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TITLE

Potential effectiveness of seat belt interlocks

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ABSTRACT

Seat belt interlocks are a vehicle safety technology that aims to increase seat belt usage by restricting the vehicle from being driven until occupants have fastened their seat belts. While this technology is generally not found on modern vehicles, it was made mandatory for vehicles manufactured in 1974 in the USA. Since then, little research has been done on the potential effectiveness of seat belt interlocks, but the literature does indicate the benefits of seat belt interlocks would outweight the costs. In this study three datasets were used to examine the vehicle age profiles of drivers who were not wearing a seat belt. These datasets included an observational study from 2009, hospital admission data from 2008-2010, and Coroner's report data from 2008. In each dataset, the drivers who were not wearing a seat belt were driving older vehicles than those who were wearing a seat belt. Overall seat belt usage was 98% in the observational data, 89% in the hospital admissions data, and 66% in the Coroner's data. A hypothetical scenario was considered in which seat belt interlocks were made mandatory in all new vehicle models from 2015 onwards. Under this scenario, the vehicle age profiles from each dataset were used to examine the time it would take for seat belt interlocks to be found in vehicles driven by those who would otherwise not be wearing a seat belt. These results were used to calculate a 'strongest case' estimate of the potential effectiveness of seat belt interlocks: by 2030 there would be a potential 2% reduction in injuries requiring hospital admission, and a 7% reduction in fatalities. By 2050 these values would approach 5% and 16% respectively. These reductions would apply on top of any casualty savings already made through enhanced vehicle technologies, infrastructure and regulations. Despite the relatively long time required for interlocks to reach maximum effectiveness, the low cost and complexity of introducing seat belt interlocks merits some encouragement, with some consideration given to after-market installation targeting users who are at high risk.

KEYWORDS

Seat belt interlocks, vehicle age, vehicle technologies

Summary

Seat belt interlocks are a vehicle safety technology that do not allow a vehicle to be started unless the occupants of the vehicle have fastened their seat belt. This vehicle technology became well known in the 1970s, after the National Highway Traffic Safety Administration (NHTSA) in the US made interlocks mandatory on all 1974 model year vehicles. Despite some early research indicating public acceptance of interlocks, there was widespread backlash about the regulation and after 1974 they were no longer a requirement. Since then, there has been little research on interlock effectiveness, with most research being focused on seat belt reminder systems, which give an audio and visual warning when an occupant has not fastened their seat belt.

To estimate the potential effectiveness of seat belt interlocks it is necessary to know the effectiveness of interlocks at enforcing seat belt use, the effectiveness of seat belts in preventing casualties, and the proportion of injured vehicle occupants travelling without a seat belt. These values could be estimated from existing studies and data. In this report, vehicle age profiles of unrestrained drivers were used to estimate how long it would take for seat belt interlocks to reach those who would otherwise be unrestrained, if seat belt interlocks were to be made mandatory in new vehicles. The potential future marginal benefits were then estimated for each year.

Three South Australian data sources were used for the vehicle age profiles of unrestrained drivers: (a) observational seat belt use data collected in 2009, (b) hospital admission records collected between 2008 and 2010, and (c) Coroner's files for fatal crashes in 2008. Seat belt use was highest in the observational study drivers (98%), followed by the hospital admissions (89%) and then the Coroner's files (66%). In each dataset, the unrestrained drivers were found to be driving older vehicles than the restrained drivers, with the difference being greater for those who died or were admitted to hospital as a result of a crash (datasets (b) and (c)). The mean vehicle ages for restrained drivers versus unrestrained drivers were as follows: (a) 9.9 years versus 12.6 years, (b) 12.0 years versus 16.3 years, and (c) 11.9 years versus 15.5 years.

For the effectiveness estimates, a hypothetical scenario was assumed where seat belt interlocks were phased into all new vehicles between 2015 and 2020. It was assumed also that without the presence of seat belt interlocks, the vehicle age profiles for the unrestrained drivers would stay the same, as would the proportions of unrestrained drivers. Under these assumptions, by 2030 seat belt interlocks would be present for around 60% of all otherwise unrestrained drivers (based on the observational data), around 45% of otherwise unrestrained fatally injured drivers (based on Coroner's data) and around 40% of otherwise unrestrained drivers that would require hospital admission. Seat belt interlocks would approach 100% saturation in these three groups by around 2050.

Using the hospital admission and Coroner's datasets, a yearly effectiveness of seat belt interlocks was calculated, based on a 95% effectiveness for seat belt interlocks at enforcing seat belt use among otherwise unrestrained occupants, and a 50% effectiveness for seat belts in reducing fatal and serious injuries. Under these values and the assumptions listed above, by 2030 there would be a potential 2% reduction in injuries requiring hospital admission, and a 7% reduction in fatalities. By 2050 these values would approach 5% and 16% respectively. These reductions would apply on top of any casualty savings already made through enhanced vehicle technologies, infrastructure and regulations. The assumptions used to derive these figures give a 'strongest case' estimate for the use of seat belt interlocks. In reality the benefits may be smaller, as some benefit will be derived from seat belt reminder systems and an increased use of seat belts due to societal factors. Nevertheless, the low cost and complexity of introducing seat belt interlocks merits some encouragement, with some consideration given to after-market installation targeting users who are at high risk.

Contents

1 Background

Seat belt interlocks are a vehicle safety technology that is designed to raise levels of seat belt compliance. They allow a vehicle to be started only when the vehicle's occupants have fastened their seat belts. Some systems restrict the vehicle in other ways, for example by restricting the speed or only allowing the lowest gear to be used.

Many modern vehicles are equipped with seat belt reminders that activate visual and auditory warning signals if the vehicle is started when occupants are seated and have not fastened their seat belts. Seat belt reminders are required to obtain a five-star rating under the Australasian New Car Assessment Program (ANCAP). In vehicles with seat belt reminders, the additional cost of installing an interlock system is very low, as all that is needed is additional circuitry or onboard logic that links the seat belt reminder sensors to the ignition system.

Seat belt interlocks are rarely, if ever, found on modern vehicles in Australia. However, this technology rose to prominence in the USA roughly 40 years ago: in August 1973, a mandate was issued under federal law to have seat belt interlock systems installed in all model year 1974 vehicles sold in the US. The mandating of seat belt interlocks in the US was thought to be the next logical step from the 8-second 'buzzer light' reminder systems that had been made mandatory in the preceding year. However, the law was met with widespread public backlash and was repealed in the following year. Additionally, US Congress passed leglislation prohibiting the reintroduction of mandatory seat belt interlocks or mandatory seat belt reminders that last longer than 8 seconds (Committee for the Safety Belt Technology Study, 2004).

In hindsight, the backlash over the law might have been predictable, given that only 1 in 4 people wore a seat belt at the time (Robertson, 1975; Cohen and Brown, 1973). However, there was some reason for lawmakers to expect higher levels of acceptance. Perel and Ziegler (1971) conducted surveys on interlock systems, and of their respondents, 80% thought that interlocks were a good way to increase seat belt usage, and 70% said they would not object if new cars were required to be fitted with interlocks. Prior to the introduction of mandatory interlcoks, Cohen and Brown (1973) also demonstrated that a seat belt interlock system installed in rental cars increased seat belt usage from 23% to 56%, giving weight to the idea that the interlocks would be a success.

Indeed, aside from the issues of public disapproval, the mandatory interlocks were successful at encouraging greater seat belt usage. Robertson (1975) presented the results of an observational study of seat belt usage in US vehicles. For vehicles manufactured in 1972 without a 'buzzer light' seat belt reminder, 23% of drivers wore seat belts. In 1972 vehicles that had buzzer light reminders, selt belt usage was 25%. In 1973 the 8-second buzzer light reminders became mandatory for new vehicles and 28% of drivers in those vehicles were observed wearing their seat belts. In 1974 vehicles with the then mandatory seat belt interlocks, belt usage was dramatically higher at 59%. (One assumes that the remaining drivers bypassed the system in some way.) Put another way, the 1974 vehicles had roughly half as many unrestrained[1] occupants (41%) compared with the 1973 vehicles (72%).

While the results of the US 1974 experience are interesting from an historical standpoint, they are unlikely to bear relevance to the present situation. In 1970s USA, the majority of vehicle occupants did not wear a seat belt; seat belt use was perhaps not accepted as being necessarily safer (anecdotal evidence suggests that many people believed that being ejected from the vehicle was safer), and seat belt use was perhaps not a social norm. This is in constrast to present-day South Australia in which

[1] Although features such as airbags are also a form of restraint, in this report the terms 'restrained' and 'unrestrained' refer exclusively to seat belts being used or not used, and the word 'restraint' refers to seat belts.

the vast majority of vehicle occupants do wear a seat belt: the CASR observational study conducted in 2009 suggested seat belt usage of over 95%, despite much lower usage amongst fatally injured drivers (Wundersitz and Anderson, 2009).

There have been limited studies on the effectiveness of seat belt interlocks in more recent literature. Turbell et al. (1996) discussed various interlock options, including only allowing first gear to be used when unrestrained, or limiting speed to 30 km/h. The authors suggest that interlock systems that disable the vehicle from starting would be too aggressive. The authors give a benefit-cost ratio estimate of 100:1, based on a 50% effectiveness of converting fatalities to non-fatalities for vehicles equipped with an interlock. The paper also contained an attitude survey that showed divided results on the idea of interlocks, but positive results for reminder systems. Unsurprisingly, those who frequently went without wearing a seat belt were more likely to disapprove of interlocks.

Van Houten et al. (2005) performed a study of five delivery van drivers who frequently drove unrestrained. The vehicles were equipped with sensors to monitor whether or not the driver was wearing a seat belt while driving. A full interlock system was not used, but a gearshift delay was installed that prevented the drivers from shifting into gear for a short time period after starting the vehicle, if they did not fasten their seat belt. Prior to the study, the drivers had seat belt use rates of around 0-30% (based on visual observations at the gate of the delivery depot). When the seat belt monitoring equipment was installed (without any interlock) this rose to 10-50%, and when the gearshift delay was installed this rose to 80-95%. Thus, even using a relatively non-aggressive form of interlock, the rate of seat belt use was dramatically increased. Some caution is needed interpreting these results due to the small sample size and the potential that the participants were more likely to wear their seat belt because they knew they were being monitored.

We can also turn to literature on seat belt reminders to give some indication of the potential effectiveness of seat belt interlocks (keeping in mind that for future vehicle models, interlocks would be likely to be installed on top of existing reminder systems).

The Committee for the Safety Belt Technology Study (2004) produced a report on technologies that might help increase seat belt usage. In 2002, seat belt usage in the US was at around 75%, so there was still a significant proportion of the population that were travelling unrestrained. The focus of this report was on reminder systems, and the recommendations of the study include allowing NHTSA to introduce mandatory seat belt reminder chimes that last longer than 8 seconds. This recommendation is supported by an IIHS (2012) study that found higher rates of belt usage with a longer 90-second reminders (as per the Euro NCAP protocol). Regarding interlocks, the Committee for the Safety Belt Technology Study (2004) report recommends the development of interlock systems to target particular applications, including motorists with poor driving offence records, teenage drivers and company fleets. A survey of drivers in this report gives a similar result to Turbell et al. (1996), with divided results on the acceptability of interlocks, and with seat belt non-users less likely to approve. The report notes that the “pace and type of technology introduction continue to be affected by the interlock experience” (referring to the 1974 mandatory interlock law).

Lie et al. (2008) conducted an observational study of seat belt usage in cars equipped with and without seat belt reminders. The study was conducted in seven countries and a total of 10,237 cars were observed. The presence of a reminder was determined by the vehicle model, and only a specific list of models with a known reminder installation status were included. The maximum age of any vehicles that in the “with seat belt reminder” group was 5 years, and the vehicle models “without seat belt reminders” were generally older. Overall, the level of seat belt usage was 86% in cars without reminders, and 98% in cars with reminders. This suggests a very strong positive effect of seat belt reminder systems. France had the highest level of belt usage (observations conducted in Paris), with a seat belt usage rate of 96.9% in cars without reminders, and 99.8% in cars with reminders.

In a previous CASR report, Anderson et al. (2011) examined the potential benefits of seat belt interlock systems using crash data from New South Wales. They found that the estimated benefit-cost ratio was 1.6 for passenger cars equipped with interlocks, and 3.3 for trucks equipped with interlocks. This was based on a 50% reduction in the probability of being killed for drivers wearing a seat belt, and 28% reduction in the probability of being injured. Slightly lower reductions were used for rear seat occupants. The interlocks were assumed to be 100% effective at convincing otherwise unrestrained occupants to wear their seat belt. The authors noted the inconsistency between seat belt usage in observational studies and seat belt usage in fatal crashes, and suggest that understanding this inconsistency might be key to estimating the effectiveness of seat belt interlock systems.

This inconsistency was examined in another recent CASR report by Raftery and Wundersitz (2011). The findings of this report suggested that unrestrained occupants were likely to be engaging in other risky behaviours that would boost their chances of being involved in a crash. Additionally, the report notes that the most recent observational study of seat belt use in South Australia (Wundersitz and Anderson, 2009) was not conducted at the same times and places that fatal crashes are likely to occur.

At the very least, an estimate of the effectiveness of seat belt interlocks requires knowledge of (a) the effectiveness of seat belts at reducing the severity of injury in a given crash, (b) the proportion of casualties that are not wearing seat belts at present, and (c) the proportion of the those casualties that would have been likely to use a seat belt in the presence of an interlock. For (a), it would seem that 50% is generally accepted as the effectiveness of seat belts in preventing fatalities. For (b), such information can be obtained from routinely recorded police data, hospital records, or Coroner's data. For (c), little information exists, but the results of Van Houten et al. (2005) and Lie et al. (2008) suggest that interlocks could potentially lead to very high levels of seat belt use (80-99%).

In estimating the benefits of any new vehicle technology, it is also necessary to account for the time taken for new vehicles to filter into the fleet and be driven by those who need to be exposed to that technology. The relatively high age of the vehicle fleet in South Australia generally means that new vehicle technologies will take some time to filter through, but seat belt interlocks would take even longer again to filter through to those who need to be exposed to them: Raftery and Wundersitz (2011) found that unrestrained occupants in fatal crashes in South Australia were more likely to be travelling in older vehicles (mean vehicle age of 14 years, compared with 11.4 years for restrained occupants).

The finding of Raftery and Wundersitz (2011) in relationship to vehicle age and belt usage may be confounded by the fact that non-belt wearing is associated with a higher fatality risk, as is driving an older vehicle. As such, it is also of interest to examine the ages of vehicles containing unrestrained occupants in the general fleet, and also for unrestrained drivers involved in less serious crashes.

In this report, three data sources are examined to compare vehicle age with belt usage: observational study data from 2009, hospital admission data from 2008-2010, and Coroner's data from 2008. Consultation of these data sources allows us to build a picture of the age of vehicles being used by unrestrained occupants, which gives us an idea of the short term and long term potential benefits of introducing such a technology into the vehicle fleet.

2 Method

Three sources of data were compiled that linked seat belt use and vehicle age. A hypothetical scenario was considered, where interlocks were made mandatory in new vehicle models from 2015. From the vehicle age profiles it was then possible to estimate a yearly profile of interlock prevalence amongst those drivers that would otherwise be unrestrained, and this was used to construct a 'strongest case' estimate for the reduction in fatalities and serious injuries as a result of mandatory seat belt interlocks.

2.1 Data sources

Three data sources were used: observational seat belt use data from 2009, hospital admissions data from 2008-2010, and Coroner's data from 2008.

Seat belt use data from police reports was not considered for this study, due to the relatively low reliability of those records. Coroner's data was considered more accurate for fatal crashes. For non-fatal crashes requiring hospital admission, hospital records were considered to be more accurate as seat belt use had been recorded by ambulance officers in order to ensure an accurate injury diagnosis.

For the hospital admission data, only information on vehicle drivers was available. This was because the information had been previously collected for a study on human factors in crash causation, and thus 'non-active' crash participants (e.g. vehicle passengers) had been excluded. For consistency, the observational data and the Coroner's data were also limited to drivers of vehicles, and this also meant that each vehicle would only be counted once for each crash in the data.

The data were also limited to drivers of cars and car derivatives (including passenger cars, SUVs, station wagons, utilties and vans). Trucks and other heavy vehicles were not recorded in the observational study data, and were excluded from the hospital admission and Coroner's data for this study.

2.1.1 Observational study

The CASR observational study was conducted in March 2009, in rural and metropolitan South Australia during the daytime. Observers stood at selected intersections and recorded the seat belt use of vehicle occupants by seating position, age and sex. The full details of the study can be found in the report by Wundersitz and Anderson (2009).

The complete dataset from the observational study consisted of 16,890 observations of occupant seat belt use, occupying 10,954 vehicles. Of those, 16,304 occupants were wearing a seat belt, 353 were not and so the overall seat belt use in the study was 97.9%. The remainder had an unknown seat belt use status due to difficulty in observation.

For each vehicle in the study, the number plate was recorded by the observers. The initial intent of recording number plates was to ensure that the same vehicle did not get counted more than once at each survey location. The number plate recordings were used in the present study to look up registration data associated with each vehicle, including the vehicles' year of manufacture. This was obtained from the South Australian Department of Planning, Transport and Infrastructure, with the data backdated to March 2009 to include number plates that have since been retired, and to eliminate errors caused by number plates that may have been reassigned to new vehicles.

When the observational data were limited to drivers only, in vehicles that could be matched to registration data, there were a total of 10,848 records remaining. Of those 10,625 were wearing a seat belt and 201 were not wearing a seat belt, the remainder had an unknown seat belt use status. This gives an overall seat belt usage of 98.1% for the drivers with a known vehicle age and seat belt use. This was consistent with the rate for all observations in the study.

2.1.2 Hospital admissions

Hospital admission data were previously collected by CASR as part of a study on medical conditions and crash causation (Lindsay and Ryan, 2011). The database compiled for that study contains details of every active crash participant admitted to the Royal Adelaide Hospital (RAH) as a result of a crash on a public roadway in South Australia between 1/1/2008 and 31/12/2010. An 'active' participant was one who had some level of control over the accident occurring, including vehicle drivers, pedestrians, pedal cyclists and motorcycle riders. Hospital admission data were not collected for non-driver passengers of vehicles. Any hospital stay of over 4 hours qualified as admission. Patients who were admitted to hospital and later died as a result of their injuries were included in the original dataset, but for the purposes of the present study, these records were not included.

The resulting dataset contains records for 811 drivers of cars or car derivatives who were admitted to the RAH (the remainder were pedestrians, truck drivers, motorcycle riders, or pedal cyclists). Of those, 599 had a known seat belt use status and of those, 69 were not wearing a seat belt. Seat belt use was generally recorded by ambulance personnel or had been determined by medical staff. Given these values, seat belt usage amongst these drivers was 88.5%.

For each driver, vehicle information was obtained using the Traffic Accident Reporting System (TARS). TARS contains police recorded information on vehicle crashes that result in medical treatment, or property damage of $3000 and over. Part of the information recorded is the vehicles' year of manufacture. The TARS records for each vehicle were matched by the number plate recorded in the hospital admission data, and by the date of the crash.

After matching to TARS records, there were a total of 702 drivers with a known vehicle age (the remainder could not be matched to a TARS record or had an unknown vehicle year). Of those, 470 were recorded as restrained, 56 unrestrained, and the remainder had an unknown seat belt use. This gave a seat belt usage of 89.4% for the drivers with a known vehicle age and seat belt use status, which was slightly higher than the overall rate.

2.1.3 Coroner's reports

Data obtained from Coroner's files were also used. The Coroner's database consisted of South Australian fatal crash participants from 2008. Records existed for 217 people involved in 90 fatal crashes (crashes in which at least one person died as a result of the accident). Vehicle age was recorded in the database.

Of all the car occupants in the dataset for whom seat belt use was known, 74 were wearing a seat belt, 38 were not. This gives an overall seat belt usage of 66%. Additionally, 5 occupants were classed as "probably not" wearing a seat belt, and 18 and "probably yes" to wearing a seat belt. Taking these numbers into account gives a seat belt usage of 68%.

For this study, the records were limited to drivers, and to those who died as a result of the crash. This left 14 unrestrained drivers, and 27 restrained drivers, for a seat belt usage of 65.9%. There was 1 driver with an unknown seat belt use. There were also 2 drivers recorded as "probably yes" to wearing a seat belt, and 1 driver as "probably not". Taking this into account gives the same seat belt usage of 65.9%. This was consistent with overall seat belt usage in the dataset.

2.1.4 Summary of datasets

The datasets are summarised in Table 2.1, by the number of drivers in each set with a known vehicle age, the number of those that were known to be restrained, and the number of those that were known to be unrestrained. Note that the "known restrained" and "known unrestrained" columns do not sum to the total, as in each case there were some drivers with an unknown restraint use.

The final "restraint use" column is calculated from the drivers with a known restraint use only.

Table 2.1
Summary of restraint use datasets

Dataset	Injury severity	Number of drivers with known vehicle age	Known restrained	Known unrestrained	Restraint use
Observational study (2009)	-	10,848	10,625	201	98.1%
Hospital admissions (2008-2010)	Hospital admission	702	470	56	89.4%
Coroner's data (2008)	Fatal	45	27	14	65.9%

2.2 Effectiveness estimate

The vehicle age profiles determined by the three data sources were used to estimate the potential future effectiveness of seat belt interlocks on a yearly basis. The effectiveness estimate was a marginal effectiveness – that is, it was a percentage injury reduction that would happen on top of any other injury reductions that might be obtained through other vehicle technologies and improved roads and driving laws.

The first step was to determine the time it would take for seat belt interlocks to penetrate the fleet such that typically unrestrained drivers would be driving interlock equipped vehicles. It was assumed that the vehicle age profile for unrestrained drivers would remain constant with time without any intervention from interlocks. The vehicle age profiles were taken from each dataset, and a Weibull statistical distribution was fitted to each.

A hypothetical interlock introduction rate was also assumed. The hypothetical introduction rate was based on interlocks becoming mandatory on new vehicle models from 2015 onwards. Assuming a five-year model turnaround, it was assumed that all new vehicles would have interlocks installed by 2020, with a linear rate of introduction between 2015 and 2020.

Using these two assumptions, for each future year it was possible to estimate the proportion of vehicle drivers that would otherwise be unrestrained, who would then be in vehicles equipped with interlocks.

The second step was to link the presence of interlocks to a reduction in injury occurence. For this step, only the Coroner's and hospital admission data were used, as they were representative of fatally and seriously injured drivers. It was assumed that without any intervention from seat belt interlocks, the proportion of unrestrained drivers in each dataset would remain constant with time.

Two effectiveness values were assumed:

1. The seat belt interlock effectiveness was assumed to be 95%. That is, of those drivers who would otherwise be unrestrained, 95% would wear a seat belt in the presence of a seat belt interlock. (The remaining 5% would find some way to circumvent the interlock or would

remove their belt after starting the vehicle.) This assumption is speculative, but inline with the results reported by Van Houten et al. (2005).

2. The injury reduction effectiveness of the seat belt was assumed to be 50% for both datasets. Elvik et al. (2009, p. 603) reviewed many reports of seat belt effectiveness, and suggest an effectiveness of around 50% for fatal injuries, and close to this for serious injuries. Since the Coroner's data correponds to fatal injuries, and the hospital admission data to injuries that were generally 'serious', this estimate seems reasonable. Turbell et al. (1996) and Anderson et al. (2011) also used an injury reduction effectiveness of 50%. Elvik et al. suggest lower levels of effectiveness for minor injuries in front seat passengers (20-25%) and for rear seat occupants at all levels of injury (20-25%). Thus, if these effectiveness estimates were extended to rear seat passengers, they should be reduced by half. Note also that the hospital admission criteria of a 4 hour stay means that some casualties in the hospital admission data set might fit the definition of a 'minor' injury rather than a 'serious' injury in these effectiveness estimates.

In each future year, the potential reduction in injury was calculated by the following:

$$\text{Percentage injury reduction} = I \times P \times E(\text{interlock}) \times E(\text{seat belt}) \times 100\% \quad (1)$$

The value of *I* was the proportion of otherwise unrestrained drivers that would be in interlock equipped vehicles. This was calculated for each future year in the first step described above. For example, if this value were 30% for a certain year, then we could say that of all the vehicle occupants that would otherwise be travelling unrestrained in that year, 30% would be in vehicles that have seat belt interlocks installed.

The value of *P* was the proportion of all vehicle drivers that travel unrestrained. This was based on the value obtained from the revelant dataset – i.e. the right-most column in Table 2.1.

The values of *E(interlock)* and *E(seat belt)* were the assumed effectiveness values described above, and were 0.95 and 0.50, respectively.

Thus, for each future year, a percentage reduction in injuries was calculated due to the effect of mandatory seat belt interlocks.

3 Results

3.1 Vehicle age distributions by seat belt use

Table 3.1 lists the mean vehicle age for all drivers, restrained drivers and unrestrained drivers in each dataset. The median vehicle ages are listed in Table 3.2. On average:

- In all datasets the unrestrained drivers were in older vehicles than the restrained drivers.
- The drivers in the observational study were in newer vehicles than those in the hospital admission or Coroner's data.

The results suggest that for drivers being seriously injured or killed while unrestrained, around half are driving vehicles that are at least 15 years old. This implies that if interlocks were introduced in all new vehicles, it may take at least 15 years for half of the otherwise unrestrained drivers involved in accidents to be driving vehicles with interlocks.

The distribution of vehicle ages for each dataset are shown in Figure 3.1, Figure 3.2 and Figure 3.3. These plots again illustrate the difference in vehicle ages between those who are wearing seat belts and those who are not.

Figure 3.4 illustrates seat belt use by age of vehicle. Due to the limited data for older vehicles, the data were grouped into increments of 5 years up until 20 years old, then in two 10 year increments to 40 years old. The Coroner's data did not include any vehicles in the 30-40 age group.

This plot indicates that seat belt non-usage increased with vehicle age in all three datasets. The Coroner's data consistently has the highest level of non-use, followed by the hospital admissions, then the observational study. This is expected – if lack of seat belt use leads to a higher chance of serious injury or death, then we would expect to see higher levels of non-usage in these datasets. In vehicles aged over 20 years old, over half of the drivers in the Coroner's data were not wearing seat belts.

Table 3.1
Mean vehicle age by seat belt use in each dataset

	Mean vehicle age		
Dataset	All drivers	Restrained drivers	Unrestrained drivers
Observational study (2009)	9.99	9.94	12.62
Hospital admissions (2008-2010)	12.66	12.05	16.32
Coroner's data (2008)	13.09	11.93	15.50

Table 3.2
Median vehicle age by seat belt use in each dataset

	Median vehicle age		
Dataset	All drivers	Restrained drivers	Unrestrained drivers
Observational study (2009)	9	9	11
Hospital admissions (2008-2010)	12	11	15.5
Coroner's data (2008)	11	10	16

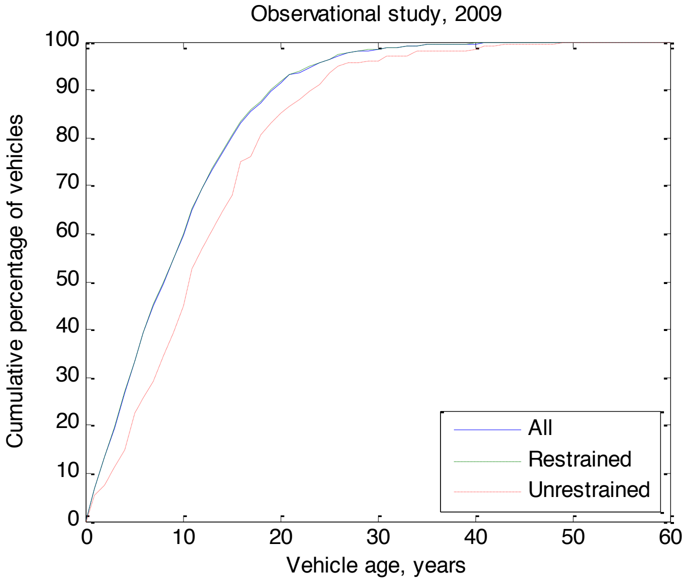

Figure 3.1
Cumulative distributions of vehicle age by driver seat belt use for the observational study data
(Note that the line for ‘restrained’ lies on top of the line for ‘all’)

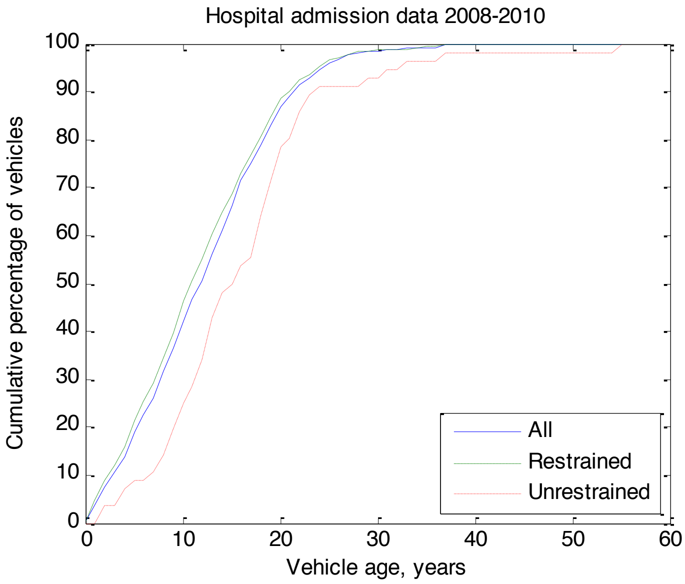

Figure 3.2
Cumulative distributions of vehicle age by driver seat belt use for hospital admission data

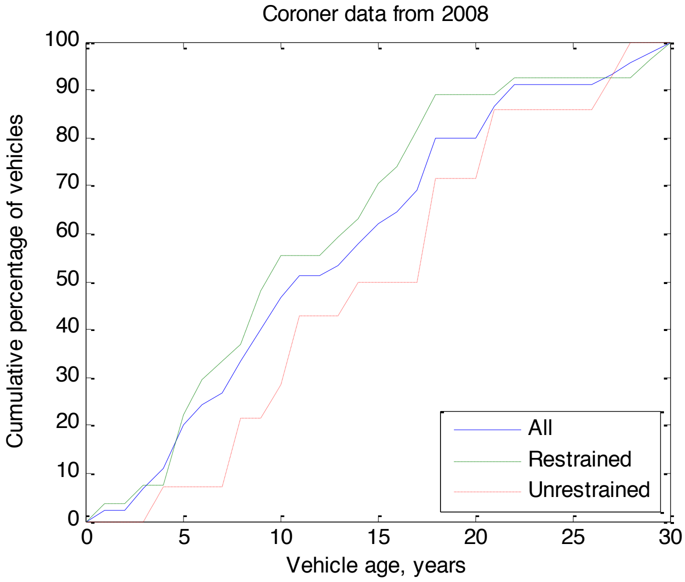

Figure 3.3
Cumulative distributions of vehicle age by driver seat belt use for Coroner's data

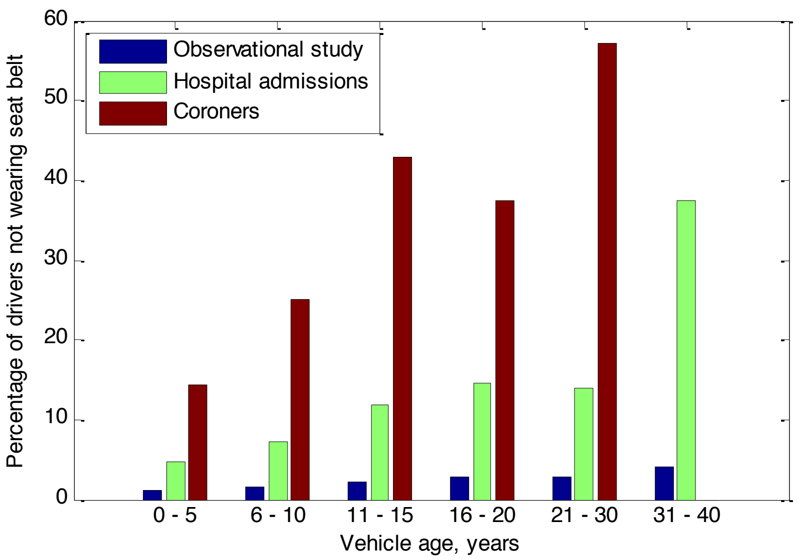

Figure 3.4
Seat belt non-usage by vehicle age for each dataset

3.2 Effectiveness estimates for seat belt interlocks

For this effectiveness estimate, we assumed that without any intervention from seat belt interlocks, the proportion of unrestrained drivers in each dataset would remain the same, and that the unrestrained drivers would be driving vehicles of a similar age profile from year-to-year.

We have assumed a linear rate of introduction of seat belt interlocks from 2015 to 2020. Figure 3.5 shows the percentage of drivers that would otherwise be unrestrained, who would be driving interlock equipped vehicles in each year. This is split by dataset. Thus, the line corresponding to the Coroner's data implies that by 2030, approximately 45% of fatally injured drivers that would have otherwise been driving unrestrained would be in interlock equipped vehicles. The introduction of interlocks is most rapid for the unrestrained 'general population' (based on observational study data), due to this population being in the newest vehicles. This is followed by the population of unrestrained occupants implied by the Coroner's data, and then the population of unrestrained occupants implied by the hospital admission data. For all three populations, 95% interlock usage is achieved by 2045. In the nearer future, we see that by 2025 we would expect 33% of the general unrestrained population in interlock equipped vehicles, and 20% and 15% for the Coroner's data and hospital admission data, respectively.

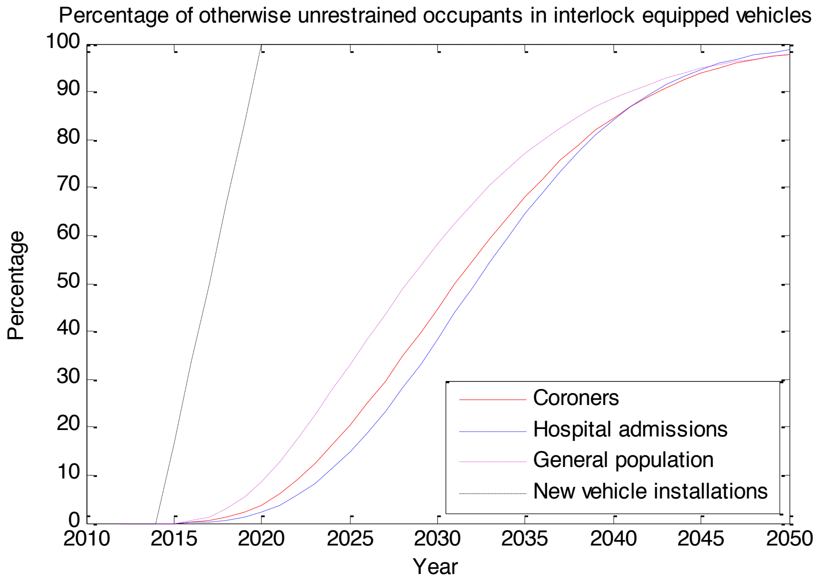

Figure 3.5
Percentage of otherwise unrestrained drivers who would be in interlock equipped vehicles, given a linear introduction of interlocks installations in new vehicles from 2015-2020

Equation (1) was used to calculate the potential casualty reduction each year due to introduction of seat belt interlocks, for the Coroner's data and hospital admission data. This is shown in Figure 3.6. The Coroner's data implies a reduction in fatalities, and the hospital admission data implies a reduction in casualties with injuries requiring hospital admission.

Figure 3.6 implies that by 2050, the presence of seat belt interlocks would reduce fatalities by around 16% and casualties requiring hospital admission by 5%. At this point the otherwise unrestrained population is almost entirely driving vehicles equipped with interlocks (see Figure 3.5), and so the percentage reduction in casualties is driven by the proportion of the population driving unrestrained (around 34% for fatalities and 11% for hospital admissions), multiplied by the assumed effectiveness values of 95% and 50%.

It is important to note that Figure 3.6 gives a percentage reduction in the casualties that would have occurred in those years without the presence of interlocks, but that the number of casualties is likely to decrease even without the presence of interlocks due to the effects of other technologies, infrastructure and regulations. Thus, if the non-interlock road toll in 2050 were 50 fatalities, then the presence of interlocks would reduce this by 8 (under the assumptions used to construct this graph). In 2035, if the non-interlock road toll was 75, then the 11% fatality reduction implied by the graph would also reduce the road toll by 8. While these are contrived numbers, it illustrates that the absolute benefit of the presence of interlocks is dependent on other factors that have not been quantified here.

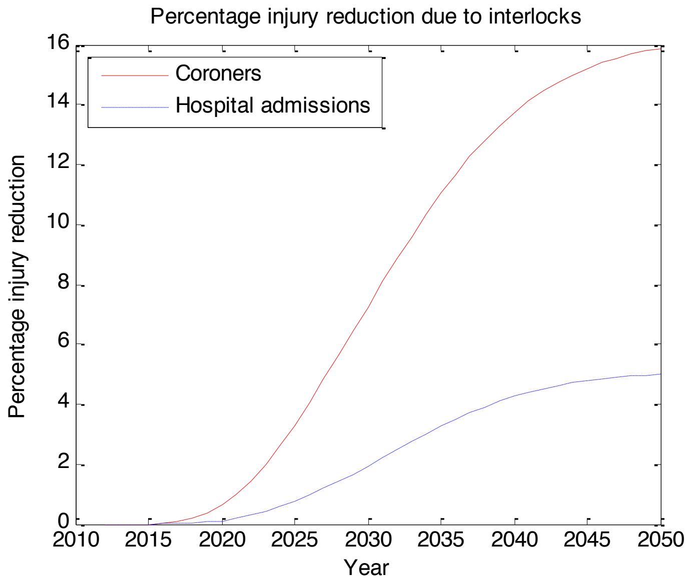

Figure 3.6
Potential injury reductions per year given a linear introduction of interlock installations in new vehicles from 2015-2020

4 Discussion

Seat belt interlocks have not received a lot of attention in recent literature and the US 1970s experience remains the only large scale deployment of this technology. The results of that experience are interesting from an historical standpoint, but do not give an indication of what might occur if interlocks were made mandatory in the current setting, as restraint use was much lower in the USA in 1973 (around 25%).

In present day South Australia, seat belt use is very high (around 97% according to observational study data from 2009), but unrestrained occupants are overrepresented in crashes, particularly those that are fatal. Seat belt use amongst fatally injured vehicle drivers was just 65% for the Coroner's data used in this study. This is expected to some degree as unrestrained occupants are more likely to be injured or killed. However, even assuming a fatality odds ratio of 4 for unrestrained occupants, Wundersitz and Anderson (2009) show that a seat belt use of 97% would imply 89% seat belt use in fatal occupants. For seat belt use to be 65% for fatal crash occupants, and with an odds ratio of 4, we would expect to see a seat belt use of around 88% in the general population, if all other things were equal.

A previous CASR report by Raftery and Wundersitz (2011) discussed this discrepancy, and the findings of that report suggest that unrestrained fatal crash victims are more likely to be engaging in other risky behaviours, or to be part of at-risk segments of the population. Thus, even if seat belt use is very high in the general population, in the segment of the population that are involved in fatal crashes, the level of seat belt use is much lower and so seat belt interlocks could potentially have a meaningful effect.

The results of this study show that unrestrained occupants are generally found in older vehicles, particularly those that are involved in crashes, but also those in the general population. This has also been found in other studies of seat belt use and vehicle age (McCartt and Northrup, 2004; Preusser et al. 1991).

The presence of seat belt reminders in newer vehicles may be having an effect on the distribution of vehicle ages amongst unrestrained drivers. Lie et al. (2008) suggest a strong effect of seat belt reminders on restraint use. If newer cars are more likely to have reminder systems, then we would expect to see less occupants of newer vehicles travelling unrestrained, shifting the vehicle age distribution for unrestrained drivers towards older vehicles.

For this study, we essentially assumed a 'strongest case' scenario – in other words, assumptions were made that would give the strongest case for seat belt interlocks. It was assumed that seat belt interlocks would be the only factor that would affect future seat belt use (in reality, the increased prevalence of reminder systems and other factors would most likely continue to increase overall seat belt use). It was also assumed that the vehicle age profile of unrestrained drivers would not change over time, without the presence of interlocks (in reality, the vehicle age profile may indeed become older, as newer vehicles with reminder systems penetrate the fleet). A fairly rapid introduction of interlocks was assumed, beginning in 2015 and reaching 100% installation in new vehicles by the end of 2020. This was on the basis of a five-year design cycle for new vehicle models.

Under this 'strongest case' scenario, we see that it takes until 2050 for the unrestrained driver populations to approach 100% interlock installations, with a 16% reduction in fatalities and 5% reduction in hospital admitted casualties. Since it is difficult to predict with accuracy everything that will be happening in 40 years time, it is perhaps more realistic to examine the graph for the nearer future. We see that in 2030 (10 years after all new vehicles would come with interlocks installed under this hypothetical scenario), there is a potential 7% reduction in fatalities and 2% reduction in casualties requiring hospital admission.

Realistically these numbers would be lower, as overall seat belt use will probably increase with time regardless, due to the increased presence of seat belt reminder systems in the vehicle fleet and other societal factors. This decreases the benefit available from seat belt interlocks alone, but will also mean that the vehicle age profile for unrestrained drivers will shift to being even older.

The greatest advantage to seat belt interlocks is the small, almost negligible cost of their inclusion in new vehicles. Due to seat belt reminder systems becoming very common, most new vehicles are already equipped with sensors to detect the presence of occupants in each seating position, and whether or not each seat belt is fastened. In this case, the installation of an interlock simply requires linking these sensor measurements to prevention of the vehicle from starting. Under these circumstances, it is reasonable to argue that benefits will easily outweigh the costs and the 'inconvenience' to a very small minority of drivers who currently drive unrestrained (in contradiction to the road rules).

The results in this paper demonstrate that even if a technology promises strong benefits, it may take a long time for vehicles equipped with that technology to pass through the fleet and affect those who need to be exposed to it. This is particularly the case when the people who need to be exposed to the technology are driving older vehicles than the general population. This is the case for seat belt interlocks – a large proportion of crash victims are travelling unrestrained, so there is a large benefit available if technology can be used to enforce seat belt use in this population. However, because that unrestrained population are in older vehicles, the technology would take a long time to filter through.

Nevertheless, due to the low cost of including seat belt interlocks, their introduction should be encouraged. Other means of 'fast-tracking' seat belt interlocks to those who are at high risk could also be considered, as after-market installation remains an option, albeit a more costly option.

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