead to the increased crash risk.

The analysis of the New Zealand data estimated that the crash rate decreased by 8% with a 95% confidence interval 0.4% to 15% associated with the switch from annual to 6-monthly inspections. The decrease in the rate of vehicle faults was estimated to be 13.5% (with 95% CI 12.8%-14.2%). Despite these safety benefits estimated, the costs to the motorist of the 6-monthly inspections over and above the annual inspections were estimated to be considerable. This means that the 6-monthly inspections compared to annual inspections *as imposed by the scheme* were not considered to be cost-effective.

In terms of the cost-effectiveness of the New Zealand WoF scheme as a whole, we placed the known costs of the scheme to the motorist as one side of the cost-benefit equation and then estimated the necessary benefits to equal these costs, represented by Figure 10. The benefits started to exceed the costs only when the drop in crash rate associated with the scheme reached 12%. This is evidently quite a demandingly high level of injury reduction. It is unlikely from the literature and from the rate of fault detection in the NZ WoF scheme that 12% of crashes can even be considered to be caused by mechanical defects, let alone able to be prevented by periodic inspection and repairs. However, it is also likely that vehicle defects may play a more important role in more serious crashes. If this is the case, then the percentage of *social cost* attributable to vehicle defects would exceed the percentage of *crashes* attributable to vehicle defects. However it is still considered unlikely that the higher social cost reductions that might be associated with periodic inspections would be large enough to exceed the costs of the inspections themselves to the community.

Limitations of the Victorian analysis

When analysing the Victorian data, it would have been interesting to have analysed how for a given vehicle the risk of crash involvement changes from the period before change of ownership (the point at which we know there is a roadworthiness inspection with accompanying repairs of faults) to the period after change of ownership. As with the NZ analysis, a complicating factor is that crash involvement will affect the roadworthiness of a given vehicle (in the sense that the vehicle will be repaired following the crash) and also its probability of being sold to another owner will change. Crash-related factors influencing the likelihood of sale include: the vehicle may be written off (not sold at all); the vehicle may be roadworthy but less desirable to a purchaser. These factors tend to constrain the analysis to the period following the change of ownership.

In theory, there is a gradual increase in risk as the vehicle ages, which appears to be approximately linear according to the NZ analysis. As noted in the Victorian Results section, the average risk for vehicles classed according to their age did seem to be lower at the point in time of vehicle acquisition than the risk for vehicles of a comparable age that had not been newly acquired. As a newly acquired vehicle is likely to be driven differently, differences in risk are not surprising. However, these unknown exposure effects are likely to have obscured any detectable safety effects. In Victoria, vehicles are still required to be roadworthy in the intervening period between ownership changes, which is enforced by occasional roadside inspection of vehicles by police. There may be an argument for a further roadworthiness inspection after acquisition. However it is difficult to justify this in terms of expected safety benefits, which cannot be estimated precisely but are likely to be in the order of annual crash reductions less than 4% as described above for an annual inspection regime. Also, as shown in Figure 13, following a point of maximum risk, there is then a plateau. The analysis could not control for the amount of driving undertaken in the vehicle and it is highly likely that older vehicles, particularly those more than 15-20 years after manufacture, are driven less. For example, they may be potentially used as secondary vehicles by families. It can be argued that a reduction in the amount of driving of older vehicles reduces their annual risks, which in turn reduces potential benefits of certifying older vehicles for roadworthiness compared to certifying younger vehicles.

The aspect of the Victorian analysis that is most comparable to the New Zealand analysis (Figure 8) is the curve for vehicles aged less than one year at acquisition in Figure 13. This is because the New Zealand analysis focused on vehicles aged between one and ten years old. Over that period, the risk of crash involvement per year approximately doubled for both the New Zealand and Victorian fleets. In comparison with the steadily increasing risk with increasing age for the New Zealand vehicles, with a plateau around six-year-old corresponding to the change in inspection frequency, the comparable Victorian data show a steeply increasing risk up to age three, followed by relatively uniform risk to age eight, after which risk increases again. Although it might be tempting to attribute the steep increase in the initial part of the Victorian curve (in comparison to the more modest increase in the New Zealand data over the same age range) to the lack of a New Zealand-style WoF, there are two key problems with this inference. First, the difference in slopes is too great to be solely attributed to safety-related vehicle faults. There must be other exposure-related changes occurring in that fleet that are different from those that occur in New Zealand. Second, the lack of periodic inspections cannot then explain the Victorian plateau in risk from vehicle age three to eight years (see Figure 13, vehicles aged less than one when acquired). Even if the increase in risk represented in Figure 13 is due to vehicle roadworthiness issues, an annual maximum crash reduction of only about 4% can be inferred (Table 4), making the scheme unlikely to be cost beneficial.

Generalisability of NZ analysis

New Zealand has a relatively old light vehicle fleet compared to other countries with a similar degree of motorisation. The average age was a little over 12 years in 2008, compared to about 10 years in Australia and about 9 years for cars in the US (Ministry of Transport, 2011a). The increase in faults found in vehicles as they get older implies that the New Zealand fleet would have a higher rate of safety-related defects than other younger fleets, all other things being equal. This also implies that there may be more to be gained from a periodic inspection regime for an older fleet, meaning that smaller safety benefits might be presumed to accrue from similar regulation of younger fleets.

In Victoria, 74% of vehicles (weighted by years licensed) had been acquired when the vehicle was less than 5 years old. This means that the effect of the roadworthiness inspection at the time of change of ownership is likely to have a relatively small fleet-wide safety effect given the relatively low rate of defects in relatively new vehicles noted in the New Zealand analysis. Of course, legal requirements for roadworthiness coupled with on-road enforcement can be expected to have an effect on vehicle maintenance in the intervening period.

Effectiveness of inspections to produce fault-free vehicles

Periodic inspection regimes can be seen as a form of quality control of the fleet. An important question with any quality control system is the ability of the system to detect and repair faults reliably. When evaluating the Norwegian scheme, Christensen and Elvik (2006) analysed of the number of faults found in subsequent inspections. They found a large drop in the number of faults detected, indicating that the inspection regime with associated repairs (made in response to the inspections) substantially reduced the prevalence of vehicle faults. Of course, such analysis is only valid when the inspections are made independently of one another. In the New Zealand system, for example, the results of an inspection are recorded on-line and any subsequent inspector has access to the results of the previous inspection, which would invalidate analysis of this sort. As shown above, doubling the frequency of the WoF inspections from annual to twice annually was only estimated to reduce the prevalence of defects by 13.5%. If it is assumed, in the absence of maintenance and repair, that general wear and tear will always reduce the roadworthiness of a vehicle over time, no periodic scheme will ever produce a perfect fleet (with respect to the sorts of faults targeted) as a vehicle may pass a given standard (for tyre tread depth, for example) in one month, but have failed that standard in a subsequent month (where tyre tread depth falls below the threshold of the test, for example). Nevertheless, if each given test and requisite repairs were assumed to remedy all the defects as defined by the scheme, we would expect the reduction in the prevalence of faults to be reduced by closer to 50% where the inspection frequency was doubled. To our knowledge, there is no systematic checking of the consistency of the New Zealand inspections to measure the proportion of faults identified for a vehicle with known faults, nor systematic checks of the adequacy of the repairs. It is nevertheless likely that a reasonable proportion of obvious faults are identified, as the repairs are normally carried out by the same mechanics that assessed the vehicle for faults, providing a clear financial incentive for the inspector to find faults needing repair. However, it is possible that there is room for improvement in the New Zealand scheme that could yield marginally higher safety benefits.

Increase in crash rates with vehicle age

Common to both the New Zealand and Victorian analyses, the rate of crash occurrence generally increased as the vehicle aged. A potential contributor to this increase is the increase in safety-related defects as the vehicle ages (see Figure 3 from the NZ analysis), but the way the vehicle is used and the cohort who drives the vehicles also changes in ways that could not be captured in the current analysis. The Victorian analysis showed that even for vehicles that are newly acquired (so recently inspected and repaired to the standard required), this differential still remains. Despite regular inspections and consequent repairs to New Zealand vehicles, supposedly reducing the prevalence of safety-related faults particularly in older vehicles, the increase in crash rates with increasing vehicle age was clearly apparent. Note that fleet secondary safety – and potentially primary safety – also improves over time. Although the improvement in secondary safety is well documented (Newstead et al, 2004; Newstead et al, 2011), primary safety improvements are more difficult to establish as exposure (the way the vehicle is used) is difficult to control for adequately. This will be the main factor behind the increased risk for vehicles as they age, although there is little research to identify the changes in exposure potentially leading to the higher crash involvement rates.

CONCLUSIONS

Analyses were conducted of merged crash and licensing data from two jurisdictions, Victoria and New Zealand, where periodic vehicle inspections are conducted to certify roadworthiness at the point of sale of a vehicle (Victoria and New Zealand) or at 12-montly or 6-monthly intervals (just in New Zealand). Using the New Zealand data, an analysis was made of the safety benefits and the reductions in safety-related vehicle faults associated with the increase from annual to biannual inspections that occur six years after the car's manufacture date. The logistic regression analysis estimated that the crash rate decreased by 8% with 95% confidence interval 0.4% to 15%. The decrease in the rate of vehicle faults was estimated to be 13.5% (with 95% CI 12.8%-14.2%) associated with the switch from annual to 6-monthly inspections. The proportion of vehicle faults prevented is likely to be at least maintained over the vehicle age range 7-20 years, suggesting that the resultant safety benefits should also be maintained. The confidence interval for the drop in crash rate was wide, showing considerably statistical uncertainty about the precise size of the drop.

Despite these safety benefits estimated, the costs to the motorist of the 6-monthly inspections over and above the annual inspections were estimated to be considerable. This means that the 6-monthly inspections compared to annual inspections were not considered to be cost-effective. The benefits of the WoF scheme as a whole cannot be robustly evaluated using the analysis approach used here, but they would need to be substantial – yielding at least a 12% reduction in injury crashes – for it to be cost-effective.

The Victorian analysis of potential periodic roadwothiness certification safety benefits was not entirely conclusive. It suggested the maximum annual crash savings associated with moving to annual vehicle roadworthiness inspections for vehicles over 5 years old to be around 4%, which is likely to be much less than required to make an annual periodic scheme cost effective.

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