Working paper

Insurance influence on road-safety

Dr Richard Tooth

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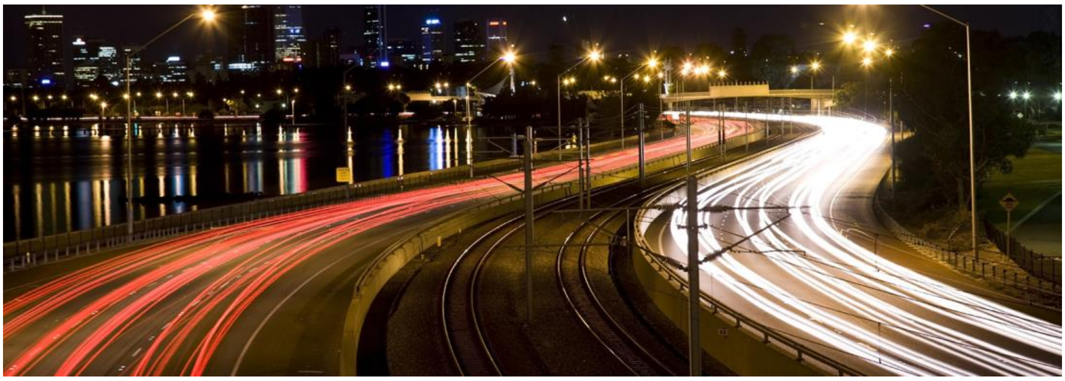

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Glossary

ABI	Association of British Insurers (UK)
ACC	Adaptive cruise control
ADAS	Advanced driver assistance systems
AEB	Autonomous emergency braking
Baseline	The scenario involving no change to insurance regulation
BI	Bodily injury (including fatalities, serious and minor injuries)
BIL	Bodily injury liability — a type of insurance cover in the US
BIBA	British Insurance Brokers Association (UK)
CTP	Compulsory third party
ESC	Electronic stability control
FCAT	Forward-collision avoidance technology
FOT	Field operational test
FCW	Forward collision warning
HDW	Headway monitoring and warning
HLDI	Highway Loss Data Institute
IIHS	Insurance Institute for Highway Safety (US)
ISA	Intelligent speed assistance
LCV	Light commercial vehicle
LDP	Lane departure prevention
LDW	Lane departure warning
MAIC	Motor Accidents Insurance Commission (Queensland)
NSW	New South Wales
Optimal-Scenario	Another name for Scenario 2
PAYD	Pay as you drive
PCW	Pedestrian collision warning

PHYD	Pay how you drive
Risk-based premiums	Insurance premiums are priced based on the risk of the individual policyholder
Scenario 1	A scenario considered in the report whereby, similar to the UK (and other jurisdictions), a single insurance policy covers both vehicle damage and bodily injury claims and premiums are risk-based. Also referred to as the UK-Scenario
Scenario 2	An extension of the UK-Scenario whereby insures have societally optimal incentives for safety. Also referred to as the Optimal-Scenario
Societal value	Refers to the benefit to society. In the context of this report, this refers to the WTP of the community to prevent road-crashes
SUV	Sports utility vehicle
UBI	Usage based insurance
UK	United Kingdom
"UK-Scenario"	Another name for Scenario 1
US	United States of America
WTP	Willingness to pay

Executive summary

Introduction

Despite the adoption of a safe-systems strategy and substantial improvements in road-safety in the past decade, road-crashes continue to be a major public-health issue. Technology advances, such as autonomous vehicles, are not expected to address the problem for some decades. Improved infrastructure may also help but involves substantial investment.

This paper considers an approach involving the insurance sector to achieve a greater benefit at lower cost. Insurers can influence road-safety outcomes in a number of ways. However, the current regulatory environment limits insurers' incentives and flexibility to address road safety.

A common issue around the world is that insurer incentives are less than optimal because the insurers' liability for crashes that cause fatalities and injury is much less than the value of prevention. In Australia and New Zealand insurers' incentives and flexibility to manage risk are further limited due to CTP (compulsory third party) scheme regulations which separate liability for bodily injury (BI) claims from property damage claims and limit the extent to which premiums are risk-based (i.e. aligned to individual risk of a road-crash).

Reform and implications

This paper considers reforms to improve insurer incentives and flexibility to manage road-safety based on two scenarios.

- Scenario 1 (the "UK-Scenario") whereby (as in the UK and other jurisdictions) insurers have liability for both BI and property damage claims and can price premiums based on individual risk, and
- Scenario 2 (the "Optimal-Scenario") whereby insurers also have the societally optimal incentives for safety.

Adopting the UK-Scenario would roughly double the extent to which premiums covering road-crashes are risk-based and quadruple a vehicle insurer's incentive to prevent road-crashes that cause injuries and fatalities. Furthermore it would significantly increase incentives to avoid crashes among high-risk groups. Adopting the Optimal-Scenario (which is without precedent around the world) would increase incentives again by a factor of two to three. In total under this scenario there would be roughly a ten-fold increase in the incentive to prevent road-crashes that cause BI.

Under both scenarios insurance premiums would be more risk-based and encourage insurers to offer financial incentives for safer choices and behaviour. Empirical evidence (based on variation in regulations across jurisdictions) and expert opinion provide strong support for risk-based insurance premiums over the status quo. Due primarily to improvements in technology the significance of the benefit appears to be increasing.

The potential safety benefits are examined in terms of whether, what and how people drive.

1. Whether to drive

Each additional driver contributes to the risk of road-crashes and some (particularly the young and very old) contribute substantially more to this risk. Risk-based insurance premiums would provide greater incentives for the high-risks to opt for other forms of transportation.

2. What to drive

Vehicle choice can improve safety by reducing the likelihood and severity of crashes. Historically, much of the improvement in vehicle safety has come from passive safety features (e.g. air-bags). Going forward much of the interest is in advanced driver assistance systems (ADAS), including warning systems (potentially installed after-market) and autonomous systems (installed at time of manufacture). Existing evidence suggests these ADAS can reduce fatalities caused by motor-vehicles by up to 50 per cent (autonomous systems) and 30 per cent (for warning systems).

With the appropriate incentives, insurers would encourage people to drive safer vehicles, install safety devices and use autonomous vehicles (when they become available). Furthermore, the encouragement would be aligned to individual risk. For example, insurers in the UK give drivers premium discounts for vehicles with autonomous emergency braking installed and give much larger discounts to young drivers.

3. How and when to drive

Insurers influence driver behaviour, primarily through financial incentives that include deductibles on claims and premium discounts for a safe driving record. Insurers are now able to use telematics-enabled usage based insurance (UBI) policies whereby they monitor and reward safe driving behaviour.

In international jurisdictions with favourable regulation, UBI is growing rapidly and is commonly used by young drivers. Existing evidence suggest UBI is used to reduce crash-risk by 20 per cent and more (up to 40 per cent) in high-risk drivers.

The potential impact of the reforms

Quantifying the potential impact of the reforms in terms of safety is challenging, in particular due to the wide-reaching implications and uncertainty over the penetration and effectiveness of emerging technologies.

Nevertheless, this paper includes some indicative estimates of benefits of the key effects. The results for a seemingly plausible set of assumptions, is summarised in Figure S1 overleaf. The modelling estimates the reforms would, within 10 years, lead to additional reductions in the aggregate annual road-toll (i.e. reductions relative to the baseline case) of around 80+ fatalities in the UK-Scenario and of 300+ fatalities in the Optimal-Scenario. The cumulative additional reduction in fatalities in the next 20 years (to 2037) is in excess of 1,300 in the UK-Scenario and 5,000 in the Optimal-Scenario. In the Optimal-Scenario, the benefit is valued at around $6 billion per-annum and around $100 billion over the 20-year period to 2037.

The results are, of course, sensitive to the assumptions. However, there does not appear to be any plausible set of assumptions under which the benefits to the alternative scenarios are not significant.

There would be other benefits to the changes, most notably reductions in congestion and environmental costs due to reduced motor vehicle use. The main ongoing additional costs will relate to insurers investments in monitoring and regulating policyholders. The equity implications will depend on how the reforms are implemented.

Next steps

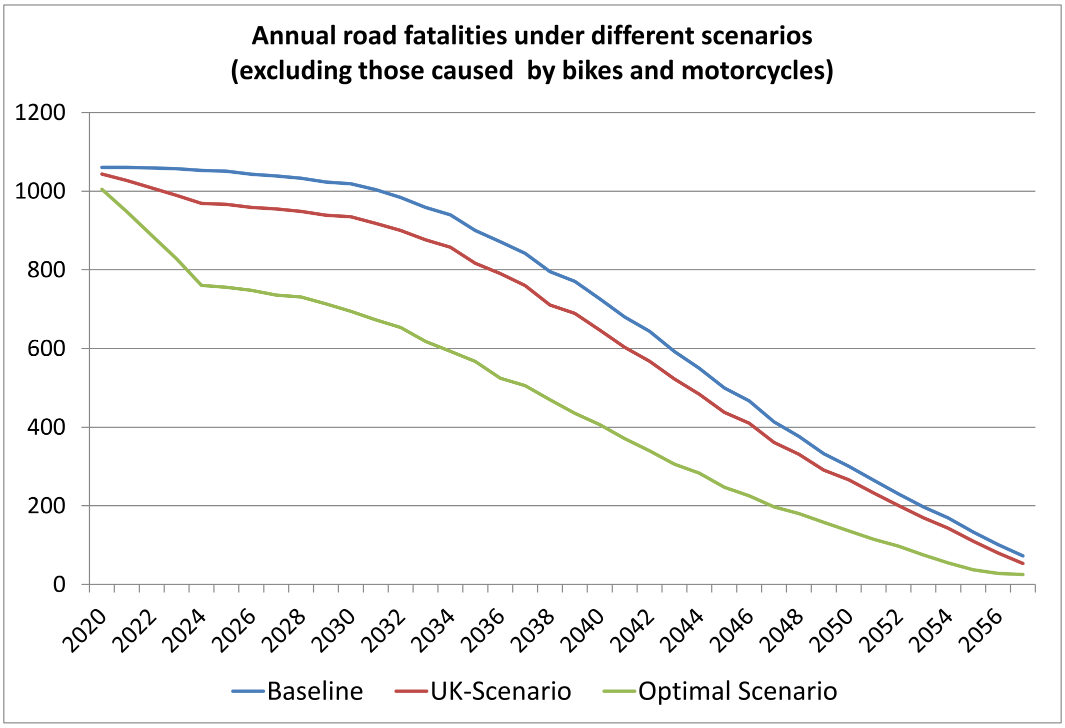
Despite the potential significance, there has been minimal investigation of insurance reform to improve road-safety. Consequently there are many research gaps.

Given the potential significance, the case for further investigation appears overwhelming. Research priorities relate to:

- the case for change; that is, further analysis of the costs and benefits of implementing the scenarios
- policy design; how the policy would be implemented, and
- policy implementation; the road-map to implementation.

Due to the wide-reaching implications there will be a large number of stakeholders to consider. Stakeholder consultation and engagement is likely to be important for gathering data, getting input on issues and ensuring the reforms are appropriately considered.

Figure S1: Projected road-fatalities by scenario



1. The baseline includes reductions in fatalities due to the penetration of AEB and autonomous vehicles.
2. See Section 6 for assumptions and further detail.

1. Introduction and overview

Despite substantial improvements in road-safety in the past decade, road-crashes continue to be a major public-health issue. In Australia and New Zealand over 1500 people die on the roads each year and tens of thousands are seriously injured. Autonomous vehicles may address the road-safety problem; however, even under aggressive growth forecasts it will be another 30 years before autonomous vehicles dominate the vehicle fleet.

This paper examines the opportunity for reforms to the insurance sector to complement efforts to encourage safer road-use. The broad rationale for insurance sector reform for addressing road-safety is that:

- insurers can influence most aspects of road-use relating to whether, what and how people drive, but
- the current regulatory environment limits insurers' incentives and flexibility to address road safety.

The paper describes insurance reforms, benefits and implications. It also provides indicative estimates of the safety benefits. It is, however, a brief scoping paper and not a comprehensive review. In this regard it:

- discusses benefits and issues but does not examine them in detail
- provides estimates that are purely indicative
- has not involved consultation with stakeholders, and
- does not consider in any detail how reforms would be introduced.

The rest of the paper is organised as follows:

- The following section (section 2) provides a background as to the current regulatory environment and possible reforms.
- Sections 3 to 5 discuss the implications of reform relating to decisions regarding
  - whether to drive
  - what to drive, and
  - how people drive.
- Section 6 provides an indicative estimate of the benefits.
- Section 7 concludes and covers next steps.

2. Insurance sector and road-safety

2.1 The current environment

Incentives for insurers to prevent road crashes come (primarily) from their liability to pay for insurance claims related to road-crashes.[1]

This incentive is less than the social optimum for two reasons. First, in Australia and New Zealand (NZ) cover for the bodily injury (BI) claims (i.e. costs associated with injuries and fatalities such as medical costs, loss of earnings etc.) is unbundled from motor vehicle insurance that covers property damage (e.g. damage to vehicles). Vehicle insurance is provided by competing insurers. BI claims are managed through insurance schemes (commonly known as compulsory third party (CTP) insurance).[2]

A related issue is that CTP premiums are largely not priced according to risk. In all jurisdictions except NSW[3], the premiums within a vehicle class (e.g. passenger vehicles) are fixed regardless of driver behaviour and vehicle choice.[4] Thus, for example, the CTP premium will be the same for a heavy car that is driven recklessly and frequently and for a compact car that is driven rarely and carefully.

In contrast, in most jurisdictions in developed countries (including those in Europe and the United States) vehicle owners purchase a single vehicle insurance product that includes cover for property damage (typically optional) and a compulsory level of third-party liability cover for BI claims. Insurers are largely free to price insurance premiums based on their assessment of risk.[5]

The cost of BI claims per road-crash appears to be similar in magnitude to property damage claims[6] and therefore if insurers covered both BI and property damage their financial incentive to prevent road-crashes among their insured would roughly double. Because most road-crashes (around two-thirds) do no result in BI, the increase in incentive to prevent

1 Insurers may also obtain some brand benefits from appearing to address road-safety.

2 Schemes vary by jurisdiction. In NSW, Queensland, ACT and South Australia there are competing CTP providers. A government scheme operates in other jurisdictions (Victoria, Tasmania, Northern Territory and Western Australia). In NZ, BI claims are covered by the Accident Compensation Commission.

3 In NSW some limited risk-based pricing is possible. Arguably NZ is another exception as the NZ scheme is partly funded through a fuel levy and a vehicle license levy which is risk-based.

4 There are other small variations: for example in some states, the scheme premiums can vary by postcode.

5 In Europe motor vehicle insurance premiums are largely unregulated (In accordance with European Union directives, insurers are not allowed to price based on gender or race). In the US, insurers are subject to an oversight regulation whereby insurers are required to file their rates with a state regulator and in some states gain prior approval before using.

6 Aggregate CTP claims are around two-thirds of motor vehicle claims (based on APRA data in NSW and Queensland), however motor vehicle claims includes claims from theft, fire and storm damage etc and therefore damage from crashes is likely to be similar.

serious road-crashes that cause BI would be much greater; in the order of a factor of four times larger.[7]

A second reason, common around the world, is that the value of BI claims following a crash is generally much less than the societal value of preventing the BI. For crashes for which there is only vehicle damage, an insurers' claims liability relates to the cost of repair or replacement, which should be similar to the societal benefits to preventing the crash.[8] However, for injuries and fatalities the societal value of prevention (which reflects society's willingness-to-pay (WTP) to avoid crashes) is typically much greater than the claims liability. In Australia the recommended societal value of preventing a random road fatality (for use in economic appraisals) is around $7 million[9] but the average BI claims cost associated with a fatality is around $0.2 million.[10] The difference between the value of prevention and claims liability is less significant for less severe injuries. I estimate that across all injuries the average social cost per injury is a little less than three times the average BI claims cost.[11]

Combining the two reasons discussed above, if (in Australia and NZ) insurers' financial incentives to prevent road-crashes were increased to match the societal value of prevention their financial interest in preventing road-crashes would increase (roughly) by a factor of four and their financial interest in preventing road-crashes that *cause BI* would increase (roughly) by a factor of ten.

2.2 The insurance reforms

This paper considers scenarios that involve improving the incentives and regulatory environment for insurers to address road-safety.[12] There are numerous options, varying in terms of:

- the significance of incentives for insurers
- how the change in the incentives are implemented, and
- the road-map to reform.

With regard to the incentives, two scenarios are considered in this paper

7 This result is consistent with the findings of Davey et al (2005) who found that in incidents involving property damage and injury claims the ratio of total insurance costs to property damage costs was 4.1 to 1.

8 In property-damage-only crashes the insurer of the at-fault vehicle-owner bears most, but not all, of the costs incurred. Additional costs include the costs of inconvenience to others involved in the crash and disruption costs to other road-users.

9 The societal value of preventing a random road fatality is estimated from people's willingness to pay (WTP) (either observed, or in response to surveys) to avoid small risks to life. Austroads (2015, p. 23) recommends adopting the value used by Transport for NSW (Transport for NSW, 2013) which allowing for inflation is around $7 million in June 2016. Similarly the WTP to avoid a serious injury is around $0.5 million.

10 The average claims payment for maximum severity claims in Queensland (which is primarily fatalities) in Queensland is $200,000 (source, MAIC Annual report 2015-16, p. 30).

11 Ratio estimated using MAIC data (see footnote 10) for cost and frequency of bodily injury claims by injury severity and Transport for NSW estimates of WTP to avoid injury (see footnote 8).

12 A reader may query what advantage insurers have in managing road-safety issues. These are discussed in Appendix 1.

- **Scenario 1 – the "UK-Scenario"**

  Vehicle insurers would bear the cost of BI claims and be free to price based on risk; that is they would have similar incentives and freedoms to insurers in the UK, US and other countries in Europe.

  Under this scenario

  – vehicle insurers' incentives to prevent injuries would increase by the BI claims cost (by around ~$0.2 million per fatality and ~$0.5 million per serious injury)

  – insurance premiums for high-risk drivers would increase and the premiums for low-risk drivers would decrease.

- **Scenario 2 – the "Optimal-Scenario"**

  This is the same as first scenario except that insurer incentives are aligned with societal incentives for road-safety. Under this scenario insurers' incentives to prevent BI would increase — indicatively by a factor of two to three relative to Scenario 1 — to reflect the greater benefit of preventing BI.[13] Under this scenario the difference between insurance premiums for high and low-risks (for the same cover) would increase significantly.

In both scenarios insurers are encouraged to price based on individual risk. Based on variations in regulation across US jurisdictions, there is strong empirical evidence and expert support for risk-based pricing. For example:

- Weiss et al. (2010) from an examination of US vehicle insurance markets found evidence to 'suggest that rate regulation that systematically suppresses (some or all) drivers' insurance premiums is associated with significantly higher average loss costs and higher insurance claim frequency.'
- In a recent survey of US insurance experts most respondents agreed that limitations on risk-based pricing of insurance premium lead to adverse outcomes.[14]

From a road-safety perspective, Scenario 2 (the Optimal Scenario) appears to be clearly preferable to Scenario 1 (the UK-Scenario). Nevertheless, Scenario 1 is considered as it is already implemented in the UK and other jurisdictions.

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13 There are numerous variations to this scenario. For example, potentially insurers could also be given incentives to reduce the impact of heavy vehicles regardless of whether they are deemed at-fault; incentives could be introduced to encourage at-fault drivers to reduce their risk of self-injury.

14 A 2013 survey of insurance experts in the US concluded that:

> *Most experts participating in the survey disagreed with statements that premium caps, premium subsidies, and restrictions on territory-based rating and the use of driver characteristics (such as gender and credit scores) are appropriate to promote auto insurance affordability.*
>
> *Respondents were most likely to believe that all or most rating and underwriting restrictions negatively affect the viability of insurance markets and are therefore inappropriate. Consistent with these views, expert opinion strongly favors the idea that auto insurance prices should closely reflect a driver's accident risk and be determined by competitive market forces.*

Source: Insurance Research Council, News Release Expert Views of Auto Insurance Rate Regulation. 21 August 2013. Available at http://www.insurance-research.org/research-publications/expert-views-auto-insurance-rate-regulation.

Of note the regulation in Australia and New Zealand has the effect of a greater limitation on premium rates than the US jurisdictions.

How changes to incentives are implemented is out of scope of this paper. However, it is noteworthy that there appear to be feasible options. As noted above, Scenario 1 is already implemented elsewhere. The Optimal-Scenario could potentially involve allowing insurers to bundle CTP cover with motor insurance policies and charging insurers of at-fault vehicles an additional financial penalty that reflects the additional social cost of road-trauma. The revenue from financial penalties could be used to subsidise insurance premiums (or transport use more generally) such that the average cost of insurance (or transport) does not change (or, more likely, falls due to reduced crash-risk). Conceivably this scenario could be implemented largely independent of reforms to CTP schemes by modifying the incentives of private vehicle insurers.

There are also multiple potential pathways to implementation. For example, it may be more politically palatable to initially introduce reforms to heavy-vehicle and commercial vehicle markets and/or to gradually increase insurers' incentives overtime.

2. The insurance reforms — Key points

- Currently, insurers' incentives and flexibility to manage road-safety are less than optimal:
  - Insurers' liability for bodily injury (BI) claims is much less than the value of prevention (a common issue around the world)
  - CTP regulations in Australia and NZ separate liability for BI claims from property damage claims and limit risk-based premiums to cover BI
- This paper considers two reform scenarios.
  - Scenario 1 (the UK-Scenario) whereby (as in the UK and other jurisdictions) insurers have liability for both BI and property damage claims and can price premiums based on risk, and
  - Scenario 2 (the Optimal-Scenario) whereby insurers also have the societally optimal incentives for safety.
- The UK-Scenario would roughly quadruple a vehicle insurer's incentive to prevent road-crashes that cause BI. The Optimal-Scenario increases incentives again by a factor of two to three. In this second scenario, there is (roughly) a ten-fold increase in the incentive of insurers to prevent road-crashes with BI.
- The scenarios would lead to risk-based pricing of insurance premiums. Empirical evidence and expert opinion from the US provide strong support for risk-based pricing on the basis that it reduces the incidence and severity of claims and lowers overall insurance premiums.

3. Whether to drive

3.1 Overview

The decision whether to drive is important from a road-safety perspective. Each additional driver contributes to the risk of road-crashes. Some drivers, particularly many who are young and very old, contribute substantially more to this risk.

Governments regulate who can drive through a licencing system that includes proficiency testing, age-based limitations and a demerit point system.[15] Insurance premiums may also influence the decision to drive,[16] as they may form a significant portion (in the order of 20 per cent or more) of the cost of running a vehicle.[17]

A key benefit of insurance influencing the decision to drive comes from targeting of risk. Licencing is only to some extent risk-based.[18] However, for example, while it is clear that, among full licence holders, young people (and the very old) impose a higher risk to society the licencing system provides no greater disincentive for them to drive.

Risk-based insurance premiums can provide an additional and more refined influence on the decision of whether to drive or use alternative transport. Insurance premiums can have the effect of discouraging high-risk drivers from owning and driving a car. If (as in Scenario 2) insurance premiums reflected the societal cost of road-crashes, then (from a safety perspective)[19] people would only be encouraged to drive if it was in society's interest (i.e. where their private benefits of driving exceed the social costs). The benefits may be significant; particularly in situations where high-risk drivers have access to alternative transport. Furthermore the benefits may increase over time as a result of increase in transport alternatives such as those offered by ride-sharing services.

15 In addition Government-imposed charges (e.g. registration fees and fuel taxes) may influence the decision of whether to drive.

16 There is evidence for this effect from the UK where a Department for Transport survey found 41 per cent of '17 to 20-year-olds cited the cost of insurance as one of the reasons they had not started learning to drive, second only to the cost of learning.' As quoted in ingenie (2014, p. 15).

17 Vehicle running and insurance costs vary greatly. Running costs for an inexpensive car start around $100 per week. Insurance costs (including CTP contributions) for a young driver depending on the insurance purchased and location may be around $20 to $40 per week. The RAA of South Australia provides a recent estimate of running costs for different vehicles. See http://www.raa.com.au/motoring-and-road-safety/car-advice/vehicle-running-costs

18 For example, graduated licensing attempts to manage the risk associated with young drivers; demerit point system penalises dangerous drivers.

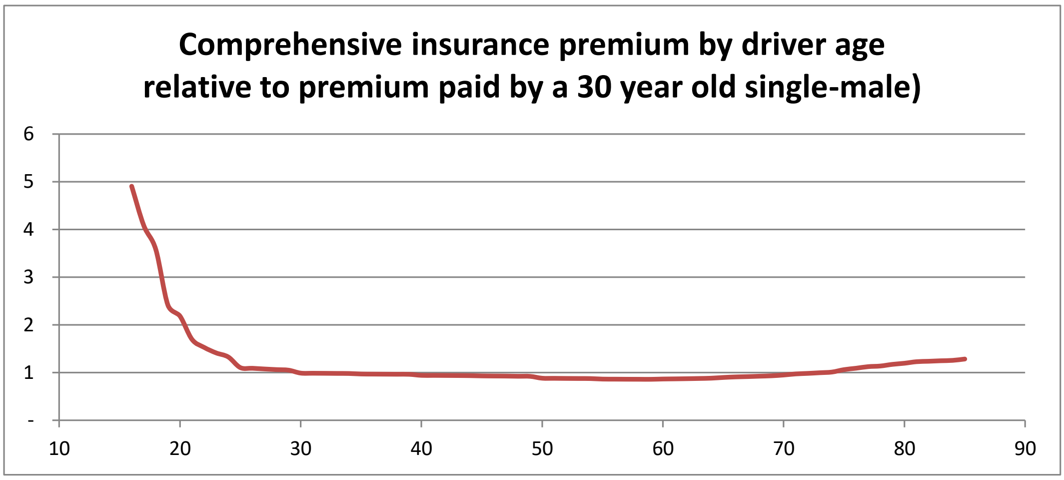
19 There are numerous other external (i.e. non-private) costs and benefits of driving a vehicle. These include costs to the community associated with congestion and benefits to the community from higher contribution to fuel taxes.

3.2 Estimating the potential benefits

The potential safety benefits from risk-based insurance pricing on the decision to drive come from providing additional incentive for high-risk drivers to defer or stop driving. An indication of the importance of this can be obtained by examining the insurance premiums in markets where risk-based pricing occurs.

Figure 1 below shows data on how average motor insurance premiums in the US vary based on age alone. As reflected in the figure, the young (aged 16 to 20) would pay 2 to 5 times more for the same policy as a 30 year-old male. Based on the same data source, the average premium is around 80 per cent higher for those with a serious driving offence (e.g. reckless driving or driving under influence of alcohol). The actual premium paid by high-risk drivers may be considerably less because they will take-out a different policy which reduces the risk to the insurer (e.g. a higher deductible) or select a vehicle that is less expensive to insure.

Figure 1: Relative insurance premium by age for the same policy in the US



1. Source: The Zebra (2015) 'The State of Auto Insurance'. Available at www.thezebra.com/insurance-data/
2. The base profile for the insured is a 30-year-old single male driving a 2012 Honda Accord EX with a good driving history and coverage limits of $50,000 bodily injury liability per person/$100,000 bodily injury liability per accident/$50,000 property damage liability per accident with a $500 deductible for comprehensive and collision.

In Australia and NZ, the variation in total insurance premiums[20] will be much lower due to the regulation of liability for BI claims. In effect, relative to the insurance systems in Europe and the US, the Australian and NZ insurance schemes subsidise high-risk drivers at the expense of low-risk drivers. A shift to Scenario 1 would undo this cross-subsidy.[21] A shift to Scenario 2 would further increase the variation in premiums and, depending on how implemented, may also provide some incentive for average-risks to opt-out of driving and use alternative transport.

[20] That is, vehicle insurance premiums plus CTP premiums (in NZ, contributions to the Accident Compensation Commission).

[21] To alleviate any impacts on age-groups the current subsidy to high-risks could be replaced by an age-based subsidy which does not encourage vehicle use.

3.2.1 Impact of deferral in young people driving

Reflecting the variation shown in Figure 1 above, the most significant impact of risk-based insurance premiums on the decision to drive should come from young people deferring when they take-up driving.

There is strong evidence that young people become lower-risks with age regardless of experience. [22]

It is on this evidence that there have been calls to raise the minimum driving age. For example, the South Australian Government proposed an increase in the minimum provisional licensing age to 18 based on research estimates that it would lead to 'a 5 to 6% reduction in all serious and fatal crashes in South Australia'.[23] Furthermore, evidence suggests that there are safety benefits from increasing the minimum driving age for a provisional licence past the age of 18.[24] Despite the safety benefits, increasing the licence age has received political opposition.

The impact could be material. In Australia CTP premiums that cover BI claims are around $500 per year.[25] Using Figure 1 as guide, under Scenario 1, the BI premiums for a 17 year old driver would quadruple. This would increase the annual cost of owning and driving an inexpensive car — which is around $5,200 per annum[26] — by around 30 per cent and result in some to opt not to drive. An estimate of the responsiveness to price changes is given by an own-price elasticity[27] of demand for driving of -0.3;[28] implying that under Scenario 1 there

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22 If crash risk and (consequently) insurance premiums were just related to driving experience, then a delay in taking-up driving will largely just defer the period of when the driver gains experience. However, Begg and Langley (2009) conclude that 'the evidence demonstrates that young age, independent of experience, is a major determinant of risk; therefore, raising the minimum licensing age would have safety benefits'. Furthermore, potentially, people can change the experience they receive before obtaining a provisional licence.

23 Source: SA DTEI (2011, p. 10).

24 Lisa Wundersitz (Research Fellow, Centre for Automotive Safety Research, University of Adelaide) summarises (Source: Personal correspondence) that:

> "By raising the provisional licensing age to 18 years, drivers then have two years to gain experience with a supervising driver and they are also more mature. Many studies from North America and Europe have shown that the older you are when driving unsupervised, the lower the risk of crashing. For example, Waller and colleagues (2001) followed the crash and traffic offence records of a large cohort of young Michigan drivers for seven years from first licensure. They found that the odds of crashing decreased by about 5% for each additional year of age at the time of licensing (driving unsupervised). Maycock et al. (1991) examined novice drivers in the United Kingdom where the youngest age a licence could be acquired was 17 years. Consistent with other studies, the youngest novice drivers had a higher crash risk than older novice drivers. Postponement of licensure from age 17 to 18 was associated with a 6% decrease in crash risk, and a delay from age 18 to 19 lead to an additional 6% decrease."

25 There is significant variation by State/Territory. A useful recent summary can be found in http://www.finity.com.au/publication/dfinitive-motor-injury-insights-september-2016.

26 Refer footnote 17.

27 Elasticity is a measure of the percentage change in one variable in response to a percentage change in another. The own-price elasticity of demand is the percentage change in demand for a percentage change in price. This will be negative.

28 Litman (2013, p. 51) reports that the London transport modelling assumes an own-price elasticity of demand for car journeys is -0.3; i.e. a 10% increase in the cost of driving reduces car use by 3%.

would be a 9 per cent reduction in 17 year olds driving (and consequent reduction in road-crashes by 17 year-olds). A larger effect would come under Scenario 2.[29]

3.2.2 Impact on other groups

Based on the data presented in Figure 1 it seems unlikely that a shift to risk-based insurance pricing under Scenario 1 would have a significant impact on the cost of insurance for other age groups. The removal of the cross-subsidy to the high-risk groups would result in a general reduction in insurance premiums but averaged over the population this is likely to be small.

There would be some increase in insurance premiums for older people, which, based on the data, may be material but smaller relative to the impact on young-drivers. Nevertheless, this may be become an increasing significant factor with the increasing age of the population. There would also be an increase in premiums for other high-risk drivers (such as those with a poor driving record).

Depending on how Scenario 2 is implemented, there may also be a material impact on other drivers. If the excess funds collected under Scenario 2 are returned to insurance premiums then there would be little change in the average premium. However, if the excess funds are used for other purposes (e.g. as direct financial subsidies for any transport use) then many others may opt to not drive in favour of other transport options.

3. Whether to drive — Key points

- A shift to risk-based insurance premiums would provide incentives for high-risk drivers to use alternative transport thereby reducing road-fatalities.
- Based on variation in insurance premiums, the safety benefit would likely be greatest in deferring the decision by young people to drive.
- An indicative estimate is that Scenario 1 (the UK-Scenario) would lead to 9 per cent less 17 year old drivers.
- There would also be some benefits from encouraging older people to stop driving.

[29] For Scenario 2 the increase in insurance premiums for the same cover would be around $5,200 (i.e. around 100% increase in cost of driving) suggesting a decrease in 17 year old drivers of around 30%. However, in response to such a price change there would likely be significant changes in the choice of vehicle (e.g. adoption of a vehicle with autonomous emergency braking) and insurance policy (e.g. use of higher deductibles), which have the effect of reducing the insurance premium and improving safety.

4. What to drive

Vehicle choice can affect the likelihood of crashes (through the use of collision-avoidance technologies) and the severity of crashes in terms of the impact on the vehicle's occupants and others involved.

Insurers can influence the choice of vehicle by modifying insurance premiums to reflect the vehicle's risk. Insurers offer two benefits in influencing vehicle choice. First insurers can be adept at discriminating based on risk. Whereas vehicle regulation applies equally to all licensed drivers, with the right incentives insurers would encourage the highest-risk drivers to choose safer and less-aggressive vehicles. Second, the premium discounts for insurers would encourage innovation by vehicle providers to further reduce risk.[30]

To estimate the safety impact of vehicle choices from insurance reforms it is first useful to examine the significance of vehicle choices, how vehicle choices affect safety and how these vary across the vehicle fleet.

4.1 The significance of what to drive

4.1.1 Potential benefits of vehicle choice

There have been numerous advances in vehicle safety and there is evidence that the crash-risk of new vehicles has been improving. For example, Anderson et al (2015, p. 209) estimate that on average since 2004, the risk of injury in a vehicle has been declining at a rate of 6 per cent year.[31]

Historically, much of the improvement in vehicle safety has come from improved passive safety features (e.g. air-bags and improved vehicle design) which improve the crashworthiness of a vehicle.

Going forward much of the interest is in advanced driver assistance systems (ADAS), which for the purposes of this report are separated into:

- Warning systems, which detect and alert drivers to issues but rely on driver operation of the vehicle
- Autonomous systems, which upon detecting an issue take some automated action (e.g. emergency braking), and
- Autonomous vehicles, which have potential to eliminate driver error.

30 In contrast attempts to directly regulate vehicle choices can inhibit innovation.

31 There is other research.

- In a review of analysis to date, Paine et al. (2015) concluded that the risk of serious injury to drivers of 5-star ANCAP models is half of that of non 5-star models.
- Newstead et al. (2014) attempt measure the safety and aggressivity of Australian vehicles by examining the severity of crashes involving the vehicles find a correlation between manufacturing year and safety.

Separate consideration of warning systems is useful as they can be installed after-market.[32] Autonomous systems may only be practically installed at the time of manufacture.

There is substantial research (largely based on simulations, in-part based on actual crash statistics) that ADAS can have a significant impact on reducing the likelihood and severity of crashes. Details of recent literature on the effectiveness of ADAS technologies are provided in Appendix 2. In summary, the evidence suggests for motor vehicles:

- Factory installed autonomous systems (which includes automated emergency braking, AEB, and lane departure prevention in addition to warning systems) may reduce fatalities caused by motor vehicles by 20 to 50 per cent.
- This crash-risk reduction for warning systems that can be installed after-market appears to be around 60 per cent of the benefit of autonomous systems (i.e. 12 to 30 per cent).

4.1.2 Penetration of technologies into the vehicle fleet

The safety characteristics of most vehicles are determined at the time of manufacture. This fact leads to two key limitations with the impact of vehicle safety innovations.

First, it can take some time for safety features to penetrate into the vehicle fleet. The average vehicle age tends to be around 10 years for private passenger motor vehicles and motorcycles, 16 years for heavy vehicles and 11 to 12 years for most other categories including buses, light-trucks and articulated-trucks.[33]

Second, a significant concern is that the young people, and others who are high-risk, drive older vehicles that are poorer in terms of safety than the mature, lower-risk drivers.[34] This is illustrated in Figure 2 below, which shows the vehicle-age profile for the registered fleet in South Australia for segments of the population involved in single-vehicle accidents. Those aged 16-18 involved in crashes tend to drive much older vehicles with few safety features[35] than the rest of the population. Furthermore, vehicles involved in single-vehicle crashes tend to be generally older than the registered fleet.

The combined effect of the two issues is illustrated in Figure 3 which forecasts the penetration of electronic stability control (ESC) into the vehicle fleet. ESC first appeared in 2002 and is now legislated in all new cars/SUVs. As illustrated, ESC was installed in over half of all new car sales in 2009, however its forecast penetration into the vehicle fleet is only expected to reach 50 per cent 10 years later and in the high-risk driver categories (as determined by age and those who have crashed) may years later. Gargett et al. (2011) estimated that ESC will only reach 90 per cent of penetration into the vehicle fleet by 2030.

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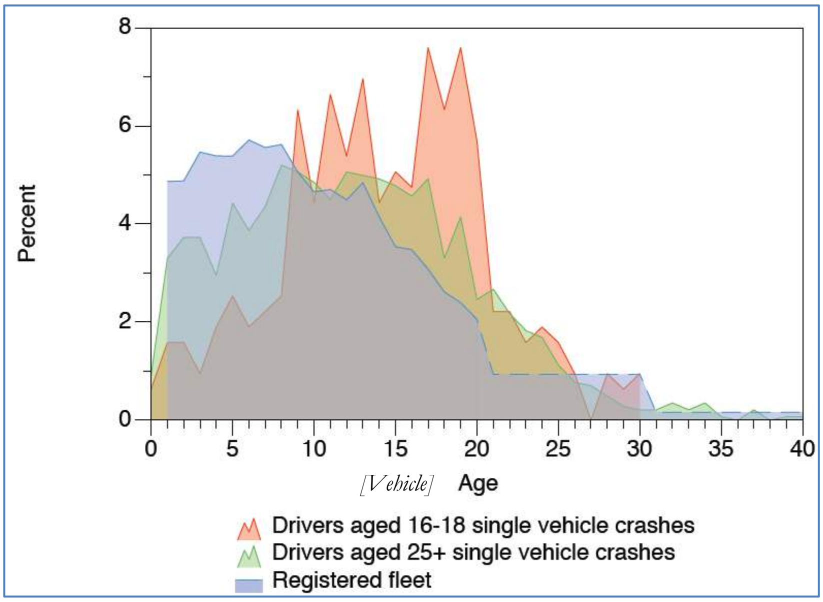
32 A warning system from Mobileye that includes lane departure warning, forward collision warning, pedestrian collision warning can be installed for around $1500. See www.andatech.com.au/driver-safety/mobileye/.

33 Source ABS: Motor Vehicle Census January 2016.

34 See for example, Watson & Newstead (2009) examined the vehicles involved in crashes and found the vehicles used by young drivers were less crashworthy (i.e. safe) than those used by older drivers.

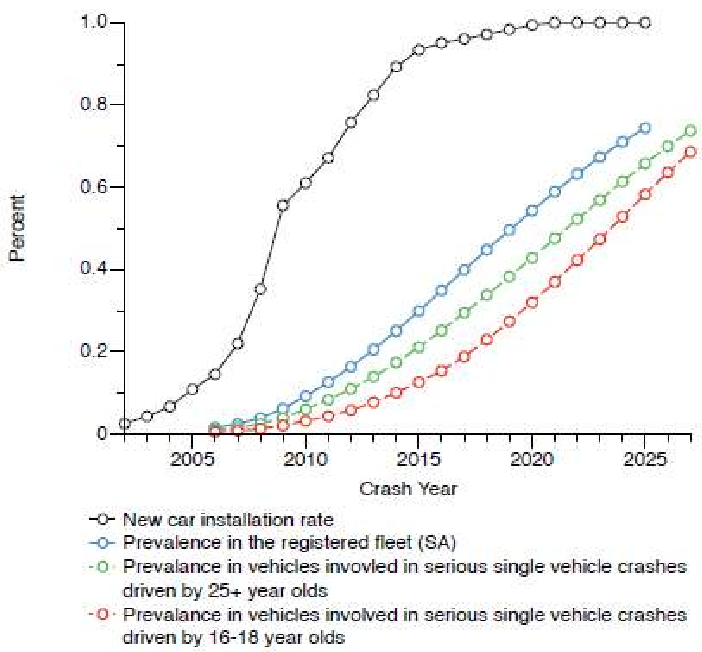
35 Anderson et al. (2013, pp. 11-12) calculated the relative prevalence of vehicle safety features in the vehicles crashed by drivers in Australia. They found that the ratio of prevalence for drivers aged 16 to 18 relative to drivers aged 25 and over was 0.62 for air-bags, 0.28 for Break Assist Systems, 0.16 for ESC, 0.30 for 5-star safety, and 0.24 for side curtain airbags.

Figure 2: Vehicle-age profiles of light passenger vehicles of the registered fleet and those involved in single vehicle crashes in South Australia (2006 – 2012)



Source: Anderson et al. (2013, p. 8).

Figure 3: New car installation rates and penetration rates for ESC



Source: Anderson et al. (2013, p. 9).

4.2 The influence of insurers on vehicle choice

4.2.1 Existing evidence of insurers influence

If insurers priced based on risk, people would be encouraged to choose safer vehicles and install safety technologies so as to reduce the cost of insurance. Furthermore, high-risk drivers would receive larger premium discounts.

There is some (mainly anecdotal) evidence of insurers providing discounts for safer vehicles and installed devices. For example Mobileye[36] reports insurers' offering 10+ per cent discounts on insurance premiums for installing their system.[37]

However, some commentators have suggested that average premium discounts tend to be small.[38] Observed discounts may be small for a few reasons:

- Insurers don't provide discounts because they lack information on:
  - real-world results to determine cost-savings, and/or
  - whether an individual vehicle has the technology installed.
- Lower crash risk is offset by other costs. Potentially the installed safety-technology may increase the cost to replace the technology in the event of accident or theft.
- The observed safety discounts are average results which may be small because safer drivers tend to choose safer vehicles and technologies.[39]

To address the last challenge information on premiums discounts by different risk-categories from the UK was obtained (see Box 1 below).[40] This (albeit limited) evidence suggests that insurers premiums when priced based on risk provide significant financial incentives for safer vehicles.

The UK data is of perhaps greatest interest in the average premium discount provided for autonomous emergency braking (AEB). AEB as an option costs in the order of $1700

36 See footnote 32.

37 There is some other anecdotal evidence. For example, the NRMA in 2014 announced it would be using AEB as a rating factor. https://www.nrma.com.au/nrma-insurance-counts-collision-avoidance-technology

38 Recently The Zebra (which claims to be the US's largest comparator website for car insurance) examined how insurance premiums in the US varied across multiple dimensions using a base profile of a 30-year-old single male driving a 2012 Honda Accord EX with a good driving history. For this profile, they found that insurers provide no discount for many safety features (including rear view camera, park assist device, night vision device, lane departure warning device, heads-up display, driver alertness monitoring, collision preparation system and blind spot warning device). They found a small discount for electronic stability control and telematics. For more information see https://www.thezebra.com/insurance-data/. See also discussion in footnote 39 below.

39 The results from The Zebra (discussed in footnote 38 above) are consistent with small discounts being offered to low-risk drivers. Unfortunately The Zebra survey did not assess discounts provided to high-risk drivers.

40 Unfortunately there appears to be little other research that links financial incentives to choice of vehicle safety. Due to the CTP regulations, insurance premiums in Australia are not useful to analyse.

(£1000). The average premium discount for AEB for drivers over 45 was £10 (i.e. around 3 per cent of the cost). The discount for AEB among drivers aged 17 to 24 was £313 (around 30 per cent of the cost of AEB). This data suggests that in the UK the cost of AEB for high-risk drivers may be offset over a few years through lower insurance premiums.

Box 1: Insurance discounts by risk

The data in Table 1 below on insurance premiums from the UK provides some evidence of how insurers may encourage higher risks to choose safer vehicles and safer options. Across the vehicle types the variation in insurance premiums for the over 45 age group is small. However the variation is substantial for the high-risk '17 to 24' age group. Notably, the cheapest to insure vehicle, the Nissan Qashqai, has the highest safety rating scores and the second lowest vehicle weight (an indicator of aggressiveness).

The research was used to estimate the benefit of installing AEB. AEB was found to reduce the average quoted insurance premiums on all vehicles by most significantly for young drivers. The average saving (across all vehicles) for the 17 to 24 age group was £313, but only £28 for the over 45 age group.

Table 1: Vehicle choice and insurance premium in the UK

Vehicle	ABI Group rating*	Weight (in kg)	European NCAP Safety rating points (higher is better)*				Premium	
			Adult Occupant	Child Occupant	Pedes-trian	Safety Assist	Over 45	17 to 24
Nissan Qashqai	13	1,388	33.8	40.8	24.9	10.3	£299	£1,643
Fiat 500L	7	1,245	33.7	38.0	23.4	6.7	£316	£1,930
Mazda 6	19	1,420	33.4	37.9	23.8	9.0	£327	£1,798
Mercedes Benz C200	25	1,570	35.1	41.6	27.7	9.2	£342	£2,709
Mitsubishi Outlander	22	1,495	33.7	40.6	22.9	8.7	£354	£4,395

Source: Thatcham Research – provided through personal correspondence.

*Notes The insurance premiums are comprehensive insurance (including third-party liability). The Euro NCAP Safety ratings can be found at http://www.euroncap.com/en. Premiums shown for model with AEB installed and safety assist ratings modified to reflect this. ABI Group is an insurance costing group provided by the Association of British Insurers; a lower number indicates a lower insurance cost.

4.2.2 The impact of vehicle choice under different scenarios in Australia

Baseline

In the absence of insurance reforms there should be continual improvements in vehicle safety as older less-safe vehicles are retired and technologies such as AEB and fully autonomous vehicles become standard.

However, the penetration of technology such as AEB into the fleet will take some time. A recent (June 2016) US estimate was that only around 6 per cent of new vehicle sales have AEB as a standard feature but that it was available on around 51 per cent of all model lines.[41] In March 2016, it was announced that the majority of automakers committed to AEB being a standard feature in all new vehicles in the US by 2022.[42] Even if such a commitment applied to Australia, using the penetration of ESC (Figure 3 on page 12) as a guide, it will be at least 15 years before AEB is in the majority of vehicles driven by the high-risk drivers.

Another concern is that, without reform, manufacturers will install basic, less effective systems that are focussed on reducing property damage and not BI. Anderson et al. (2012) found that types of AEB systems varied in effectiveness (in reduction of trauma) by up to a factor of two.

Direct regulation to require vehicle manufacturers to install ADAS may be possible but difficult, in part due to the high costs (AEB costs around $2000 as an option) and in part due to difficulties of determining an appropriate standard.[43] As was the case with ESC, the adoption of AEB may be hastened by its inclusion as a factor in determining ANCAP ratings.

Alternative scenarios

Safety impacts

Under the alternative scenarios there would likely be a much more significant impact of the safety technologies due to three effects.

First, the greater incentives for safety would hasten the introduction of safer vehicles and technology. Under Scenario 1, and more significantly Scenario 2, vehicles with safety technologies such as AEB should be less costly to insure and consequently be more valuable to consumers.

41 http://www.jato.com/wp-content/uploads/2016/06/Market-Insights_US_2016_AEB-1.pdf. See also http://www.bosch-presse.de/pressportal/de/en/emergency-braking-and-lane-assist-systems-on-the-rise-43164.html

42 See IIHS News, March 17, 2016 available at http://www.iihs.org/iihs/news/desktopnews/u-s-dot-and-iihs-announce-historic-commitment-of-20-automakers-to-make-automatic-emergency-braking-standard-on-new-vehicles

43 Anderson et al. (2012) concluded that for the average vehicle the costs of AEB exceeded the social benefits. The costs will presumably fall over time and at some stage it will be beneficial that all new cars have AEB installed.

These incentives would encourage a more rapid disposal of the less-safe vehicles in favour of newer safer vehicles. It would also encourage after-market installation of warning system technology where it is cost-effective.

Second, insurers (who are in a better position than consumers to assess safety benefits) would have incentives to encourage more effective technologies and systems. In particular, with the right incentives insurers would encourage the adoption of ADAS that reduce the risk from the crash types that most contribute to the road-toll. Similarly insurers would encourage the adoption of fully-autonomous vehicles when they become available.

Finally, and perhaps most significantly, insurers would offer greater incentives for high-risk drivers (e.g. the young, and drivers of trucks and commercial vehicles) to use safer vehicles and technologies. For example, while the costs of AEB may currently outweigh social benefits for the average driver, for many high-risks the societal benefits will already exceed the costs; consequently insurers (with the right incentives) would financially reward their policyholders to adopt the technology.

Further implications

The reforms would likely have further implications for the vehicle fleet, insurance markets and government regulation.

With regard to changes in the vehicle fleet likely additional implications include the following.

- Vehicle distributors would take a more active role in advertising the insurance-discount benefits of safer vehicles
- There would be a change in how the vehicle fleet is used with the safer vehicles being more frequently used by high-risk drivers, and conversely the less-safe vehicles being more frequently used by low-risk drivers.
- The relative resale value of safer vehicles (in particular with AEB) would be much higher due to higher demand from young drivers to obtain insurance discounts and consequently less safe (older vehicles) would more rapidly lose value, resulting in a faster turn-over of the vehicle fleet.

Potential changes in insurance markets include insurers:

- taking a more active role in monitoring the safety of heavy vehicles and other commercial vehicles
- partnering with aftermarket installers of technology such as Mobileye so as to market safety technologies and give insurers confidence in safety benefits
- placing greater attention on which drivers are using a vehicle, with heavier penalties for unnamed high-risk drivers using older less-safe vehicles.

The reforms have potentially significant implications for other regulation. Under Scenario 2 insurers have the full societal incentive for ensuring a vehicle is appropriate from a safety perspective. This may lead to simpler direct government regulation of vehicles.

4. What to drive - Key points

- Through risk-based insurance premiums, insurers can influence what vehicle is driven.
- Advanced driver assistance systems (ADAS) including autonomous systems and warning systems are expected to significantly reduce fatalities cause by light and heavy motor vehicles (up to 50 per cent reduction).
- The impact of autonomous systems will take some time as the average motor vehicle has an age of 10 years and new cars tend to be purchased by safer drivers. Warning systems that have (lesser but still) significant safety benefits can be installed after market.
- Under the insurance reform scenarios there would be increased incentives for drivers to adopt safer vehicles, ADAS and autonomous vehicles when they become available.
- A key benefit is that the highest risks would receive the largest discounts for safer choices.

5. How and when to drive

5.1 Overview

Driver behaviour is commonly recognised as contributing factor to most road-crashes.

Governments manage driving behaviour through a combination of road rules (e.g. speed limits), monitoring (e.g. police force) and punishments (e.g. demerit point system and charges).

Insurers also influence driver behaviour, primarily through financial incentives that include using deductibles on claims to share financial risk and premium discounts for a safe driving record. In part, these incentives build on the road-rules.[44] However they also go further. For example, insurance premiums are affected by behaviours and events independent of the road-rules (e.g. a road-crash may lead to an in increase in insurance premiums but not a Government imposed penalty). Furthermore, insurance premium incentives can be more aligned to risk than Government penalties; for example, the increase in premiums following a driving violation may be more severe for a young driver than for a middle-aged driver.

The ability of insurers to influence driving behaviour has increased significantly as a result of in-vehicle telematics devices that enable insurers to capture information on driving behaviour. Increasingly insurers are offering telematics-enabled usage based insurance (UBI)[45] policies through which policyholders share vehicle-use information with the insurer which is then used to encourage safer road-use.[46]

Telematics-enabled UBI offers several benefits in complementing traditional monitoring and enforcement to encourage safer driving behaviour. These include:

- refined and improved monitoring, capturing information on a range of behaviours that, in addition to speed, include acceleration (& deceleration), distance and time of travel. Recent innovations including using measures of driver distraction.[47]

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44 For example, insurance premiums may rise for those convicted of driving offences.

45 In addition to telematics-enabled UBI (often referred to as Pay how you drive, PHYD), UBI also includes low-technology distanced-based policies (based on odometer reading) such as that offered by Real Insurance in Australia.

46 Insurers use UBI to influence safety in a number of ways including:

- incentives (e.g. discounts on premiums on renewal and non-financial rewards) and penalties for poor behaviour (i.e. effectively a loss of a discount),
- feedback and support to the driver including real-time in-car feedback, on-demand feedback with risk-scores and advice provided online or via an app on a mobile device, and/or targeted feedback and support. For example, the UK insurer ingenie runs a Driver Behaviour Unit that proactively contacts the highest-risk drivers (ingenie 2014, p. 54).

47 For example, a US company TrueMotion measures distracted driving through a mobile phone app and is partnering with insurance companies who offer discounts to drivers based on undistracted and otherwise safe driving behaviours. https://gotruemotion.com/driving-distracted/

- continuous monitoring (as opposed to relying on detection by an enforcement officer or device e.g. a fixed speed camera).
- tailored feedback whereby the information captured is used to teach better driving behaviour, and
- incentives aligned to risk; for example with UBI an insurer provides incentives for a young policyholder to avoid night-time driving.

In Australia and NZ there has been some experimentation with UBI; however, as vehicle insurance does not cover BI claims the benefits of UBI to vehicle insurers is significantly reduced and consequently adoption is limited.

In other jurisdictions, such as the UK, where the regulation is more favourable, telematics-based UBI is growing rapidly. The UK may provide a useful guide as to what would occur under Scenario 1. While penetration across the entire market is low (UK estimates vary between 2 and 3 per cent penetration) growth is rapid (in the order of 30 to 40 per cent per year))[48] and adoption is large among high-risk drivers (in particular the young) who have most to gain from a UBI policy.[49] In 2015, the UK insurer Direct Line indicated that telematics represented about 2 per cent of the company's motor insurance policies, but around 60 per cent of policies for under-21s. The rate of adoption of UBI varies by jurisdiction. The penetration is particularly high in Italy and is comparable to the UK in US jurisdictions.[50]

5.2 Impact of insurance on driving behaviour

The reform scenarios would increase insurers' incentives to manage driver behaviour through both traditional measures and UBI. An indication of the potential benefits can be obtained from existing research on insurance influence on driver behaviour and the impact of UBI.

5.2.1 The impact of traditional insurance on driving behaviour

There has been some research on the influence of traditional insurance on driver behaviour. The common research strategy is to examine how outcomes change when policies or governance arrangements limit insurers' ability to influence drivers (see Appendix 3). The available research provides evidence that insurers have a material impact. For example:

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48 A number of insurers had experimented with UBI in the 2000s but it is only recently that the penetration of UBI in some markets has become significant. A 2017 study by the BIBA estimated there were around 0.5 million live telematics-based UBI products in the UK (source:https://www.biba.org.uk/press-releases/biba-research-reveals-750000-live-telematics-based-policies/). This corresponds to around 2 per cent of all polices. A 2015 survey suggested that around 3 per cent of adults had a telematics based insurance devices. Source: http://www.uswitch.com/media-centre/2015/04/brits-appetite-for-telematics-stuck-in-first-gear/.

49 Source: http://connectedconsumer.osborneclarke.com/transport/more-than-half-of-uk-drivers-would-consider-black-box-insurance/

50 Penetration in other European countries is lower. Germany, for example, has a very low level of penetration, a result that has been attributed to it being a relatively conservative market. Looft & Cooksey (2015).

- Schneider (2010) finds the accident rate of taxi-drivers who lease (and do not pay insurance) is 16 per cent higher than owners.
- Weisburd (2013) found high accident rates among workers who did not pay for insurance deductible.

In summary it seems reasonable to expect that the reforms proposed would lead to improvements in driver behaviour from insurers using traditional methods of influencing driver behaviour.

5.2.2 The impact of usage based insurance

There is a growing body of evidence showing UBI is effective in reducing crash-rates and consequently resulting in lower insurance premiums for policyholders. A variety of approaches have been used to estimate the impact of UBI including using data from insurance companies, field experiments and extrapolating the impact on reduction in distance-travelled. Details of studies are provided in Appendix 4. In summary:

- Most studies based on insurance data suggest a benefit upwards of 20 per cent reduction in crash-risk.
- Some studies suggest that UBI has been used to reduce crash risk in high-risk drivers by up to 35-40 per cent.
- UBI customers are reported as receiving significant discounts on their annual insurance premiums (up to 40 per cent which in the UK maybe as much as £1,000 (~$1700)).

The research results should be indicative of the benefits achieved under Scenario 1 for high-risk drivers. In applying these results to forecast the impact of insurance reform, there are a number of considerations.

- The impact of UBI varies across the driver population. It is has greatest benefit (and adoption) among the young and other high-risks. The benefits for lower-risk drivers will be significantly less. This is reflected in lower premium discounts for UBI among mature-age drivers.
- Over time the effectiveness of UBI may increase with improvements in technology and with insurers' increased experience in influencing driver behaviour.
- Under Scenario 2, we would expect the safety benefits to be more significant.
- The potential benefits may depend (in-part) on the penetration of ADAS.

The penetration of UBI will vary by scenario. Without insurance reform it seems unlikely that UBI will become significant in Australia and NZ. The UK experience presumably provides a guide as to what would occur under Scenario 1.

Under Scenario 2 the benefits to insurers of safer driving by their policyholders would be much greater. Consequently there would likely be increases in the incentives for policyholders to adopt UBI and drive more carefully once UBI is installed.

5. How to drive — Key points

- Insurers have traditionally influenced how people drive through financial incentives such as rewards for safe driving and using deductibles to share risk.
- Insurers can now use telematics-based usage-based insurance (UBI) to manage risk. Studies suggest UBI has been used to reduce crash risk by 20 per cent and more (up to 35-40 per cent in young drivers).
- The CTP regulation in Australia and NZ reduces incentives to use UBI. In the UK, where the regulation is favourable, telematics-based UBI is growing rapidly with a very high-penetration among young drivers.
- Under the alternative scenarios there would be greater incentive to adopt UBI and greater incentive to ensure that it is effective in managing risk.

6. Analysis of benefits and issues

6.1 Quantifying the safety benefits of reform

'prediction is very difficult, especially about the future'

Neils Bohr

This section provides indicative estimates of the benefits associated with the reform scenarios. Forecasting the benefits is challenging. There are two sets of issues.

First, there is substantial uncertainty. In particular,

- The baseline is uncertain. Since falling reasonably consistently between 2000 and 2015, the annual road-crash fatalities in most jurisdictions has increased and it is not clear what the medium-term future holds.
- There is limited public evidence to estimate effects. This is particularly the case for private solutions which do not require public investment.
- The technologies are developing rapidly and new solutions may evolve. This is particularly an issue for Scenario 2 in which the incentive for insurers to invest in road-safety increases dramatically beyond what is observed in any today. The incentives may drive new (yet-to-exist) approaches to issues such as driver distraction, speeding and influence of drugs. The significance of these is, of course, unknown.[51]

In recognition of the uncertainties, the forecast of benefits should be considered, at best indicative.

Second, modelling the impact is complex for several reasons.

- The reforms have wide-reaching impacts on road-use and consequently there are multiple effects on road-safety.
- Many of the effects interact. For example, the reductions in the road-toll achievable from AEB will be less as a result of UBI.
- The significance of any one effect may vary by category of vehicle and driver. For example, under the scenarios the adoption and benefits of UBI will be greater among young drivers and heavy-vehicle users.
- The significance of effects will vary over time due to changes in the vehicle fleet.

To simplify the challenge, only a selected set of effects are modelled, relating to the influence of insurers on:

- Whether to drive — relating to impact of premiums on young and old drivers
- What to drive — relating to the adoption of AEB, warning systems and fully autonomous vehicles

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51 It is analogous to predicting in the early 2000s what applications would be developed for a smart-phone.

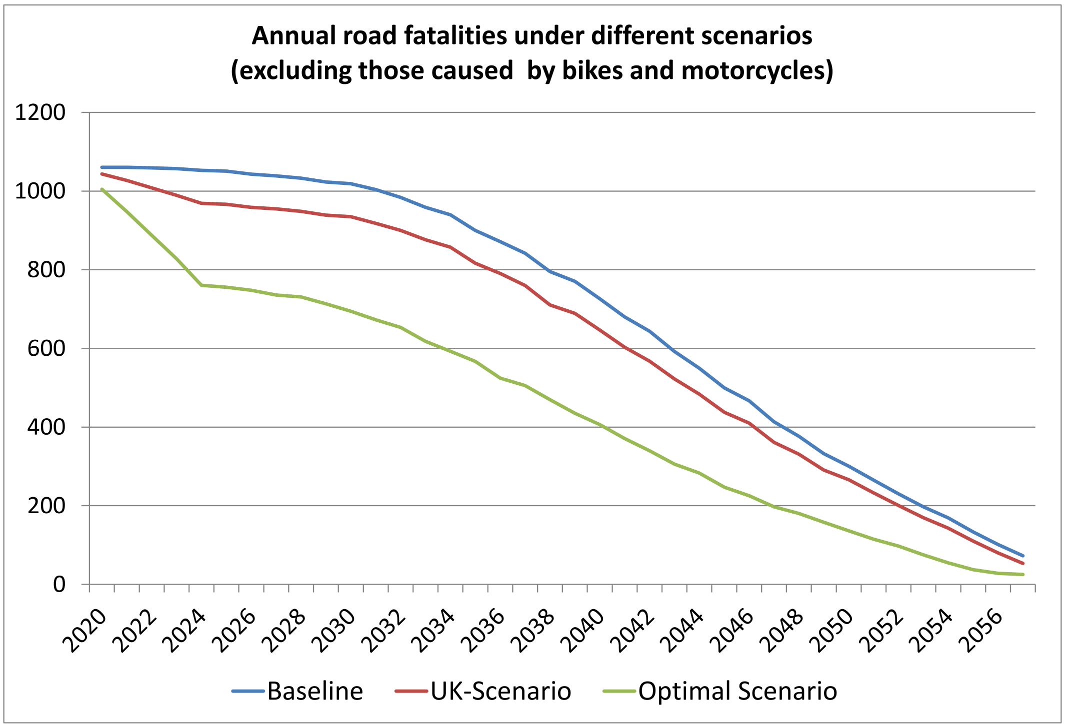
- How people drive — relating to the adoption of UBI.

The approach and key assumptions are summarised in Box 2 below. Further details including some additional modelling results are contained in Appendix 5.

The projected road-fatalities by scenario are provided in Figure 4 below. Due to the introduction of AEB and autonomous vehicles, the annual road-fatalities in the baseline falls over time. In the scenarios the reduction in the road-toll is much faster. In summary, the modelling predicts that *relative to the baseline*:

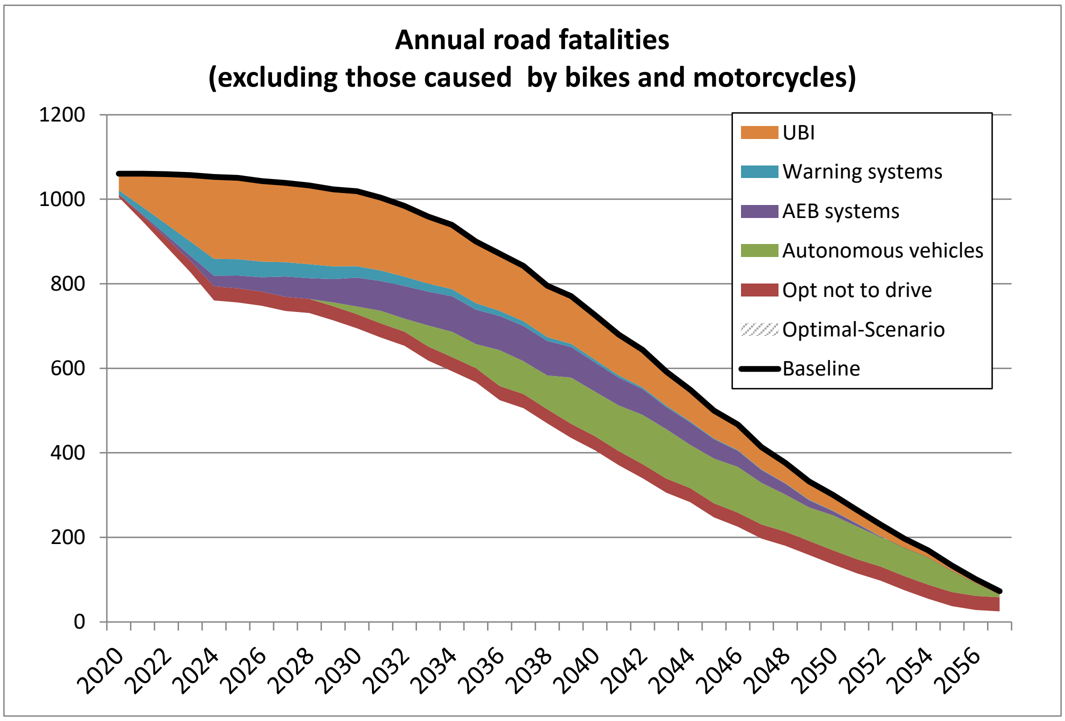
- Adopting the UK-Scenario would result in over 80 fewer road-fatalities per year in 2027 (equivalent to around 7 per cent of the current road-toll).
- Adopting the Optimal-Scenario would result in over 300 fewer fatalities per year in 2027. (equivalent to around 25 per cent of the current road-toll)
- The total reduction in fatalities in the
  - next 20 years (to 2037) is around 1,300 for the UK-Scenario and 5,000 for the Optimal-Scenario, and
  - next 40 years (to 2057) is around 2,300 for the UK-Scenario and 9,200 for the Optimal-Scenario.

Figure 4: Projected road-fatalities by scenario



The sources of the gap between the baseline and second Optimal-Scenario are shown in the Figure 5 below. Under the assumptions, UBI is the primary reason for lower fatalities. The significance of UBI diminishes overtime as there is greater penetration of AEB and then autonomous vehicles into the fleet.

Figure 5: Source of difference between the baseline and the Optimal-Scenario



There would be similar reductions in injuries and other costs (e.g. property damage, use of emergency services) of road-crashes. The total annual social cost of road-crashes was estimated to be around $27 billion per year in 2006 (the majority of which are costs associated with BI).[52] I estimate the comparable value in 2017 having allowed for the reduction in the fatalities (there were 1602 fatalities in 2006) and cost-inflation is around $31 billion.[53]

Assuming that the reductions in injuries and other costs are proportional to the reduction in fatalities then the benefit of shifting to the Optimal-Scenario will be (discounted to 2017 dollars)[54] around $6 billion per year in 2027 and in the order $100 billion up until 2037.

While the results indicate a very large benefit to insurance reform in reducing road fatalities, the estimated benefits may be conservative:

52 This amount uses the WTP approach to value risks to life but as argued by the author (see Tooth, 2011) a conservatively low value.

53 Inflation (as measured by CPI has averaged 2.5 per cent over the period). The real costs per road-crash are assumed to increase at a real rate of 1 per cent per annum based on evidence that elasticity of WTP to prevent fatalities with respect to income is around 1.44 (see US Department of Transport, 2015), real income growth of 1 per cent per year (historic real GDP-per-capita growth since 2006) and that around two-thirds of crash-costs relate to bodily injury (see BITRE 2010, Tooth 2011).

54 For discounting a real-risk free rate of around 3 per cent is used (see BITRE 2010, p. 26). Future real costs per road-crash are assumed to increase at a real rate of 1 per cent per annum (See footnote 53).

- The impacts on motor cyclist decisions and behaviour have not been investigated and estimated. Motor cyclists are estimated to contribute to around 13 per cent of all fatalities.
- Some effects have not been quantified, in particular the impact of:
  - encouraging high-risk drivers into less aggressive and safer vehicles, and
  - traditional insurance measures (e.g. use of deductibles) in encouraging safer road-use.

The modelling does not consider other government reforms to address road-safety. In theory these could equally apply to the baseline and other scenarios. However, success of insurance scenarios may reduce the pressure to introduce other reforms. For example, the lack of a graduated driver licensing system in the UK may be in part due to the effectiveness of insurance premiums and UBI reducing the need.

The results are, of course, sensitive to the assumptions. However, there does not appear to be any plausible assumptions under which there are not significant benefits to reform. For example, assuming there were no faster uptake of ADAS under the alternative scenarios and the benefits of UBI were capped at a 20 per cent reduction in fatalities, then the benefits relative to the baseline would be an annual reduction in 2027 of around 70 fatalities in the UK-Scenario and 170 fatalities in the Optimal-Scenario.

Furthermore, as noted in on page 4 in section 2.2, existing evidence (prior to the introduction of UBI) and expert opinion from other jurisdictions suggests there would be safety and cost benefits to changing the currently regulation.

Box 2: Approach and key assumptions

Approach and general assumptions

- Reductions in fatalities are estimated by selected risk-groups, categorised by type of vehicle and driver-age (e.g. heavy vehicles, drivers aged 80+). To avoid double counting, aggregate fatalities are allocated to risk-groups (see Appendix 5) based on primary responsibility for crash.
- Only selected effects are modelled. The percentage reductions by risk group and type of effect (whether, what and how to drive) are assumed to be cumulative.
- The reforms would be introduced in full by 2020.
- With the exception of AEB and autonomous vehicles, the reforms would have full effect by 2025. The adoption of AEB and autonomous vehicles is modelled by year for each risk-group.

Key assumptions by selected effect

- Whether to drive. Under Scenario 1 and 2 insurance premiums vary according to risk consistent with US experience (see Figure 1 on page 7). A 10% increase in the cost of driving reduces driving by 3%.
- AEB. In the baseline adoption is similar to that of ESC (lagged by 15 years). Under Scenario 1, the adoption rate in high-risks matches that of general population. Under Scenario 2 the adoption rate is brought forward by two years. Effectiveness is a 25% fatality reduction in the baseline and Scenario 1 and a 40% reduction in Scenario 2.

- Autonomous vehicles. The penetration of autonomous vehicles by scenario is identical to that of AEB with a 9 year lag. Effectiveness is 100% for the vehicles introduced.
- Warning systems. Warning systems have 20% effectiveness. In the baseline, adoption (for vehicles without AEB) is 10% for high-risks & high-use vehicles and 5% for other vehicles. Under Scenario 1 the adoption rate doubles. Under Scenario 2 the adoption rate doubles again.
- UBI. In the baseline, adoption of UBI is 10% for high-risks. Under Scenario 1 adoption is 60% for high-risks and 30% for high-users and 10% for others. Under Scenario 2 adoption is 90% for high risks, 50% for high users and 30% for others. Effectiveness in reducing fatalities by scenario is baseline (10%), Scenario 1 (20%), Scenario 2 (30%).

6.2 Other benefits costs and issues

Benefits

In addition to implications for road-safety, claims and insurance costs, there are ancillary benefits to the insurance scenarios.

Perhaps the most significant additional benefit will be in reducing vehicle use. Risk-based insurance pricing would increase the cost of additional driving, thereby discouraging people from driving. This would result in reduced vehicle congestion and environmental impacts associated with petrol consumption (i.e. carbon emissions and other air pollution) and vehicle noise.[55]

The alternative scenarios will likely lead to a greater use of in-vehicle technology to monitor and manage risk. There can be ancillary benefits to this technology including relating to vehicle tracking and security and communication in the event of a crash

Finally, the alternative scenarios may lead to a reduced cost (both in terms of direct financial expenditure and regulatory burden) associated with other regulations. For example, with appropriate insurance regulation, policy makers might revisit the need for some burdensome heavy-vehicle regulations. That is, it may lead to improved road-safety outcomes with a lower regulatory burden.

Costs and issues

There would be some additional costs with the discussed reforms. In addition to transitional costs, the reforms would likely lead to additional expenditure by insurers on risk identification and monitoring.

In summary the expected financial impacts of the policy are:

- a reduction in the financial costs associated with road crashes

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55 The external costs of vehicle use are (in small part) offset by some external benefits. For example, private vehicle owners contribute to the community by paying fuel taxes.

- an increase in insurer costs in identifying low-risks,[56] monitoring and influencing road-use choices, and
- a potential reduction in costs from other road-use monitoring and enforcement.

Existing evidence suggests that the aggregate financial impact would be positive, and therefore (in addition to the social benefits of safety) the financial impact to the *average* consumers will be positive.[57] That is, the reforms will result in safety benefits at lower financial cost.

Distribution of financial impacts by individual

The distribution of financial impacts will depend on how the reforms are implemented. For example, if under Scenario 2 financial penalties were imposed on insurers for at-fault crashes by their policyholders and the revenue raised was returned to road-users (e.g. through lump-sum reductions in the cost of vehicle registrations) then the average financial cost of owning a vehicle should decrease. In this case the net financial impact to an individual will depend on their relative risk. Potentially high-risks will be financially worse-off; however they may save money if they can cost-effectively reduce their risk (as perceived by insurers) to below that of the *current* average risk.

The proposals for risk-based insurance premiums may result in the substantially higher insurance premiums for high-risk drivers. While this has a benefit in terms of road-safety, it may raise concern for two reasons.

First, there is an equity concern that driving may become unaffordable for some people (such as the young and elderly) who insurers consider are high-risk. This issue may be significantly mitigated by the individual or by government-policy choices:

- Individuals may be able to significantly reduce their perceived risk and cost of insurance. They may do so by selecting less aggressive vehicles (which are generally cheaper), obtaining a usage-based insurance policy (see Section 5) and selecting vehicles with better safety technology.
- Equity concerns may be mitigated through policy choices. For example, a simple transitional option would be to use the money saved (from removing existing cross-subsidies) to provide financial support to the young and elderly whose insurance premiums may rise.

A second concern is that people whose insurance premiums increase will be more likely to drive uninsured. The international evidence suggests this is unlikely to be a material issue. In Europe where insurance premiums are largely unregulated the rate of uninsured driving varies most significantly with the method of compliance.[58]

56 Some of this expenditure could be wasteful if it does not result in any behavioural change.

57 See section 2.2. See also Tooth (2012) for an indicative analysis of CTP reform on UBI.

58 See EReg (2013, p.10).

6. Analysis of benefits — Key points

- Estimation of the impact of scenarios is challenging due to the far-reaching impact of the scenarios and the uncertainty over adoption and effectiveness of technology.
- Indicative estimates are that relative to the baseline:
  - Adopting the UK-Scenario will lead to 80+ fewer fatalities per year in 2027 and over 1,300 fewer fatalities in the 20 years to 2037
  - Adopting the Optimal-Scenario will lead to 300+ fewer fatalities fewer per year and over 5,000 fewer fatalities in the 20 years to 2037
- The societal value of the benefits of adopting Optimal-Scenario is around $6 billion per year in 2027 and around $100 billion over the 20-year period to 2037.
- A large portion of the benefits stem from greater use of usage-based insurance to manage driver risk.
- The estimates are highly indicative; nevertheless there are appear no plausible assumptions under which benefits are not significant.
- There would likely be additional benefits to reform in particular in reducing vehicle usage and associated congestion and pollution costs.
- There do not appear to be any major issues. The UK-Scenario is (in effect) implemented in the UK. Equity implications will depend on how the reform is designed and implemented.

7. Conclusions and next steps

7.1 Conclusions and discussions

This paper considers reforms to improve insurer incentives for road-safety:

- Scenario 1 (the UK-Scenario) whereby insurers have joint responsibility for BI and vehicle damage claims and price according to risk (as is the case in the UK and many other jurisdictions), and
- Scenario 2 (the Optimal-Scenario) whereby insurers also have the societally optimal incentives for safety.

The analysis in the paper indicates potentially very large road-safety benefits. Indicative benefits are an *additional* (to the baseline) reduction in the aggregate annual road-toll in 2027 of over 80 fatalities from the UK-Scenario and over 300 fatalities from the Optimal-Scenario. The societal benefits (in present-value terms) of the Optimal-Scenario are estimated around $6 billion per year in 2027 and around $100 billion over the period up until 2037. Sizeable benefits will continue to be received until fully autonomous vehicles replace the vehicle fleet.

As with all reforms there are issues to consider. However, the case for change appears solid based on evidence and expert opinion from international jurisdictions.[59] The case for change has been increasing, largely due to developments in UBI. The changes under the Optimal-Scenario potentially provide a foundation for regulation of many emerging road-use issues in particular relating to developments in automated technology.

7.2 Next steps

Despite the potential significance, there has been minimal investigation of reforming insurance markets to improve road-safety. Consequently there are many research gaps.

Given the potential significance of the benefits, the case for further investigation appears overwhelming. The research priorities may be categorised as relating to:

1. the case for change; that is, further analysis of the costs and benefits of reform
2. policy design; how the policy would be implemented
3. policy implementation; the road-maps to reform

Due to the wide-reaching implications there will be a large number of stakeholders to consider. Stakeholder consultation and engagement is likely to be important for gathering data, getting input on issues and ensuring the reforms are appropriately considered.

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59 Refer footnote 14.

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Appendix 1 Advantages of insurers in managing road-safety

In theory, it would appear that any activity undertaken by insurers to influence road-safety could be undertaken by a Government agency. However, in practice, it appears that due to competition insurers have advantages in undertaking some activities.

A benefit of competition is that it encourages firms to find cost-effective solutions that meet the needs of their customers. With regards to road-safety, with the right incentives, insurers would compete to innovate and identify the best programs, vehicles and technologies that improve safety without being overly burdensome or unreasonably restricting freedoms. Those insurers that failed to determine and enforce safe driving practices would face higher costs and be forced to modify their policies. Those insurers that enforce unnecessarily burdensome conditions would lose business to those that didn't.

The discipline imposed by competition appears to give insurers several advantages in managing risks to road-safety. These may be summarised as relating to:

- innovation and flexibility
- targeted risk management, and
- privacy.

As discussed below, each of these advantages appear to be increasing in significance.

Flexibility and innovation

Private insurers can more flexibly trial different initiatives and innovations than government agencies. Given the complex mix of technology, environment and behaviours, regulating and influencing vehicle choice and driver behaviour is difficult and particularly so given that there are multiple risk-factors that contribute to any incident.[60] Due to the needs to manage multiple stakeholders, the government regulation may take years to develop and once in place may be very difficult to change.

In contrast, a private insurer may introduce a new product or policy change with minimal consultation and remove it from the market should it not be successful. This advantage would appear to become more significant with increasingly complex developments in road-safety technology.

Furthermore, there is a risk that government regulation stifles innovation. A particularly relevant example relates to the implementation of telematics-enabled usage-based insurance, which is growing rapidly in many jurisdictions but whose growth in inhibited in jurisdictions where there is stringent regulation of insurance premiums.[61] In contrast, in a competitive

60 See for example Anderson et al. (2014, pp. 138-140).

61 See for example 'California taps the brakes on insurance telematics' by Susan Kuchinskas, TU-Automotive available here.

market place, the activities of one insurer do not inhibit the ability of another insurer to innovate.

Targeted risk management

A common concern is that governments lack the competitive pressure and the market discipline to manage risks efficiently and target policies based on risk.[62] A prominent example is the lack of risk-based pricing for BI cover in government schemes in Australia and New Zealand. This is common in other insurance markets (e.g. catastrophe cover schemes relating to earthquake and flood) and is common in many road-safety policies. For example, the benefits of vehicle safety are greatest among highest-risk drivers; however (with minor qualifications) government regulations of vehicles apply equally to all full-licence holders.

In contrast, in a marketplace, insurers are rewarded according to their ability to manage societal risks. Competition drives insurers to invest in identifying the highest risks and then use a combination of penalties and rewards to reduce the risk. For example, a high-risk policyholder will be encouraged to have a higher excess which provides greater incentive for the high-risk to take more care.

The significance of targeted risk management appears to be increasing as technology increases insurers' ability to target high-risks, monitor risky behaviour and encourage adoption of new safety technologies.

Government resistance to risk-based discrimination is commonly justified on the basis of equity.[63] However, this argument appears to have much lesser relevance with regards to road-safety; arguably all licenced drivers are capable of driving more safely than the current average risk and any disadvantage affecting the young is a temporary disadvantage that applies to all people.

Privacy

Privacy is an increasingly important issue in road-safety management as a result of new in-vehicle (i.e. telematics) technology that can be used to track how vehicles are used.

Insurers also have an advantage in tracking vehicle use. Whereas people willingly volunteer their driving behaviour information to insurers to get lower insurance premiums (as evidenced overseas) it seems likely that privacy concerns would restrict governments from collecting such information.

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62 See Priest (1996) for a discussion.

63 Governments regulate against health insurer's discriminating on the basis of genetic information.

Appendix 2 Evidence of safety benefits from ADAS

Technologies

There are a range of advanced driver assistance systems (ADAS) that have potential safety benefits. The key technologies considered in this report are categorised as warning systems and autonomous systems. These include the following.

- Warning systems
  - Blind-Spot Monitor (BSM) — Detects other vehicles located to the driver's side and rear and provides warnings to the driver
  - Headway Monitoring Warning (HMW) — Assists the driver in keeping a safe driving distance from the vehicle ahead
  - Forward Collision Warning (FCW) — Alerts the driver of an imminent rear-end collision with the vehicle ahead
  - Lane Departure Warning (LDW) — Alerts the driver if the vehicle has unintentionally deviated from the road towards the lane boundary or marking.
  - Overtaking assistant (OA) — Monitors the road ahead and assists the driver as to safety of an overtaking manoeuvre
  - Pedestrian Collision Warning (PCW) — Alerts the driver to the danger of an impending collision with a pedestrian (or cyclist) ahead
- Autonomous systems
  - Adaptive Cruise Control (ACC) — A cruise control system that automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead
  - Autonomous Emergency braking (AEB) — A system that acts independently to the driver to improve or apply braking in a critical situation
  - Lane Departure Prevention (LDP) — Directly modulates vehicle trajectory using various modalities, including steering or selective braking of the vehicle's wheels.

Many of the warning systems can be installed after-market. For example, an after-market Mobileye system, which can be installed for a one-time cost of around $1500, includes FCW, LDW, PCW and HMW. A BSM system, which involves different componentry, can be installed for less than $600.[64]

The autonomous systems (which will generally include warning systems) are only practically installed only at the time of manufacture. There are many variations in these systems

64 http://parkpro.com.au/blind-spot-detection-system/

The safety benefits of ADAS

Approaches to estimating safety benefits

Estimating the potential safety benefits of ADAS has involved several approaches.

1. Simulation studies

A common approach involves simulation studies that use details of actual crash data and an estimate "what would happen if" ADAS had been installed. The results of analysis on a set of crashes are extrapolated to estimate the full safety benefits. The approach can be applied to almost any technology and generally the volume of data is not an issue.

However, the estimates are theoretical. Estimating real benefits needs to take account of driver behaviour (including decisions to switch off the device)[65] and the design of the human-machine interface (e.g. a braking-assist system requires that the driver initially uses the brakes). A further risk is that the estimated safety benefits will be overstated because benefits will in part be offset by changes in driver behaviour who, as a result of the ADAS, take less care.[66]

2. Comparison of actual crash data

Another common approach involves comparing the rate and severity of crashes of vehicles with the ADAS installed with that of a control group of vehicles without the technology. The Highway Loss Data Institute (HLDI) (2015a, 2015b, 2015c) has undertaken a number of studies using this approach in the US.

A key issue with this approach is the limited data. As this approach relies on installed devices, these studies tend to be limited in only applying to a limited set of ADAS for the more common vehicles. A related data issue is in finding an appropriate control group. The people who purchase vehicles with ADAS are not a random sample; they tend to be more wealthier and more conservative drivers (in what is known as the "Volvo effect").

3. Field operational test (FOT)

Field operational tests involve observing the performance of ADAS in a selected group of test vehicles (e.g. 50 to 100 vehicles). These include naturalistic experiments whereby observation aims to unobtrusive as possible.

Results – warning systems

A summary of key studies is provided in the table below. Most studies are limited in some way; for example, in terms of crashes examined (e.g. rear-end collisions only), technologies (e.g. AEB only), vehicle types (e.g. trucks only) or analysis (e.g. considers crashes avoided but not the reduction in severity).

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65 For example, there are reports of many drivers switching off the lane-departure warning technology http://www.iihs.org/iihs/sr/statusreport/article/51/1/4

66 This is commonly known as the Peltzman effect. An extreme example of this is the case of a Tesla driver killed as a result of relying on autopilot. (https://en.wikipedia.org/wiki/Tesla_Autopilot)

The evidence suggests the two most significant impacts relate to systems that assist with preventing or mitigating the impacts of:[67]

- forward collisions (which include rear-end crashes, collisions with objects and pedestrians), and
- road departures, which although less common are associated with a high proportion of fatalities and severe injuries.

The benefits of ADAS on forward collisions were examined in an Australian study (Anderson et al. 2012). The authors examined the potential of forward collision avoidance technology (FCAT, i.e. autonomous braking systems) to prevent and mitigate the impact of a number of crash-types (not just rear-end crashes). They estimate that FCAT may prevent 20 to 40 per cent of all fatalities and 30 to 50 per cent of all injuries caused by the motor vehicles involved. Other studies (e.g. Kusano and Gabler, 2012) suggest around 60 per cent of the benefit comes from warning systems.

Road departures are responsible for a round one third of motor vehicle fatalities (Scanlon et al. 2015). Available evidence suggests land departure systems (LDW & LDP) have potential to reduce the number of fatalities associated with road-departures by around 20 per cent (LDW) and up to 30 per cent (LDP) thereby preventing another 10 per cent of motor vehicle fatalities.

In combination, it appears that FCAT, LDP and other systems[68] could reduce up to 50 per cent of fatalities and that around 60 per cent of this benefit (i.e. ~30 per cent) could come from warning systems.

There is evidence of similar benefit of ADAS in heavy vehicles (Orban et al 2006, Battelle 2007, Fitch et al 2008).

Table 2: Evidence of safety benefits from in-vehicle technologies

Author	Key results
Anderson et al. (2012)	Applied a simulation approach to estimate benefits of forward collision avoidance technology (FCAT). The authors developed estimates for several technologies that varied by dimensions that included detection range and braking technology. Key findings include: • Reductions in fatalities and injuries from relevant forward collisions varied between 30 and 56 per cent for fatalities and 32 and 67 per cent for injuries. • Forward collisions are responsible for around 70 per cent of all fatalities and injuries. • FCAT may prevent 20 to 40 per cent of all fatalities and 30 to 50 per cent of all injuries caused by the vehicles involved.

67 There is potential overlap as some collisions are the result of road departures.

68 Other technologies that may provide a material benefit include ACC, OA and BSM.

Author	Key results
Battelle (2007)	Undertook a FOT on the effect of ADAS in heavy vehicles. Results in heavy vehicles • FCW alone — 21% reduction in heavy vehicle rear-end collisions • FCW+ACC+AB — reduce the number of rear-end crashes by 28% • Driver acceptance was positive for FCW but much less so for ACC
Cicchino (2016)	Used similar approach to the HLDI (2015a, 2015b, 2015c). Found FCW alone and FCW with AEB are effective in reducing rear-end crashes.
Fitch et al (2008)	Used FOT data to simulate the effect of FCW in heavy vehicles. Estimated 21% reduction in heavy vehicle rear-end collisions
Doyle et al (2015)	Analysis of UK claim losses relative to cohort (similar to HLDI studies) • 21% reduction in BI claims costs for low-speed AEB on Volvo XC60 • 45% reduction in BI claims costs for long-range radar AEB in Golf 7
HLDI (2015a)	Examines the collision avoidance features on the Honda Accord (one of the best-selling passenger vehicles in America) which for some models has FCW (some based on camera system and some based on a radar system), LDW and ACC. Key results: [69] • For FCW and LDW, reduction in BIL claims (24%) and medical payment claims (22%) • For BSM (known as LaneWatch) results are equivocal.
HLDI (2015b)	Used actual claims experience to estimate the collision avoidance benefits of Subaru's EyeSight system which includes FCW with AEB, ACC and LDW and a rear-vision camera system. Results are mixed with a 35% reduction in BIL claims but an increase (but not statistically significant) in medical payment claims.
HLDI (2015c)	Used actual claims experience to estimate the collision avoidance benefits of Volvo with City Safety, a low-speed collision avoidance technology. Key results are a 19% to 31% reduction in BI claims.

[69] The types of human cost claims vary by US state (due to different regulations). The different forms are:

- Personal injury protection — covers medical expenses and, in some cases, lost wages and other damages of driver passengers and pedestrians hit. (Available in states that have enacted no-fault laws)
- Bodily injury liability (BIL) — covers losses to other people when the insured vehicle's driver is at fault.
- Medical payment — covers without regard to fault injury losses to driver, others riding in the vehicle, and pedestrians struck by the vehicle (available in states with traditional tort liability laws)

Author	Key results
Hummel et al. (2011)	Applied a simulation approach to estimate the safety potential benefits of various ADAS using insurance claims data in Germany. The headline result is AEB could potentially avoid 43 per cent of crashes caused by motor vehicles. However, following adjustments for the human-machine interface the real safety-potential is reduced to 37 per cent reduction. The authors also estimate the reduction in fatalities and serious injuries; however these results do not appear to include the benefits of reduce severity of crashes. The (theoretical) reduction in fatalities from ADAS (for motor vehicles) included LDW 10%, BSM 1.5%, OA 5% and AEB 5%.
Kusano and Gabler (2012)	Applied a simulation approach based on minor to severe rear-end collision crashes that occurred in the US between 1993 and 2008 to estimate the effect of FCW and FCW combined with pre-crash break assist (PBA) and pre-crash braking (PB i.e. AEB). Key results for rear-end collision crashes: • FCW would result in 3.2% rear-end collisions avoided and 29% reduction in injuries (belted drivers) from rear-end collisions. • FCW+PBA+PB would result in 7.7% rear-end collisions avoided and 50% reduction in injuries (belted drivers) from rear-end collisions.
Moore & Zuby. (2013)	Used HLDI data correlating claims frequency and severity with presence of in-vehicle collision avoidance systems attempting to control for other features captured in insurance data (including age, gender, deductible). Many results not statistically significant. Results appear to be superseded by Cicchino (2016).
Orban et al (2006)	Undertook a FOT on the effect of LDW in heavy vehicles. Results • 31%+ reduction in conflicts due to LDW • Driver acceptance mixed but broadly positive for FCW
Scanlon et al (2015)	Applied a simulation approach to estimate the safety benefit of LDW and LDP to reduce likelihood and severity of lane departure crashes. Key estimates: • LDW alone reduces crashes by 26% and seriously injured drivers by 21% • LDP reduces crashes by 33 to 37% and seriously injured drivers by 26 to 31% • LDP with autonomous driving reduces crashes by 51% and seriously injured drivers by 46%.

Appendix 3 The impact of traditional insurance on driving behaviour

Detecting the impact of insurers on driving behaviour is difficult. Generally the research has focussed on the reverse question; that is, how much does insurance cover create a moral hazard problem by *reducing* the financial cost of an accident and thereby reducing incentives for safety. A challenge is that it is difficult to distinguish this moral hazard relationship to an adverse selection problem whereby the higher risks take out more cover.

A common strategy is to examine differences in accident rates between groups who incur the accident cost and those who do not. For example, Schneider (2010)[70] investigates differences in driving behaviour between taxi owners and leasers in New York City. Owners bear more of the accident cost due to the additional costs of insurance premium increases. Having controlled for a wide range of observable differences in driver characteristics, Schneider finds that moral hazard (of leasing rather than owning) increases the accident rate by 16 per cent.

Similarly, Weisburd (2013) examines the differences in the rate of accidents of workers in Israel between those whose auto-insurance is paid for by the company (as a fringe benefit) and those who have to obtain private insurance. He estimates for workers who obtain private insurance the additional cost of an accident as a result of a higher deductible and increases in premiums in following years. He found 'that a $100 discount in accident costs increases the likelihood of an accident by 1.7 percentage points.'[71]

Weisburd (2013) notes other literature that has found evidence of moral-hazard effects caused by insurance. Dionne et al. (2013), for example, notes that 'when accidents and the bonus-malus are held constant, more insurance coverage leads to more accidents'.[72] Dunham (2003) estimates that fleet vehicles depreciate approximately 10 to 13 per cent faster per year than owner-driven vehicles, which he partly attributes to a moral-hazard effect.

Another approach is to compare safety outcomes and insurance costs vary with differences in regulation that restrict risk-based pricing. There is some empirical evidence that restrictions in the variance of premiums leads to higher crash rates and claims costs. Key studies include:[73]

- Tennyson (2012) in reviewing the effects of reforms in Massachusetts, South Carolina, and New Jersey found evidence that the reforms led to improvement in crash rates (as measured by property damage claims) and the severity of crash rates (as measured by the ratio of bodily injury claims to property damage claims).

70 As reported in Weisburd (2013, p. 6).

71 Weisburd (2013, p.3).

72 Dionne et al. (2013, p.35).

73 There is also significant evidence that financial incentives influence driving behaviour. For example, Cohen and Dehejia (2004) found evidence that, consistent with the proposition that financial incentives affect safety, no-fault compensation schemes weaken incentives for safer driving.

- Weiss et al. (2010) examined the distorting effect of rate regulation by analysing data for the 50 US states over the period 1980 to 1998. Specifically they examined the factors that influence insured loss costs (defined as total automobile liability losses, including loss-adjustment expenses, divided by the number of cars insured) and accident claims frequency. They concluded (p. 597) that their results 'suggest that rate regulation that systematically suppresses (some or all) drivers' insurance premiums is associated with significantly higher average loss costs and higher insurance claim frequency.'
- Derrig and Tennyson (2011) examined evidence from Massachusetts, comparing the effects of regulation with other states and the effect of geographic differences in insurance cross-subsidies within the state. They found (p. 1) 'a significant and positive (relative) growth in loss costs for towns that were subsidy receivers'.

Appendix 4 Evidence on the impact of UBI

Overview

There are several potential methods by which to assess the impact of UBI. These include:

1. Experience from the insurance industry including from companies providing UBI policies, from fleet industry providers, and from insurance aggregators on premium discounts that are achieved

2. Field experiments involving controlled studies of driver behaviour in response to incentives or feedback

3. Analysis of relationship between distances travelled and accidents

4. Cross jurisdictional comparisons.

Neither method is ideal. The following sub-sections review the evidence and issues from each method based on a review by the author in mid-2015.

Evidence from the insurance industry

From UBI providers

UBI providers have a number of advantages relative to other research sources to assess the impact of UBI. In contrast to field experiments, UBI providers are testing real-world situations and actual programs. UBI providers have access to substantial information on driver behaviour, vehicle crashes and claims from existing policyholders. Using this information, several UBI providers have made claims as to the impact of UBI on safety and insurance premiums.

A key concern with the claims made by the UBI providers is that they have an interest in promoting the effectiveness of UBI to both consumers and policy makers. Furthermore, there are numerous challenges for UBI providers in estimating the impact of UBI from the data they collect. Two key issues are that:

1. there is a selection bias — drivers selecting a UBI product may do so because they wish to demonstrate that they are lower risk, and

2. there are confounding factors when examining changes over time. Over time people gain maturity and experience thereby reducing their risk of crash.

A summary of some of the claims by UBI providers is shown in Table 3 below. There is some consistency in the claims. Two major UK UBI providers (ingenie and insurethebox) have claimed reductions in accident risk of more than 35 per cent in young drivers. Other earlier sources were claiming 20 to 30 per cent reductions in claims.

Unfortunately, none of these provider claims have been independently verified. Furthermore there appear reasons to question some of the claims. For example, the ingenie claim of a 40 per cent drop in crash risk is based on comparing the accident rates of their policyholders during their first 6 months of driving (1 in 8) with a national survey of young drivers (1 in 5). However, their policyholders may be a biased sample and the comparison survey was conducted over 10 years previously.[74] In contrast, insurethebox, in making its claim of a 35 to 40 per cent reduction, noted that their research had controlled for selection bias.[75]

In addition to accident rates, other claims made by insurers include that:

- UBI results in lower severity of accidents and therefore lower average costs of claims
- The average premium paid by high-risk drivers is lower with UBI, and
- UBI customers state that their driving improves as a result of UBI.

Table 3: Key claims from UBI providers

Topic	Key results
Accident rate – young drivers	• 40% drop in crash risk for new drivers with a telematics policy compared to those without (ingenie 2014) • The use of telematics to encourage better driving reduces accidents involving young motorists by 35% - 40% (insurethebox, 2012) • Due to Norwich Union's UK 'Pay as you drive', claims by young drivers have fallen by over 30%. (Aviva *Corporate Social Responsibility report* 2008, p. 13). • 20% drop in car accidents thanks to telematics insurance (The Co-operative Group, 2012 & 2013).
Average cost of claim	• Average cost of a claim is 30% lower among young drivers with a black-box [telematics UBI policy] (The Co-operative Group 2013)
Average premium	• In trial of Norwich Union's UK "Pay as you drive" young drivers' premiums fell by approximately 30%. (Aviva *Corporate Social Responsibility report* 2007, p. 6)

74 The comparison sample comes from a 2008 report (Wells et al 2008) that used survey data from 2001 to 2005.

75 Specifically they stated "The use of telematics to encourage better driving reduces accidents involving young motorists by 35% - 40%, according to statistics released by motor insurer insurethebox. The conclusion follows analysis of more than 300 million miles of driving data from the company's customers, making it by far the most extensive and reliable research of its kind ever undertaken in the UK. Unlike previous exercises of this type, the research takes into account factors such as the likelihood that people who buy telematics policies are more likely be to more careful drivers in the first place, and the improvement that takes place naturally as young motorists learn from experience. The company's data show a greatly reduced likelihood of causing an accident between the first month after customers buy their policies and the final month of their first year. Although this improvement applies across the board, drivers aged 17-21 show the greatest progress, being 75% less likely to be responsible for an accident after they have been insurethebox customers for eleven months."

Topic	Key results
	• A third of customers aged 18–23 are saving at least 40% on their premiums. (Aviva *Corporate Social Responsibility report* 2008, p. 13) • Average saving made by drivers 25 and under when they buy an insurethebox policy is £585.[76] • Drivers have saved […] on average in their first year […] a discount of 15 per cent. (The Co-operative Group, 2015).
User feedback	• '80 per cent of young drivers with experience of a black box insurance policy told our nationwide poll that it had helped or was helping them to become a better, safer driver.' (ingenie 2014, p. 27).
Behaviour response to feedback	• [I]n nine out of 10 cases, their advisers were able to influence a positive change in the driver's attitude, resulting in long-term safer driving. (ingenie 2014, p. 27). • Telematics data shows that 74 per cent of drivers improve in the first 10 days after their call with the driver behaviour unity (DBU); 84 per cent after 20 days; and 90 per cent after a month, suggesting long-term behaviour change. Even among those customers that the DBU is unable to make personal contact with, 59 per cent improve a month after receiving a voicemail and email reminder to be more aware of their driving behaviour: awareness can have a big impact. (ingenie 2014, p. 34).

From fleet industry providers

A number of parties have made claims as to the benefits of telematics solutions for fleet applications. Such claims are not independent sources. Examples include:

- '[clients using a telematics system] see more than a 20-percent reduction in actual incidents'[77]
- Iron Mountain (a UK records management company) used a telematics system to achieve a 70% overall reduction in incidents over four years and a 57% reduction in own-damage and third-party costs and 14% reduction in insurance premiums.[78]

Insurance comparators

Another source of evidence is provided by insurance brokers/comparators who obtain quotes for individuals. The difference in the quotes obtained between traditional policies and UBI policies is an indication of the benefit provided by UBI; that is, we would expect that lower insurance premiums from UBI reflect lower claims costs and reduce risk of crashes.

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76 Source: https://www.insurethebox.com/insurethebox-in-numbers.

77 http://www.automotive-fleet.com/article/story/2011/12/how-to-sell-fleet-safety-to-your-drivers.aspx.

78 See http://www.brakepro.org/assets/docs/practitioner-tools/fleet-guidance-14-conference-technology.pdf.

This approach has a number of advantages. First, a comparator is not a UBI provider and therefore independent of the findings. Second, the risk of selection bias is reduced as the results apply to quotes provided to young drivers, not just those who have opted for a UBI policy.[79]

There is evidence from insurance comparators that young high risk drivers can substantially reduce their premium by taking a UBI policy. The comparator moneymarket.com estimates that by switching to a UBI policy (assuming they meet the targets of their policy):[80]

- those in the 17 to 19 age group stand to save £438 on the annual cost of car insurance – equivalent to 20.6 per cent;
- those aged 20-24 save up to £169.78 – or 12.9 per cent; and
- those aged over 25 save up to £117.67 – or 10.1 per cent.

Similarly the British Insurance Broker Association claim that '[UBI] policies can offer savings of up to 25 per cent for careful drivers. In particular, young drivers who often struggle to find affordable cover can save up to £1,000'.[81]

The quoted saving on insurance premiums may differ to changes in expected claims costs. For example, the premium saving may be less than the expected reduction in claims cost because of the additional administrative costs associated with providing a UBI policy.

Field experiments

Field experiments involve controlled studies whereby a group of drivers are studied and encouraged with financial incentives and/or feedback to change behaviour. Often these experiments involve comparison against a control group (who do not receive the same incentives) and/or a control period during which incentives are not provided.

Field experiments can provide evidence of the ability of UBI to change behaviour by attempting, in a controlled setting, to replicate the impact of a commercial UBI product. These experiments have been used to examine the effect of incentives and feedback on behaviours such as speeding, night-time driving and distance travelled.

Advantages of field experiments are that:

- they can be conducted by independent organisations (i.e. not providers of UBI), and
- they can involve the use of a control group and thereby reduce the risk of selection bias.

There are also numerous limitations to field experiments. First, due to the expense, the sample sizes are generally very small. As a result the experiments focus on predictors of crashes (e.g. distance travelled, speeding and night-time driving) rather than the number of

79 Some selection bias still remains as UBI providers may quote with the knowledge that young drivers who select UBI will be generally safer.

80 Boyce, L. (2014). 'We're not all hooligans!': Safe young drivers rewarded with 20% saving on premiums thanks to 'blackbox' insurance. This is money. February 2014.

81 British Insurance Brokers' Association (2015). Nine per cent increase in telematics based motor insurance policies: BIBA calls for new Government to provide young driver insurance tax break. Retrieved from http://www.biba.org.uk/MediaCenterContentDetails.aspx?ContentID=3868

crashes. An additional step is therefore required to translate the predictors of crashes into accident rates.

Second, the behaviours monitored and incentives provided will generally be more limited than real UBI policies. For example, UBI providers may monitor more behaviours (e.g. acceleration and braking speed), use other incentives (e.g. bonuses rather than piece-meal rewards) and employ a range of feedback approaches (e.g. ingenie's DBU) that are not used in field experiments. As a result field experiments may understate the impact of UBI in the real world.

Finally there are other traditional issues with conducting experiments. These include the following:

- There are still some potential selection issues in recruitment. The people signing up to be monitored may not be representative of the population who will choose UBI. For example, while Bolderdijk et al (2011) studied young people, the recruitment was up to age 30. The highest risk drivers for whom UBI is most popular will be less than 25 years old.
- There are some experimental issues, such as controlling for the Hawthorne effect whereby individuals change their behaviour, simply because they are being observed.

Broadly the field experiments that are relevant can be categorised by how behaviour is being influenced. Some experiments involve provision of financial incentives. Some experiments simply involve provision of feedback.

The devices installed in field experiments are sometimes referred to as in-vehicle data recorders (IVDR). A number of these experiments have included the use of intelligent speed assistance (ISA), whereby in response to speeding drivers receive real-time feedback or the driving systems of the vehicle are automatically controlled to reduce the vehicle's speed.

A summary of the results of some of the field experiments involving financial incentives is provided in Table 4 below. Generally the studies all provided support for the hypothesis that UBI programs could reduce risk behaviour. As recorded in the table below, a number of studies have found significant reductions in speeding and distance travelled.

A summary of the results of some of the field experiments involving just feedback is provided in Table 5 further below. The results of these studies also suggest that feedback alone can be significant in changing behaviour.

Table 4: Field experiments on UBI

Study	Description	Key conclusions/results
Stigson et al (2014)	Swedish one-year PAYS trial with 196 private insurance customers (all ages). Economic incentives for keeping to speed limits using ISA that provided real-time feedback. The full incentive was a 30 percent discount off the insurance premium.	PAYS concept is an effective way to reduce speed violations. The proportion of driving at a speed exceeding 5 km/h over the speed limit was 14% for the control group and 6% for the test group (i.e. more than a 50% reduction)

Study	Description	Key conclusions/results
Greaves, S., & Fifer, S. (2010).	Study of 125 Sydney motorists over 5 weeks with monitoring technology. Participants were given financial incentives to reduce their vehicle kilometres travelled (VKT), night time driving, and speeds.	Those who made-money significantly reduced speeding, night-time driving and VKT. Around 40% did not make money. Overall VKT were reduced by 10% and there was a net reduction of kilometres spent speeding of over 40%.
Bolderdijk et al (2011)	Dutch study of 141 participants < 30 years. Financial incentives given to reduce speeding, distance travelled and night-time driving.	Reduced volitional speeding by 14% in young drivers. No demonstrable change in distance travelled or night-time driving
Buxbaum (2006)	130 participants were outfitted with an electronic device which recorded mileage and time of travel. Prices per mile were assigned randomly to each participant, ranging from 5 cents per mile to 25 cents per mile.	Wide-scale per-mile pricing results in small reductions in driving, mainly on weekend driving and on peak weekday travel. Marginal effect of per mile prices not necessarily seems to increase the mileage reduction of households.
Mazureck & van Hattem (2006)	Dutch study on impact of feedback and rewarding on driving behaviour. Data was collected by objective measurement (in-car systems data on speed and distance) and subjective measurement (web questionnaire and open interviews).	Rewards have a very strong positive effect on safe driving behaviour. Distance covered at the correct speed increased from 68 % to 86 % on weekdays. Distance covered at a safe distance from car in front increased from 58 % to 77 %. Most drivers lapsed into their old habits at the end of the experiment where the reward was at its lowest level for the whole trial.
Biding & Lind (2002)	A large scale trial between 1999 and 2002 in Sweden of ISA	'If everyone had ISA, there could be 20% fewer road injuries in urban areas'

Table 5: Field experiments on UBI with just feedback

Experiment	Description	Conclusions/results
Dijksterhuis et	Two groups of 20 participants drove	Speeding events decreased by over

Experiment	Description	Conclusions/results
al. (2015)	with a behavioural based system in a driving simulator and were provided with either delayed feedback through a website, or immediate feedback through an in-car interface	90% compared to the baseline. The study also showed a moderate advantage of using immediate in-car feedback.
Farah et al (2014)	Investigated impact of feedback and guidance on the driving behaviour of young male drivers (17-22) during their first year of driving. IVDR was installed in 217 family cars, which were divided into four feedback groups.	Providing feedback on driving behaviour and parental training in vigilant care significantly improves the driving behaviour of young male drivers. (29% reduction in events compared to the control group).
Kwan and Boodlal (2014)	Study of truck drivers. Examined before and after effects of a safety program involving feedback, coaching, and rewards on day cab drivers and sleeper cab drivers.	Reductions (60% in severe and 55% less severe) in unsafe events recorded for sleeper cab drivers. Reductions (42% sleeper cabs, 32% day cabs) in % of miles speeding. Improvements in fuel economy.
McGehee et al. (2007)	Explored the effectiveness of feedback in modifying the behaviour of teenage drivers.	Results suggested a significant decrease in the number of incidents for the more at-risk teenage drivers. However, as the study did not assess a baseline group (i.e., drivers with no feedback), they were unable to determine the exact benefits of feedback.
Wouters and Bos (2000)	Study on vehicle fleets using vehicle data recorders. Used behavioural feedback by confronting drivers with their recorded driving actions. Relatively large sample (3100 vehicle years and 1836 road accidents).	Average estimate accident reduction of 20% from behavioural feedback.

Distanced based research

Another approach, which is only practical for the impact of UBI on distance driven (usually estimated in terms of VKT or vehicle miles travelled (VMT)), is to leverage existing analyses on the responsiveness of drivers to the cost of driving.

The basis process of this research involves:

1. Estimating the additional cost per kilometre (or mile) of driving under a distance-based policy relative to a traditional motor insurance policy
2. Using previously determined price elasticities of demand (with respect to the fuel price) for driving to estimate the impact on distance travelled.
3. Estimating the safety benefit based on existing analyses that correlate safety with distance travelled.

Such analysis is *relatively* inexpensive and straightforward to conduct. A significant limitation is that the benefits quantified are limited to distance travelled and do not include other changes in driving behaviour.

The results depend on other analysis and assumptions made in each of the three steps above.

A critical assumption is the per-mile cost of insurance under PAYD that is estimated under step 1 above. The relationship between distance travelled and road-crashes, claims and premiums is complex. While it is clear that driving greater distances increases the risk of road-crashes, there are many factors. These include that:[82]

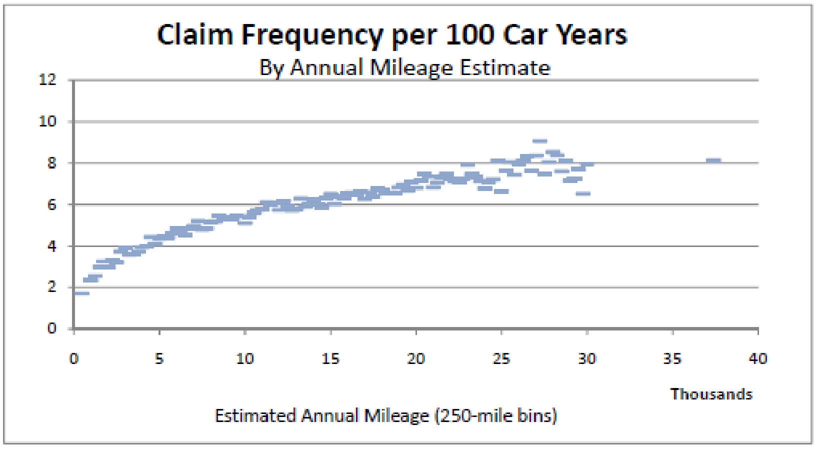
- in aggregate, motorists that drive more tend to have fewer accidents per VMT
- new and safer vehicles get driven more
- urban drivers crash more and drive less
- higher mileage driving tends to be on safer roads, and
- drivers who would most likely respond to UBI policies are the young who are at most risk of an accident.

Furthermore, a challenge to estimate the benefits of UBI or risk-based pricing is that it is necessary to estimate the benefits that are incremental to the pricing of traditional insurance.

A useful example (perhaps the most rigorous) of the analysis is by Ferreira & Minikel (2010) on the potential for PAYD insurance in Massachusetts in the US. They analysed a large dataset linking policies and associated claims in the 2006 policy year to mileage estimates based on odometer readings at mandatory safety checks. Figure 6 below is an example of the analysis that highlights (unsurprisingly) that claims frequency increases with mileage but at a declining rate.

[82] See Bordoff & Noel (2008, p. 7)

Figure 6: Claims frequency and distance travelled (Massachusetts)



Source: Ferreira & Minikel (2010, figure 6).

Calculating the per-mile cost also requires consideration of the existing rating factors on insurance premiums. To adjust for these, the authors apply a multivariate regression model to estimate how insurance losses vary with mileage after adjusting for class (the type of driver) and territory (location). They conclude if PAYD insurance was applied the average driver would pay around 7 cents per km and the highest-risk customers around 30 cents per km.[83] These rates are slightly higher that what insurers appear to advertise,[84] but appear reasonable against some measures.[85] This is a significant increase in the per-mile costs of driving; for the highest risk drivers it is more than double the fuel cost.

The second step involves estimating the impact of higher costs on driving habits. Many estimates of this effect have been derived from analyses that link fuel-prices to driving behaviour. The most commonly used estimates are that the price elasticity of demand for distance travelled with respect to the fuel price is around -.15; that is, a 10 per cent increase in costs leads to a 1.5 per cent reduction in distance travelled.[86]

The final step involves quantifying the benefits in terms of accident reduction. This is, of course, closely related to the first step in the analysis. However, it also takes into consideration the effect of multi-vehicle crashes. There is some useful empirical evidence based on factors that affected both distance travelled and accident rates that indicates that the reduction in vehicle accidents would be greater than the reduction in distance travelled. For example, a recession in 1981–82 caused a 10 per cent reduction in VMT and a 12 per

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83 Source: Ferreira & Minikel (2010, p. 3). Converted to AUD from USD at 1.29 AUD per USD.

84 Amaguiz (France) gives examples of charging 1.8 to 3.3 Euro cents per km (3 to 5 cents per km) Source: http://www.amaguiz.com/assurance-auto/tarif-assurance-voiture-payd. MetroMile (US) charges 2 to 5 US cents per mile (2 to 4 cents per km). Source: http://www.techhive.com/article/2083340/driving-with-data-metromile-app-is-nice-but-the-pay-per-mile-insurance-is-the-real-draw.html.

85 Zantema et al (2008, p. 3) notes that Norwich Union charged £1 ($2) per km for young people to undertake night-time driving.

86 That is a price elasticity of demand of -.15 has been used. See for example Bordoff & Noel (2008)

cent reduction in insurance claims in British Columbia.[87] Litman (2011, p. 10) argues that 'most studies indicate that each 1.0% mileage reduction provides about 1.5% in total crash costs'.

There have been a number of studies that have estimated the impact of PAYD on VMT. Most studies suggest that a roll-out of PAYD would reduce VMT in the order of 9 to 10 per cent.[88] Most studies do not present a percentage reduction in crash costs — however (as discussed in the paragraph immediately above), this is generally assumed to be greater than the reduction in vehicle distance travelled. Zantema et al (2008) is an exception; they estimate a roll-out reduce total crashes by of more than 5 per cent.

Another approach undertaken by Burke and Nishitateno (2015) is to examine the variation across countries between fuel-prices and road-crashes. The authors use this approach to estimate that a 10 per cent increase in fuel prices would reduce road-fatalities in the order of 3 to 6 per cent.

Cross jurisdictional comparison

If UBI has an impact of reducing the rate of road-crashes then (all else being equal) jurisdictions with higher take-up of UBI should demonstrate lower levels of crash rates.

However, there are numerous issues with this approach. All else is not equal – different jurisdictions differ significantly in other factors that affect crash rates. These differences including vehicle characteristics, driver behaviour (including cultural differences and economic differences), extent of road-safety policing, road-network characteristics (e.g. size of road network, quality of roads).

It might be possible to control for inter-jurisdictional differences by examining changes overtime (which helps control for fixed effects) and other variables. However there are challenges with this strategy. These include that:

- the take-up of UBI may be correlated with other measures. For example, the decision to introduce a road-safety measure may depend on the impact of UBI.
- the volume of available data is low. The penetration of UBI until recently has been very low and given the noise from other factors, the overall impact will be difficult to detect.

Due to the above difficulties, cross-country comparisons of road-safety that attempt to isolate the impact of a particular road-safety policy are rare. An exception is the US, where there are multiple jurisdictions within a common country. However, to-date there are no inter-jurisdictional studies on the impact of UBI (to my knowledge).

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87 Bordoff & Noel (2008, p. 7) noting evidence from Litman (2005). They also note that Edlin (2003) estimated a 10 per cent reduction in VMT would lead to a 17 per cent reduction in total crashes.

88 These include Bordoff & Noel (2008), Ferreira & Minikel (2010) and Litman (2011). Nichols and Kockleman (2014) estimate the average (light-duty) vehicle will be driven 2.7 % less with PAYD insurance, however it is not clear whether this is a comparable basis.

Appendix 5 Modelling details

Approach and key assumptions

The modelling estimates the reduction in fatalities under each scenario due to the following effects.

- Young and very-old drivers opting not to drive as a result of a change in insurer incentives
- Changes in vehicle technology relating to introduction of AEB, autonomous vehicles and warning systems
- Changes in driver behaviour as a result of UBI.

Other changes impacting on the number of fatalities are ignored.

Modelling is conducted by year to allow for penetration of AEB and autonomous vehicles into the vehicle fleet. Changes not dependent on vehicle manufacture are assumed to be implemented in 2020 have a full effect by 2025.

To avoid double-counting and allow for different adoption-rates, fatalities are allocated to risk-groups (see below) based on (a rough) estimate of the contribution to fatalities. The post-change number of fatalities in each risk-group is calculated as:

- Fatalities allocated (see table below)
- Multiplied by (1 – per cent opting not to drive)
- Multiplied by (1 – per cent of fatalities for risk-group avoided by having autonomous vehicles and AEB (if installed) or warning system (if installed)
- Multiplied by (1 – per cent of fatalities avoided by having UBI, if installed).

The risk-groups and allocated fatalities are shown in the table overleaf. Fatalities were allocated to risk groups using data from the 'Australian Road Deaths Database: Fatalities' for calendar years 2014 and 2015. Of relevance, the database records a crash-type (being pedestrian, single-vehicle and multi-vehicle), whether a heavy vehicle (rigid truck, articulated truck or bus) was involved and the type of road-user who died (e.g. driver, passenger, motorcycle rider) and their age.

Reductions in fatalities *attributed* to actions by cyclists and motor-cycle users were not modelled.

Specific assumptions for each effect are included further below.

Table 6: Risk groups - summary

Risk group	Fatalities attributed to group	Allocation basis
Heavy vehicles (Trucks and buses)	10.3%	• 44% of multiple-vehicle fatalities of drivers and passengers involving heavy vehicles[89] • All other fatalities involving heavy vehicles
Motorcyclists	12.7%	• 37% of multiple-vehicle fatalities of motor-cycle riders and passengers involving multiple-vehicles[90] • Single vehicle fatalities allocated to motor-cycle users
Cyclists	0.8%	• Single vehicle fatalities allocated to cyclists • Multi-vehicle fatalities allocated to other vehicles
Other motor vehicles by driver age		
Aged 16-21	16.5%	• Allocated to age based on proportion of driver and passengers fatalities in this age group (not involving a heavy vehicle) • Allocation to LCVs based on proportion of LCVs in the motor vehicle census
Aged 22-25	6.9%	
Aged 26-79 in LCVs (light commercial vehicles)	7.8%	
Aged 26-74 in cars	36.9%	
Aged 80+	7.2%	
Total	**100%**	

[89] Based on the large truck causation study (LTCCS 2005) that found that in two-vehicle crashes involving trucks, the truck was assigned critical vehicle status in 44 per cent of cases.

[90] Based on a NSW study (http://roadsafety.mccofnsw.org.au/a/38.html).

Modelling assumptions

Whether to drive

For age-groups up-to 25 and 80+ a proportion of drivers opt-out of driving due to insurance reforms. This is estimated based on the percentage change in the cost-of-driving multiplied by an estimate of a relevant price-elasticity. Key assumptions are:

- The annual cost of driving for those who might opt not to drive is around $5,000 (Refer footnote 17)
- The average BI premium in Australia is around $500 (refer footnote 25).
- For Scenario 1, BI premiums will change in proportion to the premium relativities by age shown in Figure 1 on page 7.
- For Scenario 2, the variation in BI premiums will increase by an additional factor of 2.8.
- The relevant price elasticity is -0.3 (refer Footnote: 28).

AEB

With regards to AEB the following assumptions are made:

- In the baseline,
  - the AEB adoption follows a similar pattern to that of ESC (Figure 3 on page 12) with a 15 year lag
  - the adoption of the 'average risk' (pre-installation of AEB) of the young matches that of the 16-20+ crash rate in the ESC figure
  - the adoption of the 'average risk' (pre-installation of AEB) of other passenger vehicles matches that of the 25+ crash rate in the ESC figure, and
  - the adoption of AEB in heavy vehicles is similar but lags due to the higher average age of the heavy vehicles (by a factor of 3 years for every 2 years).
- In Scenario 1, the adoption of AEB is the same as the baseline with the exception that the young adopt AEB at the same rate as the rest of the driving population.
- In Scenario 2, the adoption of AEB is the same as the Scenario 1 except it is brought forward 2 years.

The effectiveness of the AEB system will depend on systems installed. It is assumed that with greater insurer incentives for safety the more effective systems will be used (either as a result of vehicle choice, options selected and manufacturer/distributor decisions). For the periods considered, the average effectiveness of AEB in terms of reduction in fatalities is assumed to be as follows:

- For the baseline and Scenario 1, a 25 per cent reduction. This is consistent with the lower end of results of Anderson et al (2012).
- For Scenario 2, a 40 per cent reduction consistent with the upper end of results of Anderson et al (2012).

Autonomous vehicles

With regards to fully-autonomous vehicles the following assumptions are made:

- the adoption of fully-autonomous vehicles is identical to that of the AEB (see immediately above) with a 9 year lag (which means under the baseline there will be a 9 per cent penetration into the vehicles used by drivers aged 25+ by 2035), and
- autonomous vehicles reduce fatalities caused by vehicle owners by 100 per cent.

Warning systems

- Warning systems will only apply when AEB systems are not already installed (i.e. AEB systems include a warning system).
- Warning systems are assumed to reduce crash-risk by 20 per cent (under all scenarios).
- The rate of adoption reflects installation costs for a basic system of around $1500 and insurer discounts of 10 to 15 per cent on premiums (as is evidenced elsewhere and less than the crash risk benefit due to administrative costs).
- In the baseline, the adoption rates are low as the discount will only be applied on vehicle damage. Adoption is assumed to be 5% in motor vehicles and 10% in high-users (heavy vehicles and LCV's).
- Under Scenario 1
  - The financial incentives (in $ terms) by insurers for warning systems would increase (effectively close to double for the average driver and more for high risks). Nevertheless, given total insurance premiums on average of $1,000 to $2,000 warning systems are likely to be attractive mainly to high-risks (whose premiums are higher).
  - Adoption is assumed to be double that in the baseline (20% for high-risks and 10% for others).
- Under Scenario 2
  - The financial incentives for warning systems would increase (effectively doubling again) from Scenario 1, making it highly cost-effective for any high-risk or high-road-user to adopt the system.
  - Adoption is assumed to be double that of Scenario 1. (40% for high-risks and 20% for others).

UBI

- Adoption varies significantly by scenario
  - For the baseline, it is assumed the adoption of UBI is small (10% for high-risks, nothing for others). This is because it does not appear practical for UBI to be used with CTP schemes given the absence of competitive CTP insurance markets in some jurisdictions and the stringent rate-regulation where competition exists. It appears likely that there will be some growth in the use of telematics for fleet management purposes.
  - For Scenario 1, the adoption of UBI follows the trend in the UK and by 2027 becomes the dominant form of insurance for high-risks (adoption rate of 60%) and medium rate of adoption for LCV (30%), and low rate for other risks (10%)
  - For Scenario 2, UBI becomes the dominant form of insurance. The adoption rate of UBI is 90% among all high-risks and 50% among others

- Effectiveness of UBI varies by scenario. It is assumed for
  - the baseline the effectiveness is 10% reduction in fatalities
  - Scenario 1 the effectiveness is a 20% reduction (similar to lower-end of UK evidence)
  - For Scenario 2 the effectiveness is a 30% reduction (reflecting the much stronger incentives).

Modelling results

Table 7: Impact by risk groups for year 2027

Group	Allocation of current fatalities	Reduction by scenario		
		Baseline	Scenario 1	Scenario 2
Cyclists	10	-	-	-
Heavy vehicles (Trucks and buses)	139	5	22	47
Motorcyclists	159	-	-	-
Other motor vehicles (by driver age)				
Aged 16-21	206	9	41	89
Aged 22-25	86	4	16	36
Aged 26-79 in light commercial vehicles	98	4	12	36
Aged 26-74 in cars	461	17	29	111
Aged 80+	90	3	6	26
Total	**1,250**	**42**	**126**	**345**