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Vehicle Safety Design Features and Future Safety Benefits in London

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Contents

Executive Summary

Over the past decade London has achieved substantial reductions in road traffic casualties and collisions. However, many still occur and there is scope for further improvements in road safety in the Capital; particularly for vulnerable road users (VRUs). Between 2009 and 2013, 77% of fatal or serious collisions in London involved at least one VRU. Given the ambitions of TfL and the Mayor in encouraging sustainable transport and promoting walking and cycling, additional action is required to continue the improving road safety trend in London.

Of all collisions in London, 81% involve at least one car and therefore improving the safety of cars is one way to help reduce road traffic casualties and collisions. In general, newer cars have better safety features than older ones, due to increased standard fitment of air bags, stronger structural frames around occupants and enhanced braking and electronic stability control systems, as well as a range of driver assistance safety technologies. The addition of such features has already resulted in large reductions in the number of car occupants KSI over the last decade, and with further developments in technology, it is expected that cars will continue to become safer still. In addition, in recent years there has been an increased emphasis on improving car secondary safety for the benefit of VRUs. Secondary safety features are designed to reduce the severity of injury sustained in the event of a collision occurring.

In order to understand the impact of these safety improvements, TfL commissioned this project to collate information on the current car fleet in London, including the level of fitment of safety features. Casualty data was also examined, in order to:

- Gain a better understanding of how vehicle safety features influence casualty outcomes
- Explore trends to predict how changes to the fleet are likely to influence casualties in the future, and to
- Identify which vehicle technologies it would be most beneficial to promote a faster uptake of, in order to speed up the rate of casualty reductions in London.

Methodology

Statistical models have been developed, combining casualty, traffic and safety fitment data. The data obtained were used to produce a unique dataset ranging from 2009 to 2013, establishing the current safety fitment rate within the London car fleet population, identifying changes in the vehicle fleet composition over time and the rate that new cars have entered the population. Traffic data were used to control for the differences in exposure between different car types. The statistical models were used to evaluate the effect evolving car design has had on casualty numbers in recent years and to estimate future casualty figures for a range of scenarios.

The influence of vehicle safety features on casualties

Casualty data were investigated by the type of car involved in the collision. It is notable that there have been reductions in the proportion of car occupant KSIs, which can be attributed to secondary safety design improvements in the last decade. These features have been successful in reducing the likelihood of a serious injury to car occupants when a collision occurs. However, this is not the case for pedestrians or other VRUs. The model showed that pedestrians, injured from impacts with the front of the car only, had not received any significant benefit or disbenefits from the secondary safety changes to car design in the last decade i.e. the likelihood of incurring a serious injury is similar for pedestrians struck by all ages of passenger car. It could be possible that the design changes made to the front of cars to protect pedestrians are having positive effects. For example, there could have been a reduction in the absolute severity of the injuries VRU's experience, but their overall injury severity remains classified within the 'serious' category in police Stats19 collision records. Further evaluation is needed to understand the reasons behind these findings and to ensure future collision and injury mitigation strategies for VRUs are effective.

The effect of new technologies on casualty reductions in London

Additional modelling was carried out to quantify the casualty savings that could be achieved in London if four selected technologies were introduced at a faster rate than assumed by the baseline scenario, either through increased consumer take-up or vehicle regulation. The four technologies selected were Intelligent Speed Assistance, Pedestrian Automatic Emergency Braking, improved pedestrian secondary safety and Alcohol interlocks. These technologies were chosen as they are close to coming to the mass market and have proven safety benefits.

The potential penetration of these technologies into the Capital's fleet has been informed by the rate of uptake of existing technologies which have been promoted and/or mandated by the European Union. The effectiveness estimates for these new technologies originate from a number of sources and studies and are assumed to apply to real world collisions, in particular the types that occur in London.

Between the years 2015 to 2030 in London, the KSI casualty savings that could be achieved with enhanced consumer testing leading to more vehicles having the technology fitted or if all new passenger cars were mandated to fit the selected technologies from 2023/24 are estimated using these models to suggest that:

- Intelligent Speed Assistance: Between 154 to 649 car occupant and pedestrian KSI casualties could be prevented
- Pedestrian Automatic Emergency Braking system: Between 145 to 328 pedestrian KSI casualties could be prevented
- Improved pedestrian secondary safety measures: Between 123 to 183 pedestrian KSI casualties could be prevented
- Alcohol Interlocks: Between 1 to 108 KSI casualties from drink drive collisions could be prevented

It should be noted that the introduction of these technologies are medium term solutions due to the time lag involved in introducing new technologies into the car fleet. Neither should they replace improvements to other road safety measures, including to driver education and infrastructure. These developments are implicit within the baseline scenario and therefore, to ensure the potential casualty savings are realised, it is important to ensure that both general road safety and vehicle safety should be developed hand in hand.

Overall in the two scenarios modelled these technologies could prevent up to 9.5% of the total car occupant and pedestrian KSI casualties forecast to occur in the period 2015 to 2030.

More specifically, in the scenarios in which these technologies are made mandatory in 2023, Intelligent Speed Assistance could prevent 16 per cent of car and pedestrian KSI casualties forecast to occur in 2030, Pedestrian Automatic Emergency Braking could prevent 12 per cent of pedestrian KSI casualties forecast to occur in 2030 and Alcohol Interlocks 50 per cent of drink drive collision KSI's forecast to occur in 2030. Even when these technologies are prevalent in the vehicle fleet additional road safety interventions will continue to be needed to maintain the progress of casualty reduction.

Conclusion and recommendations

In summary this research has:

- Established the level of safety technology in London's vehicle population
- Quantified the effect on casualties from improved secondary safety in the past decade
- Estimated the rate in which certain technologies will penetrate the fleet in the future, and
- Estimated the casualty savings that may occur from different scenarios associated with a quicker uptake of new safety technologies.

The safety benefits that could accrue from additional technology in cars highlights the need for all organisations involved in road safety to consider how they can support the uptake of these technologies. Efforts by national government, the European Union, vehicle manufacturers, the insurance industry and public sector procurement could all help deliver improved road safety.

In order to further reduce casualties in London, it is recommended that TfL:

1. Encourages manufacturers to develop and implement safety features that will reduce vulnerable road user casualties as a priority, including new technologies and designs that will reduce pedestrian and pedal cyclist KSIs
2. Supports Euro NCAP new test protocols to increase the availability of consumer information on safety technologies available on cars
3. Encourages European regulators to rapidly announce legislation to bring in mandatory requirements for Pedestrian Automatic Emergency Braking and Intelligent Speed Assistance in new cars to maximise the penetration of these technologies into the vehicle fleet

1 Introduction

1.1 Setting the context

Over the past decade London has achieved substantial reductions in road traffic casualties and collisions. However, there is still work to do, particularly for vulnerable road users (VRUs) including pedestrians, pedal cyclists and powered-two wheeler riders. Between 2009 and 2013, 77% of fatal or serious collisions in London involved at least one VRU:

- 36% involved at least one pedestrian
- 21% involved at least one pedal cyclist
- 26% involved at least one powered two wheeler rider

In 2012, TfL set out its plans to reduce KSI (Killed or Seriously Injured) casualties by 40% by 2020 compared to the 2005-09 baseline (Transport for London, 2013). Given the efforts of TfL to encourage sustainable transport and promote walking and cycling, reducing KSI VRUs will be key to achieving this aim.

Of all collisions[1] in London 81% involve at least one car and therefore improving the safety of cars may be one way of helping to achieve the target. In general, newer cars have better safety features than older vehicles; for example increased standard fitment of air bags, stronger structural frames around occupants and enhanced braking and stability control as well as a range of driver assistance safety features.

The addition of such features has already resulted in large reductions in the number of car occupants KSI over the last decade, and with further developments in technology, it is expected that cars will continue to become safer still. With new cars entering the market, London's car fleet can also be expected to benefit from safety improvements, progressively. However, there are some concerns that certain safety improvements have not similarly benefitted VRUs.

1.2 Aims of the project

This project aims to:

- Understand the current composition of the car fleet in London and the level of fitment of safety features to these vehicles
- Link information on the current fleet to the casualty data to gain a better understanding how vehicle safety features influence casualties
- Explore trends in the fleet and fitment information to predict how changes to the fleet are likely to influence casualties in the future
- Consider what technologies it would be beneficial to encourage in order to speed up the casualty reductions in London.

[1] Throughout this report, unless stated otherwise, a collision is considered to be a road collision, reported to or by the police, which causes personal injury.

1.3 Report structure

Background information on the development of vehicle safety is included in Section 2 of this report and collation of data and development of the database required to achieve the main project aims in Section 3. The report also covers the four project aims, as described above, in Sections 4, 5, 6 and 7 respectively.

2 Developments in vehicle safety

The first UK road collision fatality occurred at the end of the 19th century when a pedestrian was run over by a car. Since then efforts have been dedicated to improving safety on roads and, specifically relevant here, the safety features of vehicles. Developments in this regard continue and are now fuelled by competitive innovation, consumer testing programmes and European Union regulations, as discussed in Section 2.1. As a result, it is a reasonable basic premise to assume that newer cars are safer, less likely to cause an injury or likely to cause a less severe injury, than older cars. They will, at least, tend to have more safety features than older vehicles.

In this section we discuss:

- EU front and side impact regulations introduced for new cars in 1998
- Other EU regulations such as pedestrian protection, Brake Assist and pole side impact testing introduced since 1998
- The introduction of Euro NCAP in 1997 to provide consumers with safety performance information on new cars
- The improvements in Euro NCAP scores for cars in London since 1997
- Measures which can avoid the collision from occurring, termed primary safety (see Section 2.2)
- Measures which are designed to prevent injuries or mitigate injury severity once a crash has occurred, termed secondary safety (see Section 2.3).[2]

2.1 Regulations and consumer testing programmes

Many of the developments in car safety are driven by legislative action (O'Neill, 2009): European Union countries issued UN Regulations establishing uniform prescriptions for motor vehicle type-approvals. These safety regulations set minimum performance requirements for a wide array of vehicle safety aspects such as structural crashworthiness, protection of vulnerable road users, seat belts, brakes, tyres, and safety glazing.

As the regulatory test procedures produce only pass or fail results, this does not allow consumers to make an informed choice by comparing the relative safety performance offered by different models. Modelled on the US New Car Assessment Programme (NCAP), in 1997 Euro NCAP was launched for the European Market, which aimed at giving star ratings a higher significance for consumers by stronger involvement of vehicle manufacturers and therefore provide a strong incentive for further developments in vehicle safety.

Initially Euro NCAP gave cars separate adult occupant, child occupant and pedestrian star ratings. The adult occupant rating was derived from an assessment of a frontal impact crash test and at least one side impact crash test and the pedestrian rating (see 2.3.2) was derived from tests firing a full legform impactor at the bumper of the vehicle,

[2] Tertiary safety, or the post-crash response that a car offers, is not covered by this report as this technology, which includes systems such as e-call which alert emergency services in the event of a crash, is relatively new to the market and is not installed on many cars.

an upper legform at the bonnet leading edge and headforms at the bonnet and windscreen. Test results indicated that while adult occupant star ratings were improving over time pedestrian star ratings were not and therefore in 2009 these ratings were amalgamated into one overall star rating with the intention that cars would now also need to improve pedestrian and child safety in order to achieve a high star rating.

Both the legislative and the consumer information changes that occurred in the period from the announcement of the structural crashworthiness regulations until recent legislative announcements are shown in Table 2.1. For this table, ‘vehicles’ is used to define a group including cars and light vans. Key dates in this timeline are 1997 and 1998 when new vehicle types had to meet the structural crashworthiness requirements of the frontal and side impact regulations and equivalent results were made available to the public via Euro NCAP. Then, in 2003, all new vehicles sold in Europe had to meet these requirements and the first pedestrian protection regulation was published in Europe. 2009 was a significant year because it coincided with the publication of the revised pedestrian protection requirements, the necessity to fit a ‘brake assist system’ and a major revision to the way that Euro NCAP rated vehicles.

As is shown in Table 2.1 European legislation typically defines two dates for implementation; the first corresponds to when new vehicle types must comply with the requirements and the second when all new vehicles must comply. Most manufacturers work on a model revision programme which releases a new ‘type’ once about every three to five years. Therefore there can be a range of time before a manufacturer must respond to the requirements. This can stretch from early discussions of the potential regulatory requirements (even before they are announced officially) or without any legislative prompt all the way through to the last moment before the requirements are extended to cover all new vehicles. For example, the second phase of the pedestrian regulations was announced in 2009 but will not be implemented on all new vehicles until 2018.

Table 2.1: Timeline of vehicle safety legislative and consumer information changes

Year	Legislation: Announcement	Legislation: Mandatory requirement to meet new standard	Consumer information
1995	Regulation 94 (frontal collision protection) and Regulation 95 (lateral collision protection) enter into force		
1996			Euro NCAP launched
1997			Euro NCAP begins assessing car safety and publishing results
1998		New vehicle types have to meet frontal and side impact protection requirements	
2003	Pedestrian protection directive (2003/102/EC) published	All new vehicles have to meet frontal and side impact protection requirements	Euro NCAP adds new child protection rating
2005		New vehicle types have to meet pedestrian protection requirements	
2007	Regulation 123 (Adaptive front lighting systems) came into force (applied immediately in Europe)		
2009	Second phase of pedestrian protection published (EC 78/2009) Electronic Stability Control Regulation published (EC 661/2009)	New vehicle types to have a 'Brake Assist System'	Euro NCAP substantially changes assessment procedures and rating (adds rear impact testing)
2011		All new cars to have a Brake Assist System All new vehicle types to have Electronic Stability	Euro NCAP adds Electronic Stability Control tests to the rating

Year	Legislation: Announcement	Legislation: Mandatory requirement to meet new standard	Consumer information
		Control	
2012	Advanced Emergency Braking System[3] Regulation published (EU 347/2012)	All new vehicles to have Electronic Stability Control	
2013	Regulation 131 (Advanced Emergency Braking Systems) came into force (applied immediately in Europe)	New car types (≤ 2,500 kg) have to meet second phase of pedestrian protection requirements	
2014			Euro NCAP revises rating to include Autonomous Emergency Braking systems
2015	Regulation 135 (Pole side impact) comes into force (15 June)	Larger car types and van types to meet second phase of pedestrian protection requirements	Euro NCAP adds a second frontal impact test
2018		All new vehicles to meet second phase of pedestrian protection requirements	

2.2 Primary safety

In the last fifteen years, vehicle safety research and technologies on cars has increasingly focussed on measures designed to avoid collisions from occurring. Electronic Stability Control (ESC), designed to restore stability to the vehicle in instances where it is under or over steering or beginning to rollover, was seen to propagate through the vehicle fleet after its introduction in certain makes and models. As indicated in Table 2.1, this is now mandatory for all new cars in the European Union. Another advancement related to mitigation or prevention of road collisions which has been mandatory for new cars in Europe since 2009 (Table 2.1) is Brake Assist, where the car reacts to the driver's actions in an emergency event and applies more braking than a normal driver would, stopping the car in a shortened distance. Also modern cars are increasingly fitted with

[3] Note that AEBS (referred to as Autonomous Emergency Braking System throughout the rest of this report) is defined as *Advanced* Emergency Braking System in the General Safety Regulation (EC) 661/2009 and the specific procedures, tests and requirements in Regulation (EU) 347/2012.

forward collision warning systems including autonomous braking in the event of an anticipated collision and the extension of this technology to consider pedestrians and cyclists should their paths cross that of the car. Euro NCAP already rewards the presence of these systems (Table 2.1) and plans to start testing these autonomous braking systems in the coming years (Euro NCAP, 2015). A review of some of these technologies is presented in Appendix A.

2.3 Secondary safety

2.3.1 Vehicle occupant protection

The best way to protect vehicle occupants in a crash is to design a strong and stiff safety cell around the seating area which keeps driver and passengers away from any injurious intruding structures. Around this strong cell, it is necessary to have structures which deform in a controlled way to absorb some of the impact energy - the 'crumple zones'. Further to this, to realise the full safety potential, the occupants need to be attached to the vehicle body by a restraint system (seat belt and airbag, etc.). This controls the way the bodies slow down and prevents contacts with hard surfaces inside the vehicle.

The three-point seat belt, which has been fitted to passenger cars since the 1950s, is still among the most effective safety systems in modern cars (Elvik & Vaa, 2009). In addition to reducing injuries in front and side impacts, a seat belt substantially reduces the chance of vehicle occupants being ejected from their vehicle in rollover crashes (Cuerden *et al.*, 2009).

Modern seat belt systems feature pre-tensioners to reduce belt slack and load limiters to avoid injuries due to excessive belt forces. The seat belt is, of course, a safety system that needs to be proactively engaged by the occupants. Seat belt reminder systems, which have proven potential to increase wearing rates even further than current high wearing rates (Lie *et al.,* 2007), are rewarded by consumer information programmes such as Euro NCAP and are fitted to many current passenger car models.

Front airbags supplementing seat belts became prevalent throughout the vehicle range, at least as an option, in the mid-1990s. These were followed later by side-torso airbags, usually located in the seats, and side-curtain airbags deploying from the roof to protect the occupant's head. Most modern cars are fitted at least with front and side-torso airbags. Although these are not legally required as part of the EU type approval process, they help to achieve the requirements of the structural crashworthiness regulations, 94 and 95 (mandatory for all new cars since 2003, Table 2.1).

Figure 2.1 and Figure 2.2 show average NCAP test results, weighted by the vehicles' contribution to traffic in London (see Section 3.3 for how the traffic estimates have been derived). For new cars, tested in Euro NCAP, Figure 2.1 highlights the improvement in front and side impact scores over the first 10 years of NCAP testing, with scores plateauing somewhat over the last few years. This improvement in test score reflects a reduction in the likelihood of serious injury for occupants in front and side impacts with conditions similar to those tested[4].

[4] The test conditions remained largely unchanged over this period although a side impact pole test, worth up to two points on the side impact score, was introduced in 2001.

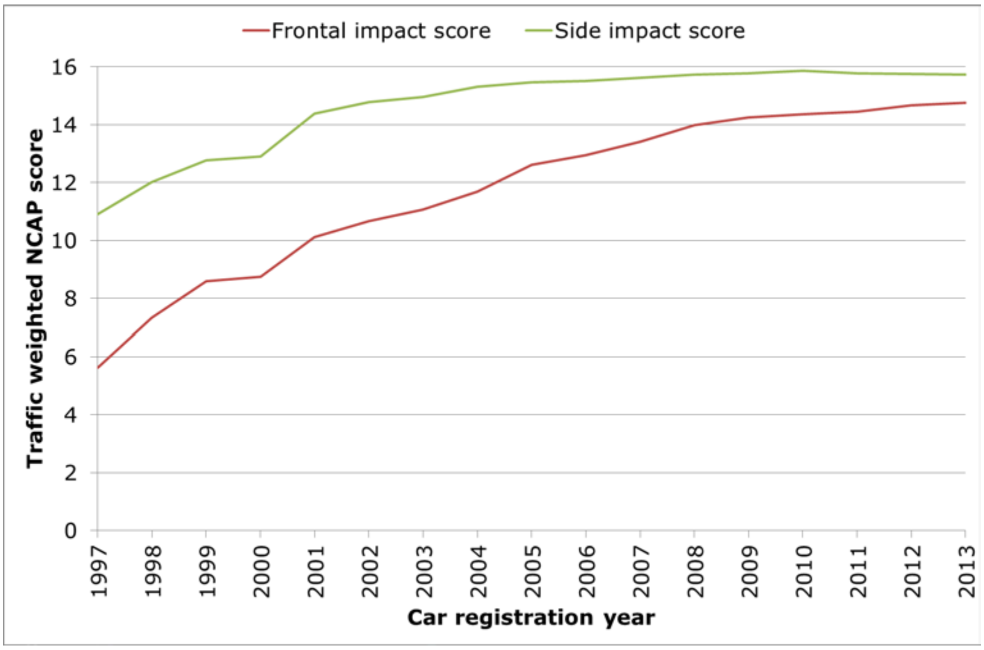


Figure 2.1: London traffic weighted average NCAP scores (new cars tested by EuroNCAP only)

Figure 2.2 shows the NCAP star ratings over the same period. It highlights that while the adult occupant rating improved greatly over the first 10 years the pedestrian star rating did not, prompting the change to an overall star rating from 2009 onwards incorporating both occupant and pedestrian safety. Typical overall star ratings have remained fairly constant of the last few years but it is important to note that criteria against which vehicles are assessed for this rating, including the relative importance of pedestrian protection, evolves over time. As such, Figure 2.2 cannot be taken to imply that secondary safety has stood still since 2009.

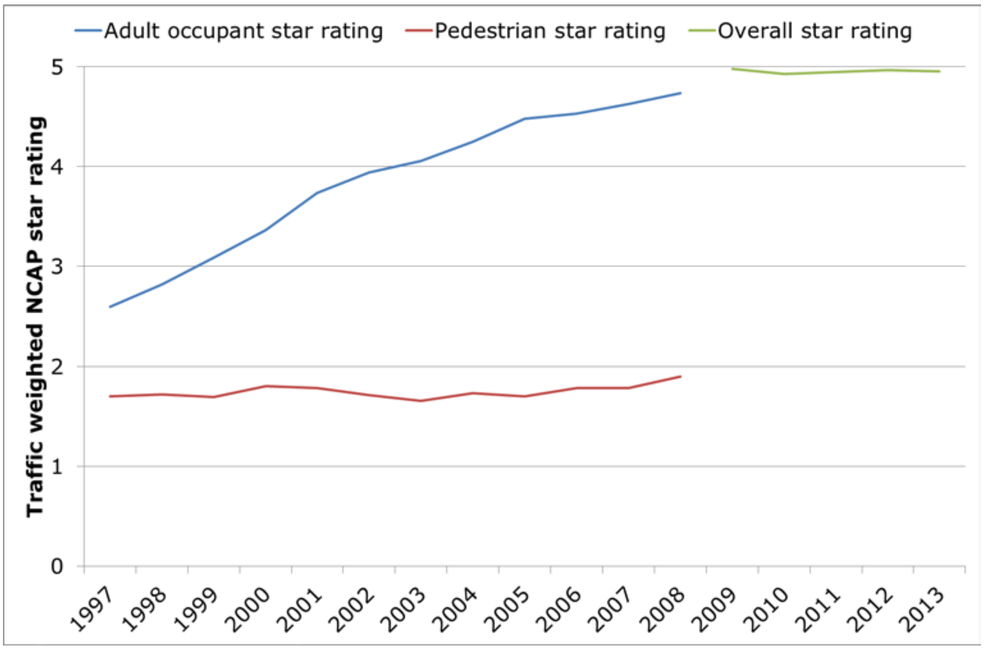


Figure 2.2: London traffic weighted average NCAP star ratings (new cars tested by EuroNCAP only)

2.3.2 Vulnerable road user protection

From the early 1980s, European research groups became more focussed in investigating pedestrian protection. This research was directed at methods to encourage the fronts of vehicles to be safer for a pedestrian in the event of a collision. Throughout the 1980s sub-system or component tests (representing one part of the contact between a pedestrian and vehicle; e.g. leg to bumper) were developed through these European activities. The component tests were adopted for use in Euro NCAP and then became part of the European legislation via Directive 2003/102/EC and then EC Regulation No. 78/2009 (as published in those years, Table 2.1).

The majority of the technologies that have been developed to protect vulnerable road users are related to primary safety. The list of technologies that are relevant to occupant and vulnerable road user protection is shown in Section 3.4. A detailed description of the technologies and their estimated effectiveness is provided for reference in Appendix A.

3 Database development

This section explains how a unique dataset which combines STATS19, traffic data and safety fitment data has been developed for the purpose of examining the casualty trends by car segments and technology fitment in more detail.

We describe:

- Classification of cars into different segments
- How the traffic data is estimated based on statistical models which combine London traffic estimates, registered cars data and MOT mileage data
- The combination of information from Euro NCAP, manufacturers specifications and second hand car websites to establish the vehicle technology fitment in a proportion of the London car fleet

Data from 2009 to 2013 (the most recent data available) were used for the purposes of this report because this provided sufficient data to examine trends over time. 2009 was also the first year in which a number of changes were made to vehicle safety legislation and consumer testing including publication of the revised pedestrian protection requirements, the necessity to fit a 'brake assist system' and a major revision to the way that Euro NCAP rated vehicles.

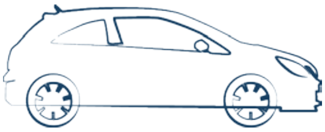
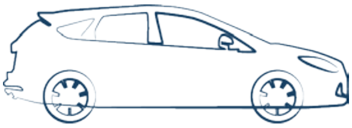
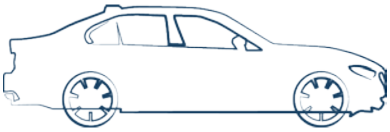
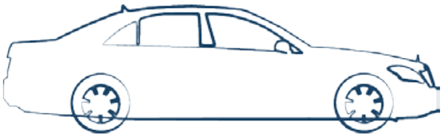
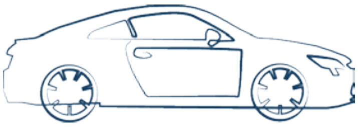
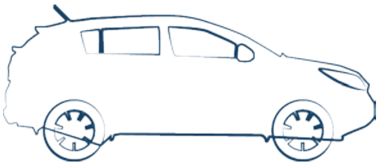
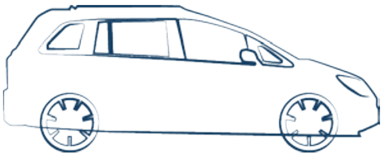
3.1 Car classification into segments

When talking about the passenger car market, it can be helpful to subdivide it into smaller parts or segments. Attempts to define distinct car groups have been proposed in relation to the engine size or total length. However, the boundaries between segments are blurred by factors other than the size or length of cars. These factors include price, image and the amount of extra accessories available to the consumer. Also, the tendency to offer more options like ABS, airbags, central locking etc. further dilutes the traditional segmentation. Customers choose their cars using a combination of parameters, such as brand, size, equipment and price.

Initially, due to the large variety of car makes and models available cars have been grouped into seven segments, see Table 3.1. These segments are derived from the make and model information and are based on the Euro NCAP classification of vehicles[5], along with expert judgement by the TRL vehicle safety specialists.

[5] Excluding vans and pickups and combining small and large off-road and MPV vehicles.

Table 3.1: Car segment classification

Segment	Example	Profile
Supermini	Vauxhall Corsa	
Small Family Car	Ford Focus	
Large Family Car	BMW 3-Series	
Executive	Mercedes S-Class	
Roadster Sports	Audi TT	
4x4	Kia Sportage	
MPV	Vauxhall Zafira	

Cars have been classified as such in order to provide more robust conclusions. Whilst make and model were used to build the dataset (using a bottom up approach), the results presented are disaggregated only at the segment level.

3.2 Casualty data

STATS19 is the database of road collisions reported to, and recorded by the police, in Great Britain. It contains details of the circumstances of the collisions, details about the vehicles and casualties involved and the contributory factors to the collision.

For the purposes of this project collision data has been restricted to collisions occurring inside London (excluding Heathrow Airport).

3.3 Traffic data

Here, traffic data are used both to understand the composition of the fleet in London but also to give some context to the collision data in the form of exposure data; the number of road casualties is a function of the risks associated with the vehicles and people involved, combined with the exposure to risk of those vehicles and people. Hence, in order to fully understand the reasons for the number of casualties in London, it is necessary to obtain data to estimate the exposure to risk.

'Composition of the vehicle fleet' refers to an estimate of traffic (in vehicle-kilometres) by the different sizes, types, and ages of car. Previous work (Lloyd & Forster, 2014) has shown that there are considerable differences in traffic exposure for different types of cars and therefore the link between traffic and the composition of the London fleet is not straightforward.

3.3.1 Data sources

In order to estimate car traffic by make, model, and registration year a statistical model has been applied to combine information from a number of sources:

- Traffic estimates: Traffic estimates of London car traffic by borough and year have been sourced from DfT (Department for Transport (a), 2013). These estimates include car traffic on both major and minor roads in London.
- Registered cars: The number of cars registered in London each year (2009-2013) by make, model, and year of first registration was provided by the DfT.
- MOT data: containing information on every car registered in Britain in 2012 and 2013 that is required to have an MOT test by law (i.e. all cars aged over 3 years), including the make, model, age and milometer readings (DVLA, 2013). This has been used to estimate annual mileage. For newer cars we have assumed a uniform distribution of miles across the first three years by taking the average annual mileage at first test.

Further information on the datasets used is given in Appendix B.

Table 3.2 shows the fields available within each data source. The data sources were combined, as described in Section 3.3.2, to derive an estimate of the traffic in London by year, segment, and registration year and the limitations of this approach are discussed in Section 3.3.3. Information at a borough level was not included since once these data are further split by segment and registration year the fact that vehicles registered within a given borough are likely to drive outside of that borough will cause the traffic estimates to be unreliable.

Table 3.2: Data source and fields available

Data source	Year	Segment	Registration year	Borough
DfT traffic estimates	✔			✔
Registered cars in London	✔	✔ (from make & model)	✔	✔
MOT data		✔	✔	
Modelled traffic data	✔	✔	✔	

3.3.2 Estimating traffic in London

These data sources were combined in a statistical model to develop the estimation of the measure of traffic in London. An overview of the method is provided here for information:

For each year independently (2009-13):

1. The registered cars data were used to estimate the distribution of London car fleet by segment & registration year.
2. MOT data provided estimates of the relative average annual mileage of the different segments and registration years.
3. Data from steps 1 and 2 were combined and weighted to sum to the total traffic estimates in London to provide traffic by car segment and age.

3.3.3 Limitations of data and method

There are a number of known limitations to the method described in Section 3.3.2, mainly due to availability of data.

The registered vehicle data have been used as the main source of information to distribute traffic by car segment. These data provide information on the car fleet registered in London however it is known that the car fleet in London consists of cars registered in and outside London, and that cars registered in London will often be used to travel outside London. Use of data from the Low Emission Zone (LEZ) cameras which cover most of Greater London was considered in order to provide further information about the cars being driving in London. Unfortunately, these data were not available in a suitable format for analysis and therefore the decision was made to assume that the cars registered in London are a representative sample of those driven in London.

The mileage analysis was based on all MOT tests in Great Britain; it could not be restricted solely to cars which drive in London. As a result, for the statistical modelling, it is assumed that the relative difference in estimated average annual mileage between the different vehicle ages and segments is representative of the relative differences between cars which drive in London.

In addition, not all of a vehicles average annual mileage will be driven in London. This analysis assumes that the proportion of each vehicle's average annual mileage in London is the same across segments and registration years. It also assumes that the average annual mileage for each segment and age does not change between 2009 and 2013.

3.4 Vehicle technology

Vehicle fitment rates were derived from a series of sources including Euro NCAP, manufacturer's websites, and second-hand car sales websites.

3.4.1 Euro NCAP

Details of Euro NCAP safety testing results and notes on safety system fitment were collated. These data include frontal and side impact test scores and adult occupant and pedestrian star ratings since 1997. Pole test scores are sporadic until 2005 at which point these data are more complete and further data on adult headform, upper legform, legform and unrounded adult occupant test scores exist. In 2009 the adult occupant and pedestrian star ratings were replaced by an overall star rating for the vehicle and additional scores are recorded for electronic stability control, speed limit detection and seat belt reminders.

In addition to these scores and ratings the presence of any airbags, seat belt pretensioners and load limiters are recorded for each vehicle tested. The data do not however include any further untested safety features which may be commented on as part of the test report and awarded extra points as Advanced Rewards.

3.4.2 Model specifications

The vehicle models in the fitment database were chosen to reflect the most prevalent cars in London in terms of registrations. They cover over 50% of registered cars in each segment[6] as well as overall.

Information on the level of safety features fitted to these vehicle models, for each year since the model first entered production, was collated from both the Euro NCAP data and model specifications gleaned from various sources for second-hand car sales as well as manufacturer's websites.

In some cases safety fitment information on older vehicles was not particularly comprehensive. However in such cases, where the vehicle number plate was known, an HPI (hire purchase investigation) database, containing detailed vehicle specifications, was used to get a more complete picture of the fitment information for the given model and year.

In addition to the systems recorded by EuroNCAP, a number of other primary and secondary systems were identified for inclusion in a vehicle fitment database. The full list of those technologies included is shown below:

- **Adaptive Cruise Control (ACC).** This maintains a desired road speed if the roadway ahead is unobstructed and a constant time gap from a moving vehicle ahead

[6] Except for those classified as 'Roadster Sports'. This segment is both very small and very diverse and, as such, the fitment data in this segment are restricted to the top three models.

- **Autonomous Emergency Braking System (AEBS).** This combines sensing of the environment ahead of the vehicle with the automatic activation of the brakes (without driver input) in order to mitigate or avoid an collision
- **Driver airbag.** A flexible fabric bag, designed to inflate rapidly during a frontal collision in order to complement the seat belt by providing additional restraint via an energy absorbing surface between the driver and the steering wheel
- **Driver knee-bag.** A flexible fabric bag, designed to inflate rapidly during a frontal collision in order to provide additional restraint to the driver's lower body and thereby reduce excessive, potentially injurious thigh, pelvic or abdominal loads
- **Load limiter.** These are designed to minimise seat belt inflicted injury, commonly caused by excessive thorax belt forces exerted on the occupant, by releasing more excess webbing in the upper belt when a large force is applied
- **Passenger airbag.** A flexible fabric bag, designed to inflate rapidly during a frontal collision in order to complement the seat belt by providing additional restraint via an energy absorbing surface between the passenger and the fascia
- **Passenger knee-bag.** A flexible fabric bag, designed to inflate rapidly during a frontal collision in order to provide additional restraint to the passenger's lower body and thereby reduce excessive, potentially injurious thigh, pelvic or abdominal loads
- **Pre-tensioner.** These tighten up any slack in seat belt webbing in the event of a crash in order to make sure a seatbelt restrains an occupant as early as possible in a crash, thereby reducing the load on the occupant, and helping to prevent 'submarining', i.e. a sliding forward motion of the lower body underneath the lap belt which can result in abdominal injuries
- **Rear load limiter.** A load limiter applied to the seat belts of rear seat passengers
- **Rear pre-tensioner.** A pre-tensioner applied to the seat belts of rear seat passengers
- **Seat belt reminder.** This system provides a visual and/or audible signal if an occupant is not using the seat belt, which can increase the uptake of seat belt use on front and rear seating positions
- **Side airbag chest.** A chest or torso side airbag is a flexible fabric bag (usually housed in the door or seat bolster), designed to inflate rapidly during a side impact between the chest and vehicle side structures in order to cushion the impact of the vehicle interior against the front row occupant and to extend and spread out the occupant acceleration period
- **Side airbag head.** A head or curtain side airbag is a flexible fabric bag, designed to inflate rapidly during a side impact or a rollover collision specifically in order to cushion the head impact against vehicle structures. Some curtain airbags are designed to support a role of the seat belt in preventing partial or full occupant ejection during rollover collisions.
- **Brake Assist.** Brake Assist is a function that interprets the manner in which a driver presses the brake pedal and, if it is computed to be in a manner typical of

responding to an emergency situation, the vehicle will boost the braking to a level higher than that demanded by the driver's pedal application

- **Collision warning.** Obstacle and collision warning systems warn the driver when there is a risk of a collision. Basic systems function by monitoring the area in front of the vehicle and warning the driver if certain criteria are met. These criteria usually relate to the proximity of other vehicles or obstacles in the driver's lane of travel
- **Night vision.** Night vision systems are designed to prevent collisions by increasing the detection performance of critical objects such as pedestrians, cyclists, animals, vehicles, and other objects in night, low light or low visibility conditions (i.e. fog)
- **Pedestrian AEBS.** An extension of AEBS technology intended to detect pedestrians in critical situations and activate the brakes autonomously
- **Pedestrian alert.** Pedestrian detection systems typically use infra-red sensing which may be linked with other data, for example radar and camera data to detect and track pedestrians. An alert is offered to the driver when a conflict of paths is predicted
- **Active (pop-up) bonnet.** To provide additional space between the exterior of the car and hard underlying structures, the bonnet is 'popped' upon hitting a pedestrian with pyrotechnic actuators at the rear corners
- **Pedestrian airbag.** Inflating once a pedestrian has been struck by a car, a pedestrian airbag can be used to provide a cushion around the windscreen base and up the stiff A-pillars around the windscreen
- **Adaptive headlights.** By offering some adaptation (e.g. illumination patterns, reactive high-beam assistance) these systems provide greater illumination of the carriageway and objects than convention static lighting arrangements
- **Alcohol interlock.** An alcohol ignition interlock device (alcolock) is an electronic device, which requires that before the driver is allowed to turn on the ignition he or she has to take a breath or finger touch test in order to check their blood alcohol concentration (BAC). If a BAC above the predetermined threshold level is measured, the alcolock is activated and it is impossible to start the car.
- **Automatic wipers.** Which react to rain on a sensor and wipe the windscreen, tailoring the wiping frequency to the severity of the rainfall
- **Curve lights.** These are lighting systems which respond to steering angle inputs and increase lighting towards the inside of a corner or curve
- **Daytime Running Lights (DLR).** These are 'on' throughout the daytime and night-time to increase conspicuity
- **Electronic Stability Control (ESC).** This monitors the actual vehicle path compared to the steering wheel input and helps to maintain control of the vehicle in cases of understeer or over-steer due to excessive cornering speeds or during evasive steering manoeuvres. ESC can correct the vehicle path by braking individual wheels and thus prevents loss of control and subsequent collisions.
- **Head-up-display.** This provides commonly viewed information from the dashboard in line with the driver's view of the road by projecting it onto the inside

surface of the windscreen. It potentially removes the need for the driver to look away from the road scene as frequently as they would without it

- **Intelligent Speed Assistance (ISA)[7].** ISA describes a range of technologies that are designed to aid drivers in observing the appropriate speed for the road environment. ISA can achieve this through different degrees of control, the three main forms of which are Advisory, Voluntary and Mandatory
- **Speed Limit Detection (SLD).** This can detect the posted speed limit by camera-based road sign recognition. The speed limit can be communicated to the driver via an in-vehicle display or it can be used for Intelligent Speed Assistance

All safety features included in the database are listed in Table 3.3 by target road user group and primary/secondary safety.

Many of these systems are relatively new and have only started to appear on models within the last couple of years. The database identifies whether or not the safety feature is fitted as standard across the model range or as an optional extra[8].

Safety fitment data were collated for each model in various years since its initial production, around every 2-3 years on average, but more regularly in recent years when more safety features became standard. Where data had to be assumed for missing years safety fitment levels from previous years were brought forward. Safety features for a given model in a given year were not assumed to be present for that model in previous years except in exceptional circumstances where there was very good reason to believe that such a feature would be present (for example if the feature was mandated by law).

[7] ISA is also referred to as Intelligent Speed Adaptation in the literature.

[8] In cases where the safety feature was standard on some model variations but not others the feature is considered optional for the purposes of the database.

Table 3.3: Safety features in the database

	Primary Safety	Secondary Safety
Occupant	Adaptive Cruise Control	Driver Airbag
	Autonomous Emergency Braking System	Driver Knee-bag
		Load Limiter
		Passenger Airbag
		Passenger Knee-bag
		Pre-tensioner
		Rear Load Limiter
		Rear Pre-tensioner
		Seat Belt Reminder
		Side Airbag Chest
		Side Airbag Head
Pedestrian	Brake Assist	Active (pop-up) Bonnet
	Collision Warning	Pedestrian Airbag
	Night Vision	
	Pedestrian AEBS	
	Pedestrian Alert	
All	Adaptive Headlights	
	Alcohol Interlock[9]	
	Automatic Wipers	
	Curve Lights	
	Daytime Running Lights	
	Electronic Stability Control	
	Head-up-Display	
	Intelligent Speed Assistance[9]	
	Speed Limit Detection	

[9] Alcohol interlocks and Intelligent Speed Assistance devices were not found to be installed on any of the cars covered by the fitment database, either as standard or as an optional extra.

4 Current composition of the car fleet in London

This section provides an overview of the car fleet in London including traffic data, the estimated prevalence of vehicle safety technology and the trends in vehicle safety technology for new cars.

We show:

- An increase in the fraction of traffic made up of MPVs and 4x4s
- An increase in the average age of vehicles being driven in London
- That information on vehicle safety technologies has been collated for 60-70% of the vehicle types and ages which comprise the majority of traffic
- An increase in the fraction of traffic fitted with safety technologies
- An increase in the proportion of car traffic which is newly registered

4.1 Traffic estimates

Between 2009 and 2013 car traffic in London decreased by 5% from 14.9 to 14.1 billion vehicle miles.

Traffic, vehicle registration and MOT data were combined in a statistical model (as described in Section 3.3) to allow traffic between 2009 and 2013 to be estimated and divided by segment and registration year. Figure 4.1 shows modelled car traffic by segment and year.

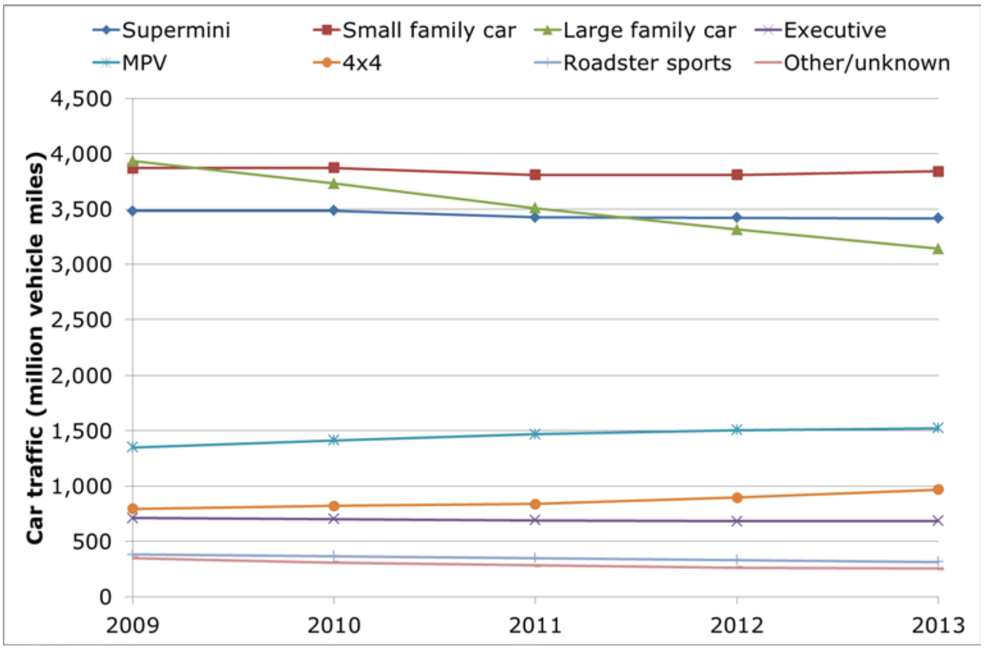


Figure 4.1: Modelled car traffic in London by segment and year (2009-13)

The data indicate that there was less large family car traffic in 2013 compared to 2009; whilst MPV and 4x4 traffic increased over the same period.

By including the registration year in the model the proportion of car traffic by vehicle age can be examined and this is shown in Figure 4.2.

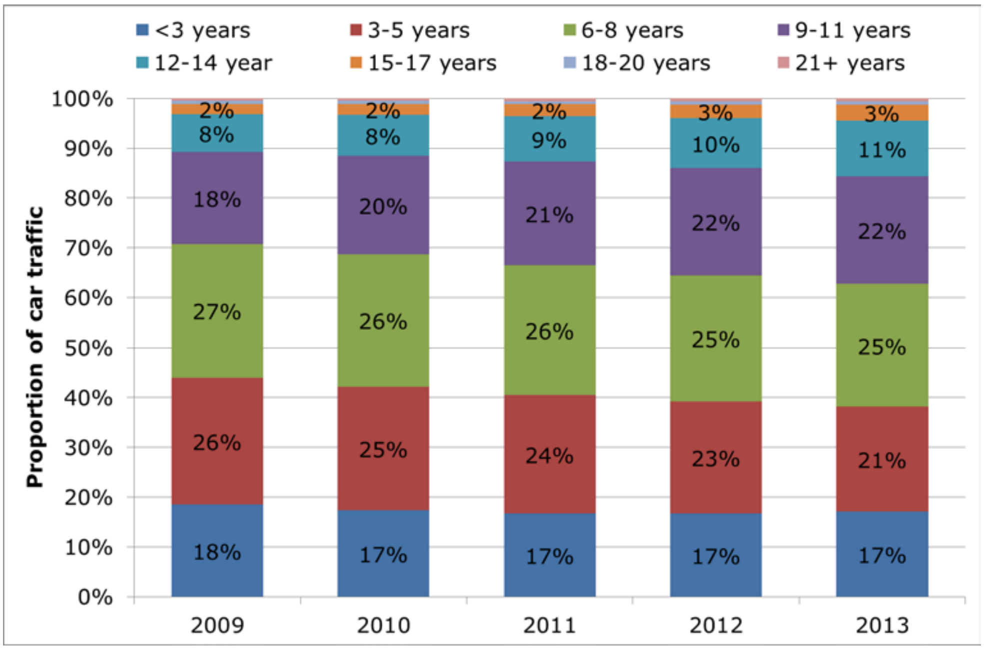


Figure 4.2: Modelled proportion of car traffic in London within each year by car age (2009-13)

Between 2009 and 2013 there was a decrease in proportion of cars aged 3-8 years and increase in those aged 9+ years. This suggests that cars in London are gradually getting older.

4.2 Vehicle technologies in the London fleet

4.2.1 Representativeness of the fitment database

In total, 69% of car traffic in London between 2009 and 2013 is covered by the vehicles in the fitment database. Figure 4.3 shows how this is distributed by segment. The blue bars (left hand axes) show what proportion of the traffic in each segment is covered by the fitment database and the red dots (right hand axes) show what proportion of the overall traffic this segment represents.

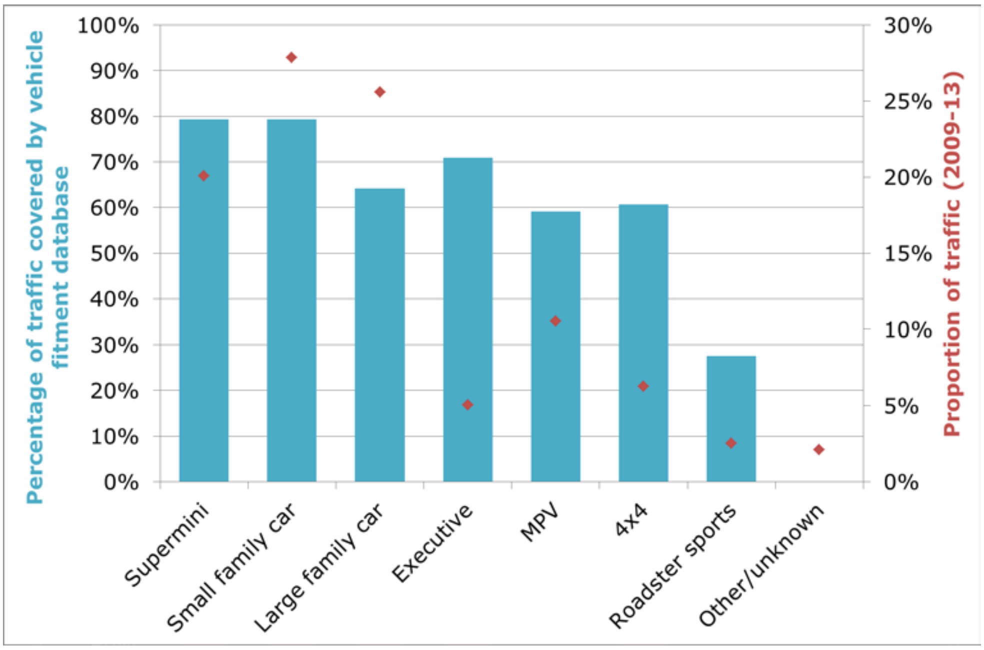


Figure 4.3: Proportion of the London traffic data covered by the fitment database by segment

The graph shows that approximately 60-80% of traffic in each segment (excluding roadster sports) is covered by the fitment database. Most importantly the three segments which, when combined, make up approximately three quarters of traffic (superminis, small family cars and large family cars) are well represented by the fitment data.

Roadster sports are a small (accounting for less than 3% of traffic) and diverse group; 5 makes and models cover only 28% of traffic for this segment, whilst the same number covers over 70% of traffic in the executive segment. Therefore it was decided that the additional effort required to ensure 60-80% of the traffic was covered was substantial and would not benefit this project. As a result, the conclusions drawn about the fitment of technologies in the roadster sports are less robust than for the other segments.

Figure 4.4 shows what proportion of the traffic by vehicle age is covered by the fitment database (green bars) and the proportion of overall traffic that each age represents (red dots).

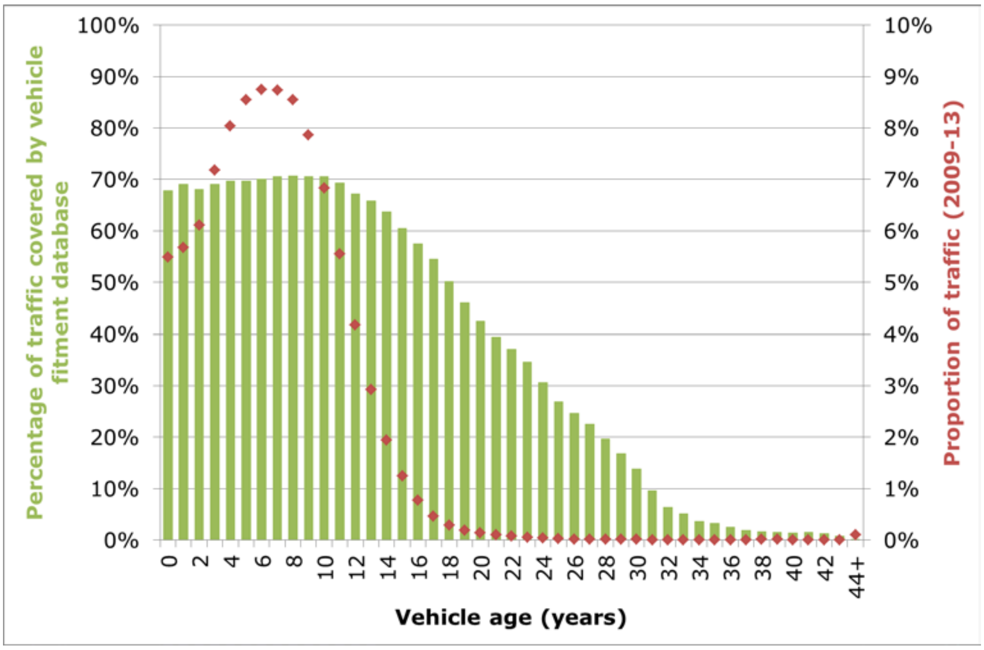


Figure 4.4: Proportion of the London traffic data covered by the fitment database by vehicle age

The graph highlights that 60-70% of traffic for cars aged 15 years or less is covered by the fitment database. Older vehicles are not as well represented, but these account for a much smaller proportion of overall traffic (those aged 16 years or more only account for 2.4% of traffic between 2009 and 2013) and are more likely to be scrapped first therefore having less influence on the London vehicle fleet as we move forwards.

Figure 4.5 shows the proportion of injury collision involved cars that is covered by the fitment database by car age (green bars) and the proportion of all injury collision involved cars that each age represents (red dots).

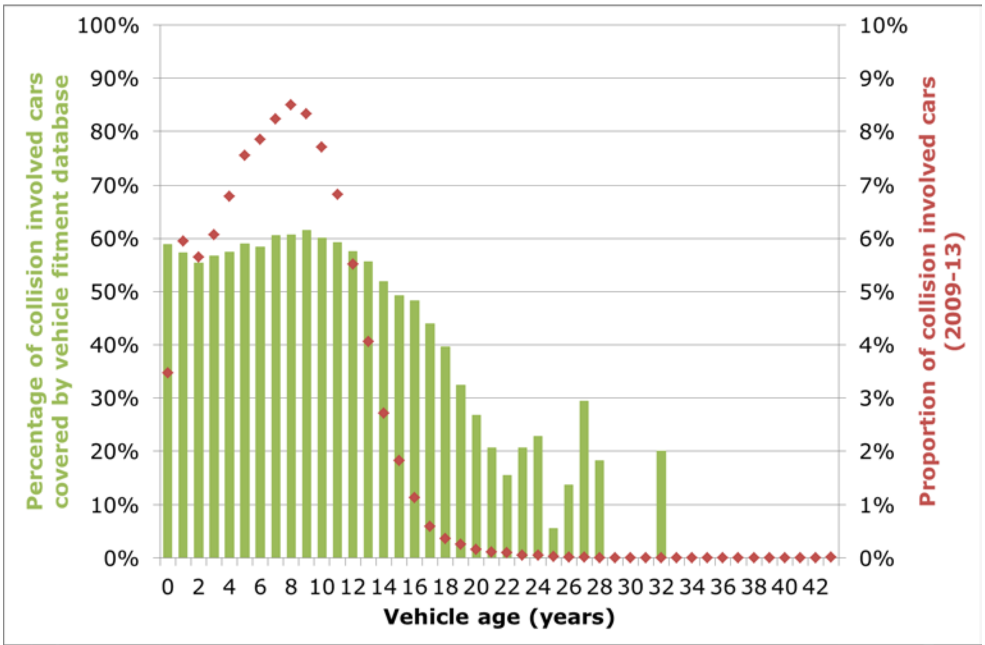


Figure 4.5: Proportion of injury collision involved cars in London covered by the fitment database by vehicle age

The graph highlights that on average, 58% of injury collision involved cars aged 15 years or less are covered by the fitment database. Older vehicles are not as well represented, but these account for a much smaller proportion of all injury collision involved cars (those aged 16 years or more only account for 3.0% of injury collision involved cars between 2009 and 2013).

The fitment analysis in this report only utilises the makes, models, and registration years covered by the database. For example, the results presented in Section 4.2 are presented as a "Percentage of car traffic (covered by the fitment database)". As a result, if we assume the 31% of traffic not covered by the fitment database is similar to the traffic which is covered, the results can be assumed to be representative of the London fleet. We think this is a reasonable assumption because:

- The makes and models have not been selected for study due to the presence or absence of different technologies, but because of their prevalence within the fleet
- The majority of segments are equally well covered by the database (approximately 60-80% each)
- Although older cars are not well covered by the database (compared to those cars aged 15 or less), these make up a small proportion of overall traffic; therefore even if these vehicles were not equipped with any technologies, the overall proportion of traffic which is equipped, would not be affected hugely.

4.2.2 Fitment of technologies

The following section examines the proportion of car traffic in London that is fitted with each of the safety technologies being considered as part of this work (see Table 3.3). The results presented are 'the proportion of the car traffic that is covered by the fitment database' and therefore do not represent the entire London car fleet. However, as discussed in Section 4.2.1, the traffic covered by the database is assumed to be approximately representative of all car traffic and therefore the results should be generalizable.

Figure 4.6, Figure 4.7 and Figure 4.8 show the proportion of car traffic fitted with each of the 25[10] technologies included in the fitment database; these have been split onto three graphs by uptake so that the charts are easier to read. Within the database each technology is recorded as fitted as standard or optional. On the following graphs, standard fitment is displayed by the data points and optional fitment using the error bars.

[10] There were actually 27 fitments in the database, but two are not shown here as they were not fitted as standard to any vehicles.

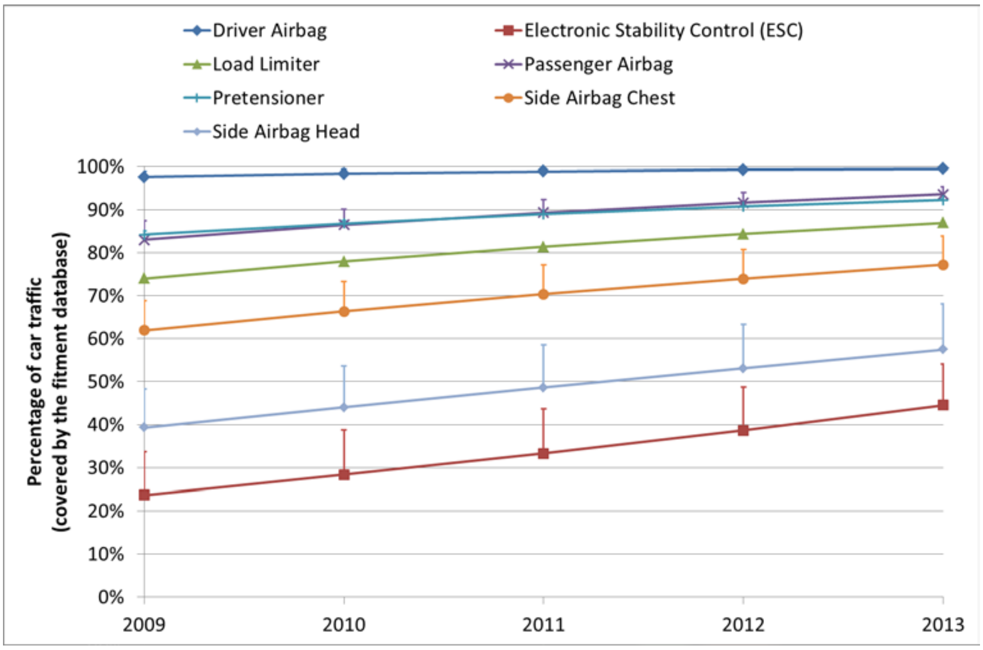


Figure 4.6: Proportion of car traffic in London (covered by the fitment database) which is equipped with the highest uptake technologies by year (2009-13)

Throughout the period of interest (2009-2013) driver airbags have been fitted as standard in almost 100% of cars. The other technologies have increased in prevalence as older vehicles (without the technologies fitted) were scrapped and replaced with newer vehicles entering the fleet.

Some of the changes in fitments have been influenced by the introduction of regulations which mandate the use of certain technologies (see Table 2.1). For example, in 2009 the EU introduced the mandatory introduction of ESC on all new types of cars (M1) and small commercial vehicle (N1) sold in the EU from 2011, with all new M1 and N1 vehicles being equipped by 1st November 2014. As a result, the proportion of the fleet equipped with this technology has shown a large increase from 2009 to 2013. Assuming that the rate of uptake continues and that the fleet renewal is similar to that seen between 2009 and 2013, we would expect that by 2021 approximately 95% of the London fleet would be equipped with ESC technology.

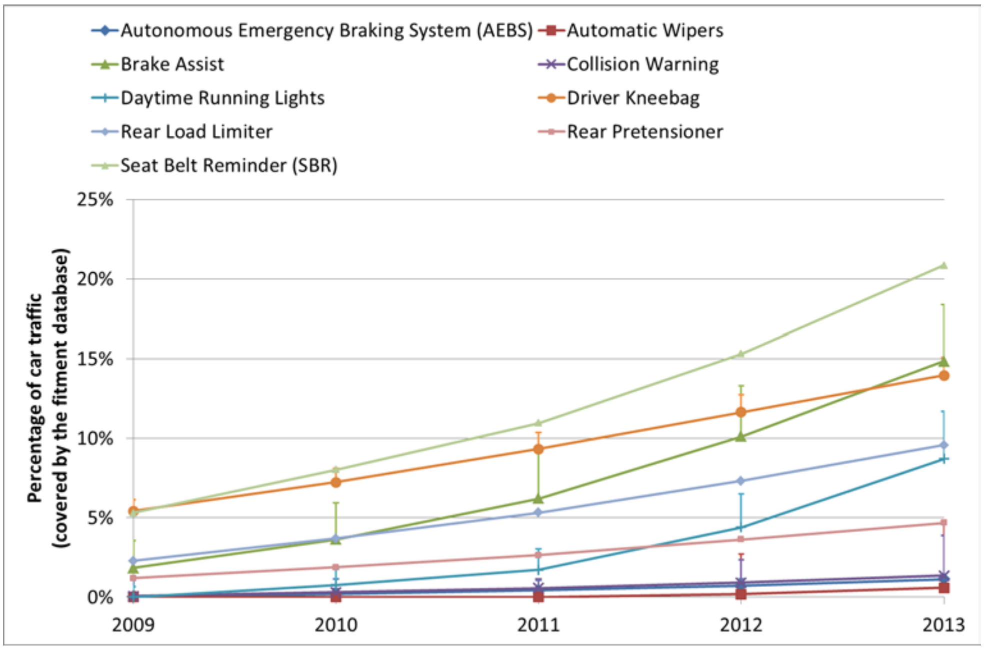


Figure 4.7: Proportion of car traffic in London (covered by the fitment database) which is equipped with the medium uptake technologies by year (2009-13)

Technologies including brake assist and seatbelt reminders (SBR) have shown a relatively steep upwards trend since 2011, as would be expected given legislation on the mandatory inclusion of brake assist on new cars; seatbelt reminders are now installed in vehicles which account for over 20% of the traffic in London and brake assist is installed in over 14%. AEBS and collision warning systems seem to be on the increase too, but are fitted to a very small proportion of the fleet.

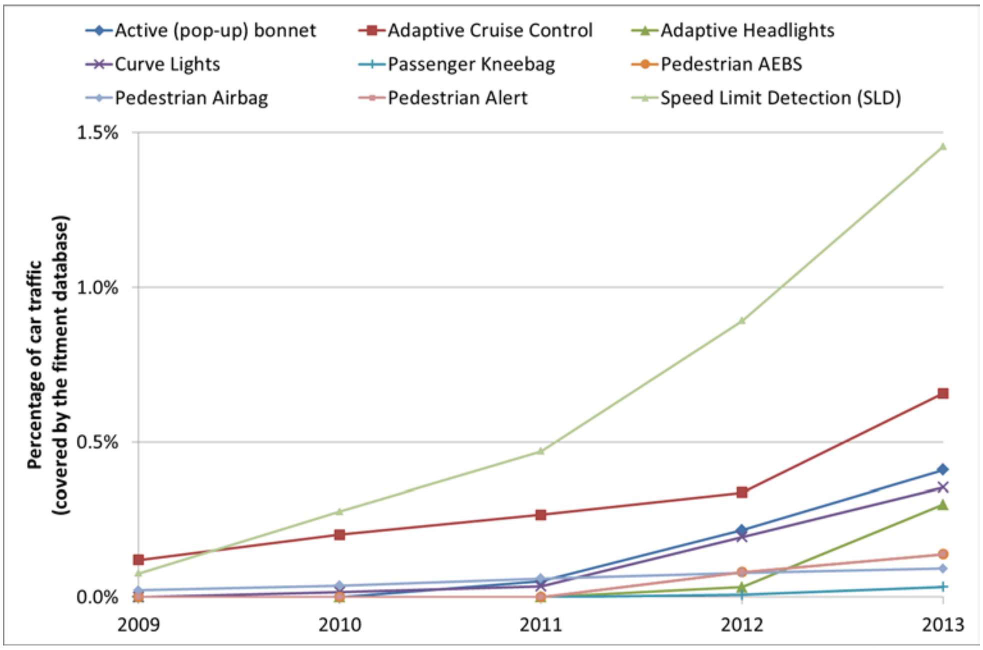


Figure 4.8: Proportion of car traffic in London (covered by the fitment database) which is equipped with the lowest uptake technologies by year (2009-13)

Although still relatively new to the market, the technologies in Figure 4.8 are beginning to be fitted to more of the London fleet. Note that the optional fitments are not displayed on this graph as the ranges are large. Also, head-up-displays and night vision fitments are not shown since they were not fitted as standard to any vehicles in the fitment database. Table 4.1 shows the 2013 levels of car traffic in the fitment database with each of the low uptake fitments as standard or optional.

Table 4.1: Percentage of London car traffic (in fitment database) with each of the low uptake fitments as optional or standard in 2013

Fitment	Percentage of car traffic in fitment database with fitment as at least optional (2013)
Active (pop-up) bonnet	0.4%
Adaptive Cruise Control	2.6%
Adaptive Headlights	6.4%
Curve Lights	2.9%
Head-up-Display	0.9%
Night Vision	0.4%
Passenger Kneebag	0.03%
Pedestrian AEBS	0.9%
Pedestrian Airbag	0.09%
Pedestrian Alert	0.6%
Speed Limit Detection	1.6%

In addition to considering how the fitment of the different technologies changes over time, it is also possible to examine differences in the fitment rates by segment. As an example of the relative fitment of primary safety features Figure 4.9 shows the proportion of London car traffic in 2013 that was fitted with ESC, by segment.

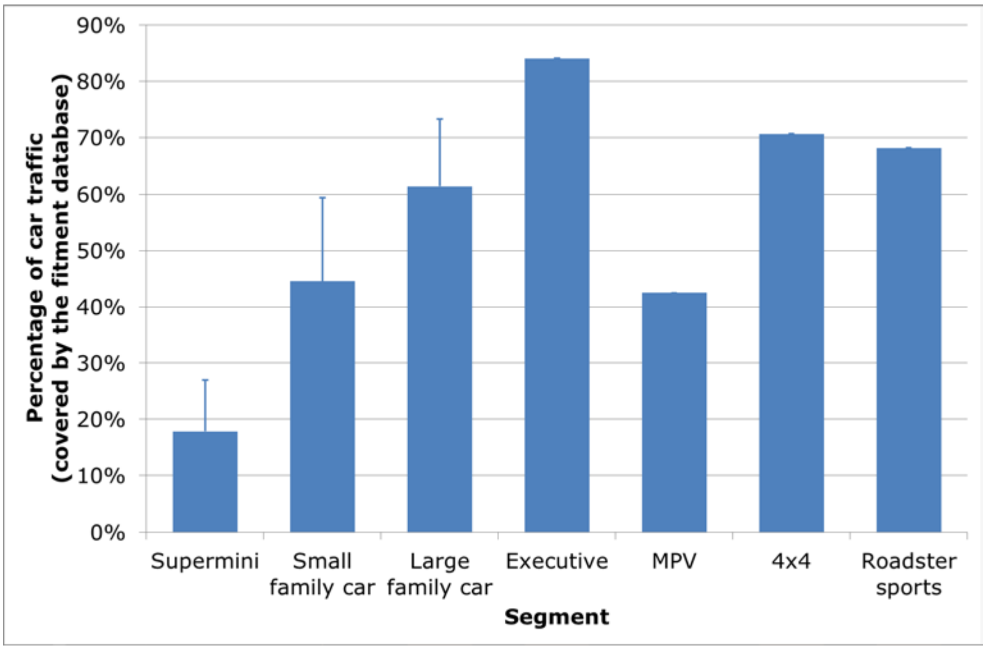


Figure 4.9: Proportion of 2013 car traffic in London (covered by the fitment database) which is equipped with ESC by segment

This highlights the large difference between the executive segment, where the majority of the traffic has ESC fitted as standard, and the supermini segment where less than 20% of traffic is fitted with ESC as standard.

There are also differences in the fitment rates of certain secondary safety features. Figure 4.10 shows the proportion of traffic in 2013 in each segment that is fitted with each type of airbag. Note that driver airbags have been excluded as they are fitted to approximately 100% of all segments; passenger knee bags have also been excluded as they are fitted to a very small proportion of the fleet. Solid bars represent standard fitment of the technology and the error bars represent optional fitment.

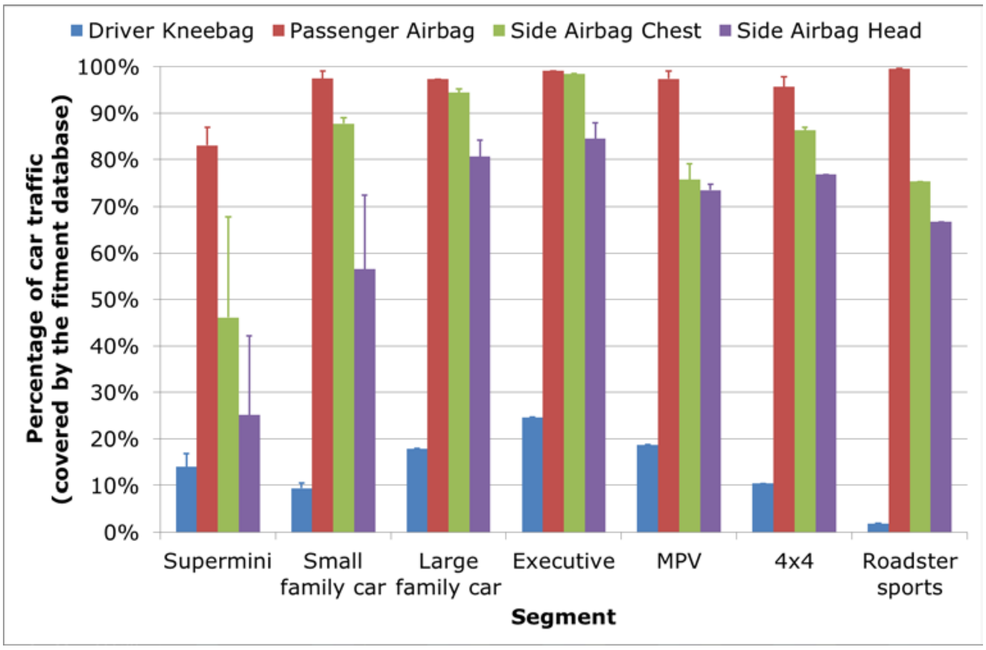


Figure 4.10: Proportion of 2013 car traffic in London (covered by the fitment database) which is equipped with airbags by segment

The graph shows that, compared to superminis, executive and large family cars are more often fitted with airbags as standard. Optional fitment is more common for the smaller vehicles (including superminis), but it has not been possible to estimate how many people choose to have these extras fitted.

4.3 Trends in new cars in the London fleet

In order to predict future trends in the purchasing of new cars in London, it is important to understand the types of cars people are currently buying. The following section uses traffic data for newly registered vehicles[11] in London to investigate:

- The cars being bought
- The technologies these cars are fitted with.

4.3.1 The amount and type of new cars

Figure 4.11 shows the proportion of car traffic in London which is attributed to newly registered cars across the period.

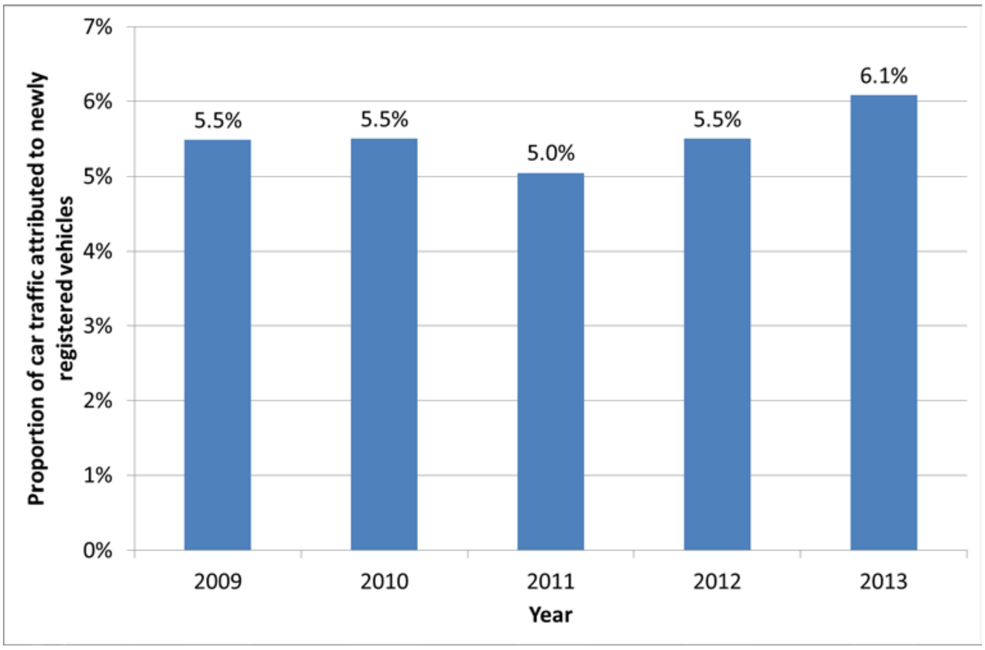


Figure 4.11: Proportion of car traffic in London which is from newly registered vehicles

The trend shows that the year with the smallest proportion of newly registered car traffic was 2011. The proportion of car traffic which was newly registered has increased steadily since 2011 to its highest (6%) in 2013. This contrasts with the finding that the average age of cars is increasing, and it is suggested that this could be due to an increasing turnover of cars in mid age groups and fewer older cars being scrapped.

Grouping the makes and models into car segment shows that the trend in the type of vehicle being brought has changed (Figure 4.12).

[11] i.e. those vehicles where registration year is equal to year of data

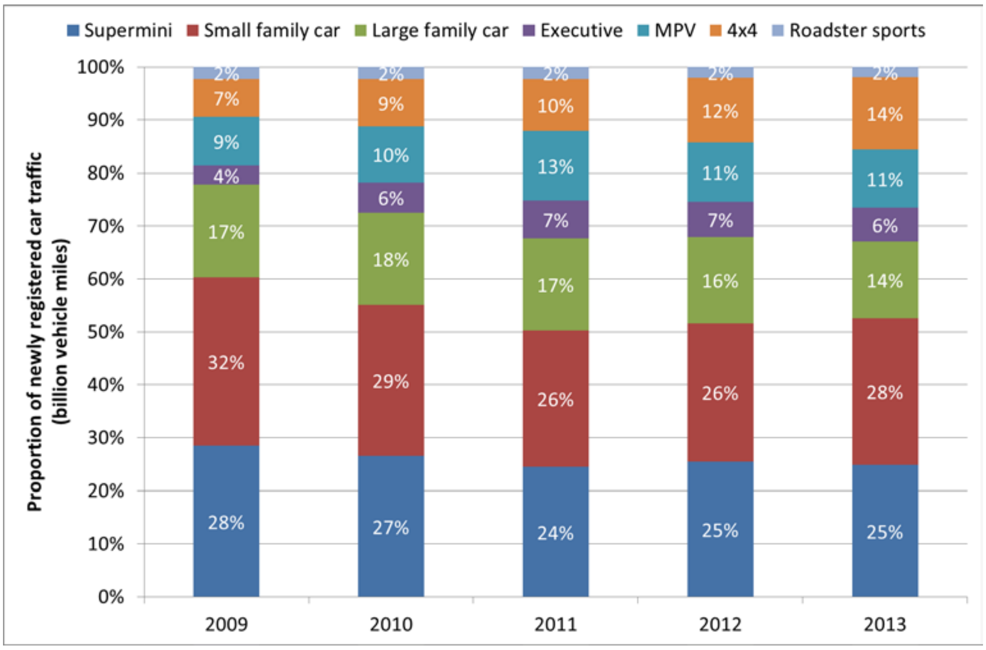


Figure 4.12: Proportion of newly registered car traffic in London by segment and year

The trend shows that the size of the vehicles in the fleet is generally increasing with fewer new superminis and small family cars being bought but more 4x4s and MPVs. This differs from the trend across the whole of Great Britain where the size of the fleet has been diverging with increased superminis and increasing 4x4s/MPVs (Lloyd, Reeves, Broughton & Scoons, 2013).

4.3.2 Technologies on new cars

The following section examines the proportion of newly registered car traffic in London that is fitted with the different technologies. These can be compared with the results for vehicles of all ages presented in Section 4.2.2. The results presented are 'the proportion of newly registered car traffic that is covered by the fitment database' and, as in Section 4.2.2 do not represent the entire newly registered car fleet in London. However, as discussed in Section 4.2.1, the traffic covered by the database is assumed to be approximately representative of all car traffic and therefore it should be possible to extend the general results to all traffic.

Figure 4.6, Figure 4.7 and Figure 4.8 show the proportion of car traffic fitted with each of the technologies included in the fitment database; these have been presented in the same three graphs as in Section 4.2.2 and again, standard fitment is displayed by the data points and optional fitment using the vertical lines.

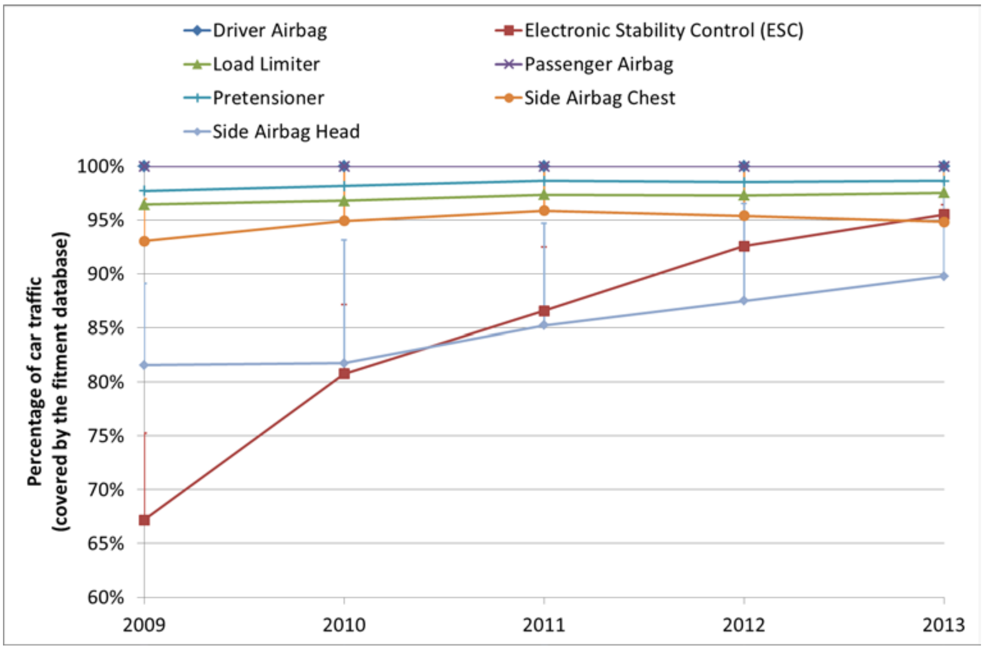


Figure 4.13: Proportion of newly registered car traffic in London (covered by the fitment database) which is equipped with the highest uptake technologies by year (2009-13)

Driver and passenger airbags were both fitted to all newly registered vehicle traffic throughout the period of interest and pretensioners and load limiters were also practically universal. The proportion of traffic with chest side airbags fitted as standard was close to 95% over the 2009-2013 period.

ESC has become far more prevalent in newly registered vehicles; 67% of newly registered vehicle traffic in 2009 had ESC fitted as standard, compared with 96% in 2013. This demonstrates the reaction of the industry to the requirement for all new cars to be fitted with ESC by November 2014.

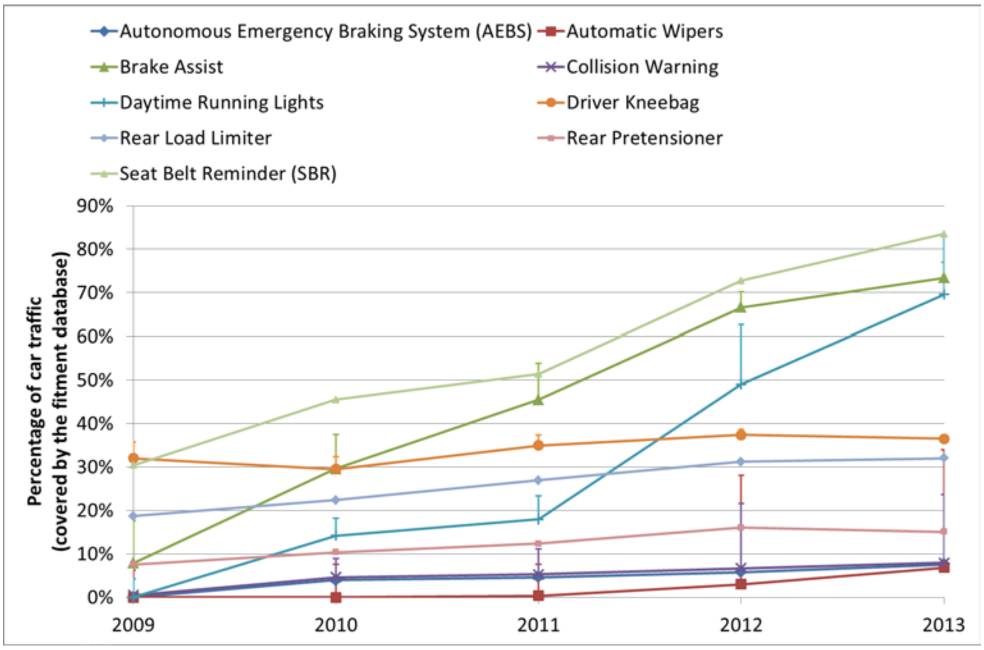


Figure 4.14: Proportion of newly registered car traffic in London (covered by the fitment database) which is equipped with the medium uptake technologies by year (2009-13)

Seat belt reminders (SBR), brake assistance and daytime running lights all became much more common in newly registered vehicles over the period 2009-2013. In particular, daytime running lights weren't commonly available in the UK in 2009, but were present in 70% of newly registered vehicles in 2013; following the mandating of this technology for new types of vehicles from 2011. Other technologies don't appear to have taken off as quickly for example Automated Emergency Braking Systems (AEBS) which have been available on production vehicles since before 2008 (Grover *et al.*, 2008), but so far the increase in the proportion of traffic with them fitted as standard is relatively small (fitted as standard to 8% of newly registered cars in 2013). This could be because there was little incentive for the fitment of AEBS over this period; since 2014, these systems have been tested by Euro NCAP as part of the vehicle rating and as such their take-up within the fleet may increase.

Other fitments have also shown a more gradual infiltration into the newly registered car market; for example driver knee airbags were fitted as standard in 32% of the newly registered car traffic in 2009 and 37% in 2013.

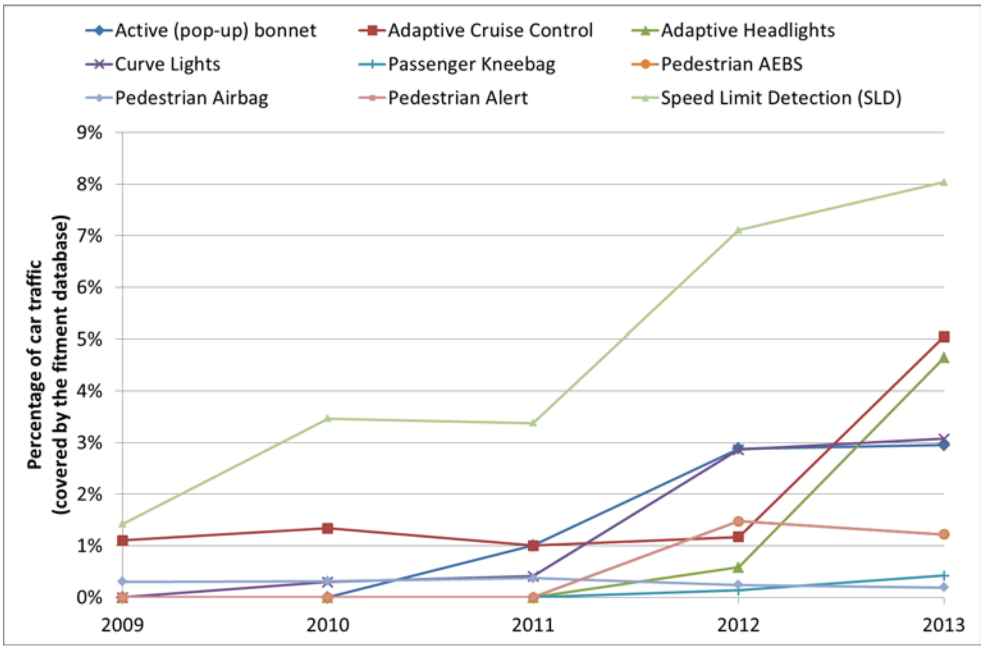


Figure 4.15: Proportion of newly registered car traffic in London (covered by the fitment database) which is equipped with the lowest uptake technologies by year (2009-13)

Speed limit detection has shown a relatively large increase over the period in the proportion of newly registered traffic for which it is fitted.

A much higher proportion of newly registered car traffic had adaptive cruise control fitted as standard in 2012 and 2013; adaptive headlights show a similar pattern. The proportion of traffic for which these two fitments are optional has also risen dramatically, particularly between 2011 and 2013. In 2013, 52% of newly registered car traffic had adaptive headlights as either optional or standard, compared with 0.7% in 2009. The same figures for adaptive cruise control are 21% in 2013 compared with 1.1% in 2009.

4.4 Summary

This section has provided an overview of the car traffic in London by segment and age. In particular, we have seen an increase in the proportion of traffic made up of 4x4s and MPVs, and a reduction in large family cars.

New car registrations have been increasing since 2011, but between 2009 and 2013 there was a decrease in proportion of cars aged 3-8 years and increase in those aged 9+ years, which suggests that cars in London are gradually getting older.

This section also examined the trend in uptake of various safety features within the whole fleet, and more specifically within the new vehicle fleet.

Throughout the period of interest (2009-2013) the prevalence of most of the technologies studied has increased, as older vehicles (without the technologies fitted) were scrapped and replaced with newer vehicles entering the fleet.

Some of the changes in fitments (for example ESC) have been influenced by the introduction of regulations which mandate these technologies on all new cars. The uptake of these technologies is generally quicker than those where the only influence is consumer based information including EuroNCAP. For ESC, assuming that the rate of uptake continues, and that the fleet renewal is similar to that seen between 2009 and 2013, we would expect that by 2021 approximately 95% of the London fleet would be equipped with this technology.

5 Collision analysis

This section examines road collisions in London and the fitment of safety technologies to cars involved in these collisions. This information is then used to model the effectiveness of selected primary and secondary safety features in reducing collisions and injury severity respectively.

In this section we demonstrate:

- Between 2009 and 2013 there were 116,511 casualties on London's roads involved in a collision with a car, 44% of which were vulnerable road users who are relatively more likely to be killed or seriously injured.
- Superminis, small family cars and MPVs are relatively more likely to be involved in injury collisions in London, and are relatively more likely to injure the car occupants and pedestrians than other car segments
- Older cars are more likely to injure car occupants than younger cars
- Older cars are slightly more likely to injure pedestrians in frontal impacts than younger cars

5.1 Collisions in London

Between 2009 and 2013 there were 118,912 collisions on London's roads, 81% of which involved a car. In these car-involved collisions there were 116,511 casualties. The breakdown of these by casualty type and severity proportion is shown in Table 5.1.

Table 5.1: Casualties in collisions involving cars in London by casualty type and proportion killed or seriously injured (KSI) (2009-13)

Casualty type	Number of casualties	Proportion of all casualties	Number of KSI casualties	Proportion of casualties KSI
Car/taxi occupant	60,793	52%	1,841	5%
Pedestrian[12]	18,887	16%	2,094	18%
Pedal cyclist	16,371	14%	2,938	11%
PTW[13] rider	16,536	14%	82	13%
LGV/HGV[14] occupant	2,083	2%	110	4%
Other[15] occupant	1,841	2%	3,335	6%
Total	**116,511**	**100%**	**10,400**	**9%**

[12] These pedestrians are not necessarily struck by the car or taxi as there are sometimes other vehicles involved in the accident too; however 99% of them are.

[13] Powered Two Wheeler

[14] Light Goods Vehicle / Heavy Goods Vehicle

[15] Includes minibuses, buses and coaches, agricultural vehicles and ridden horses

Over half of the casualties in collisions involving cars are car occupants and 5% of these are killed or seriously injured. Vulnerable road users (including pedestrians, pedal cyclists and PTW riders) also make up a large proportion of casualties (44% combined) and these casualties are much more likely to be killed or seriously injured. Figure 5.1 shows how the number of KSI casualties in these collisions varies by year.

LGV, HGV and other vehicle occupant casualties are relatively rare in collisions involving cars and for this reason these casualties will not be considered further in this report.

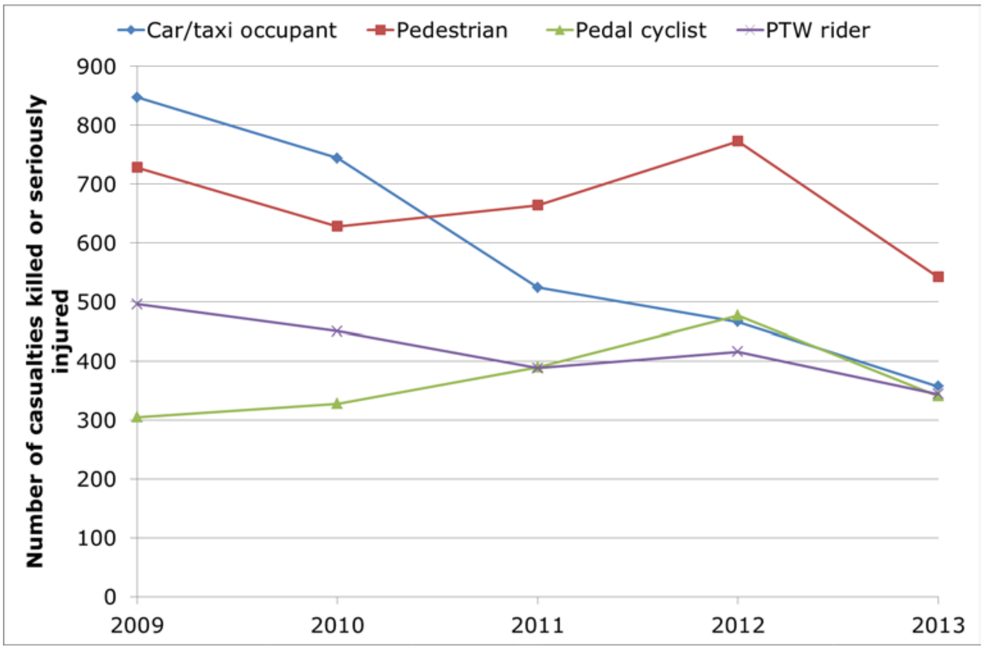


Figure 5.1: Number of casualties killed or seriously injured in collisions involving cars in London by casualty type and year

The number of car driver casualties killed or seriously injured has been declining since 2009; PTW KSI casualties also seem to have been declining but at a slower rate. In contrast, killed or seriously injured pedestrians and pedal cyclists showed a general upwards trend until 2012 but have also declined in 2013.

Appendix D contains analysis of London collision data by age and size of car. The results show that the likelihood of being involved in a collision can be influenced by many factors including exposure, the conditions, or way in which the car is driven and the presence of primary safety features.

If the car *is* involved in a collision, then many other factors influence the injury severity for the individuals involved. These include the conditions of the collision, the size and structure of the car, age and size of the casualty and the presence and use of secondary safety features.

Analysis in Appendix E compares the fitment of different technologies on collision involved cars from inside and outside of London. The majority of safety features were more commonly found on vehicles where the driver home postcode was outside of London. This might suggest that vehicles from within London are different from those outside London, perhaps that drivers from within London are less likely to pay for additional safety features.

Throughout the following analysis the cars with unknown make/model and/or vehicle age have been redistributed proportionately amongst the known vehicles or casualties. This ensures that casualty numbers and rates presented are as accurate as possible, given the data available.[16]

In addition, from Section 5.2 onwards vehicles in the ‘other’ category have been excluded as, according to the makes and models, these should have been recorded as other vehicle types including motorcycles, van and trucks. These only account for approximately 2% of casualties and therefore exclusion of these should not adversely affect the analysis.

In order to draw robust conclusions from the casualty numbers, a number of other sources of information need to be utilised:

- Traffic data
- Data on the fitment of vehicle technologies to the fleet
- Differences in the people who drive the cars
- Differences in the situations in which the vehicles are used (e.g. rural/urban driving)

Section 5.2 examines how traffic influences the number of casualties; Sections 5.3 discusses the impact of primary safety developments on casualties in London; Section 5.4 presents the results of the secondary safety modelling which aims to control for the effects of differences in drivers and situations, to estimate how improvements to cars have effected casualty numbers and finally Section 5.5 summarises what we know about how cars interact with one another in a collision.

5.2 Casualty rates

This section links the collision data from STATS19 to the modelled traffic data to calculate a collision or casualty rates (per million vehicle miles). Figure 5.2 shows the personal injury collision involvement rate for cars by segment.

[16] The proportional redistribution of cars with unknown make, model and/or age information requires the assumption that these cars are similar to the distribution of cars that have known make, model and age information. It is possible that this is an unreasonable assumption, specifically as approximately 30% of the unknown information is due to cars involved in hit and run accidents. These cars may not be similar in characteristics to the known cars involved in collisions. However, as no further information is known about these cars, equal representation has been assumed.

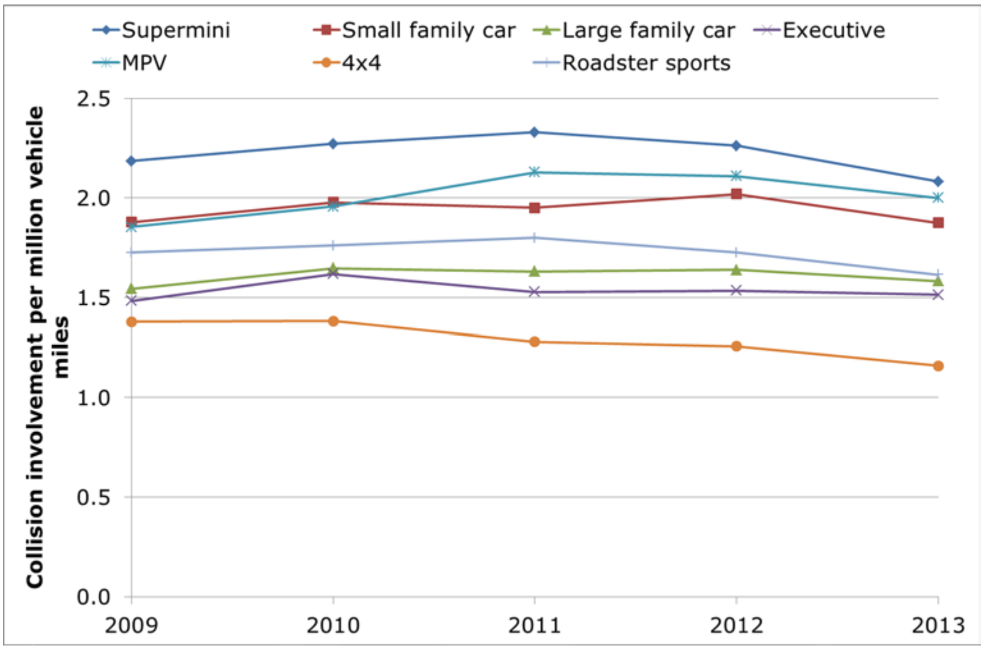


Figure 5.2: Injury collision involvement rate of cars in London (per million vehicle miles) by segment and year (2009-13)

The graph shows that, relative to the distance travelled, superminis are the most injury collision involved cars. There are a number of possible reasons for this, including:

- Appendix C shows that young drivers often own smaller cars (such as superminis); these drivers are often involved in more collisions due to inexperience (DfT, 2014).
- These vehicles are equipped with fewer primary safety features (which prevent collisions occurring) than (for example) 4x4s and executives, which have a much lower collision involvement rate.

The graph also shows that there are differences in the trends between the segments: MPVs appear to be becoming more collision involved from 2009 to 2011, but 4x4s less so. This could be due to differences in the way the technologies are adopted by these segments, changes to the types of people who drive the vehicle or the environments in which they are driven.

Figure 5.3 is similar to Figure 5.2 except that it shows the car driver casualty rate by segment rather than the collision involvement rate.

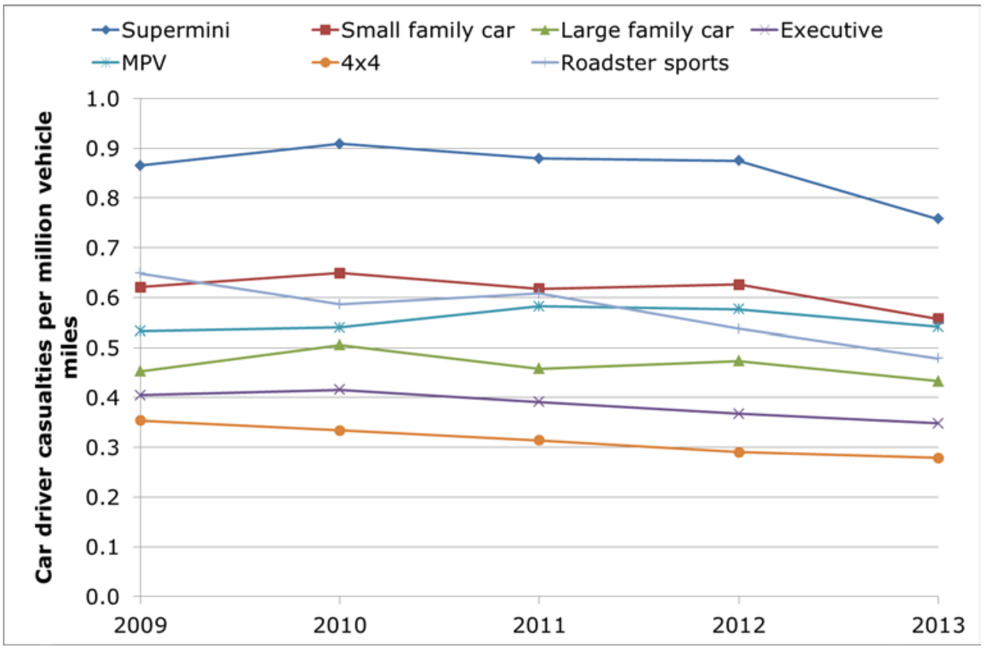


Figure 5.3: Car driver casualty rate in London (per million vehicle miles) by segment and year (2009-13)

Broughton (2008) showed that the driver casualty rate falls with an increase in the size of car: larger cars protect their occupants better than smaller cars. This analysis also showed that the driver casualty rate increased with the size of the other car (in car to car collisions): larger cars inflict more damage on the other car than smaller cars. Hence, the relative risks faced by the drivers of two colliding vehicles changes depending on the size of the two vehicles.

Figure 5.2 showed that MPVs were more injury-collision involved than small family cars, but Figure 5.3 shows that driver casualty rate for this segment is lower than small family cars. This could be due to the fact that bigger cars protect their occupants better in a collision than smaller cars (see Section 5.5 for more details), or due to different collision typology, or due to differences in the age of drivers in the two segments: older people are increasingly frail and therefore are more likely to be injured if they do have a collision (Li *et al.*, 2003).

The trend in executive cars suggests that collision involvement of this segment has changed relatively little between 2011 and 2013 (Figure 5.2); however the car driver casualty rate for this group shows a gradual decline during this same period (Figure 5.3). This could suggest that secondary safety has improved and reduced the number of casualties. The effect of secondary safety on the different segments will be examined in more detail in Section 5.4.

Finally, Figure 5.4 shows the pedestrian casualty rate (per million vehicle miles travelled by the car[17]) by segment.

[17] Note that the pedestrian casualty rates presented in this section are pedestrians *per mile travelled by the car*. Pedestrian casualty rates which take into account the *amount of travel by the pedestrian* are presented and used for the prediction modelling in Section 6.

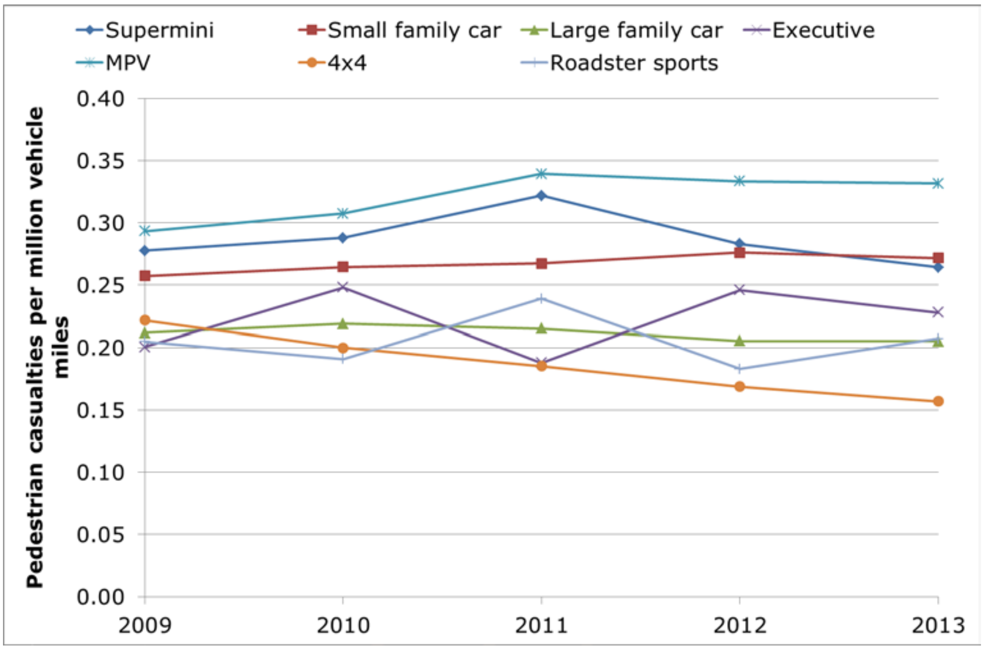


Figure 5.4: Pedestrian casualty rate in London (per million vehicle miles) by segment and year (2009-13)

The pedestrian casualty rate shows a different picture to the car driver casualty rate (Figure 5.3): MPVs have the highest rate for pedestrian casualties (it was superminis for driver casualties). There is a general expectation that larger cars, with a taller front face are more harmful to pedestrians than smaller ones because of the greater likelihood of direct loading to the head and chest of the pedestrian from the front of the vehicle. However, these data show that in 2013 4x4s had the lowest pedestrian casualty rate of the seven segments. Therefore, this may indicate a stronger dependence of the casualty rate on the differences in the locations or manner in which the car is driven (for example, MPVs may be more frequently driven in areas where pedestrians are located) than on the vehicle design.

In addition to examining differences in the casualty rates by segment, the traffic data allows us to examine differences by car age – see Figure 5.5 for car driver casualties and Figure 5.6 for pedestrian casualties.

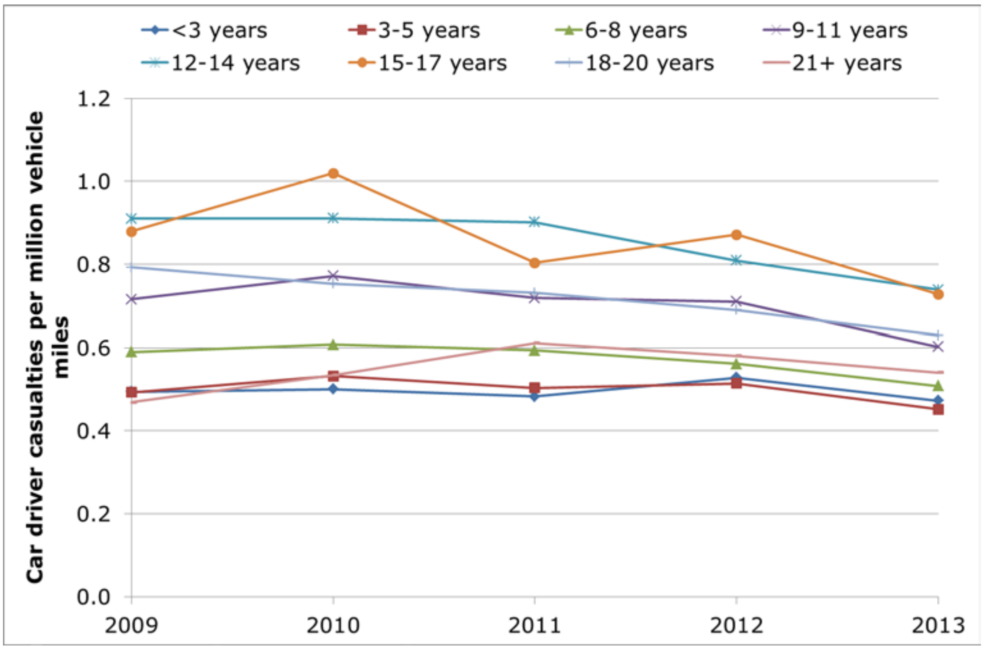


Figure 5.5: Car driver casualty rate in London (per million vehicle miles) by vehicle age and year (2009-13)

Cars aged 12-17 years have more car driver casualties per million vehicle miles than newer cars (0-5 years). There are a number of possible reasons for this:

- Differences in the types of people that drive cars in each age group. For example, as shown in Appendix C, older cars tend to be driven by younger or older people. Older people are more frail and so more likely to be injured and younger people are more likely to be involved in a collision due to inexperience.
- Older vehicles are less likely to be equipped with primary and secondary safety features which may help to prevent collisions and injuries from occurring.

Figure 5.6 shows the pedestrian casualty rate (per million vehicle miles travelled by the car) by car age.

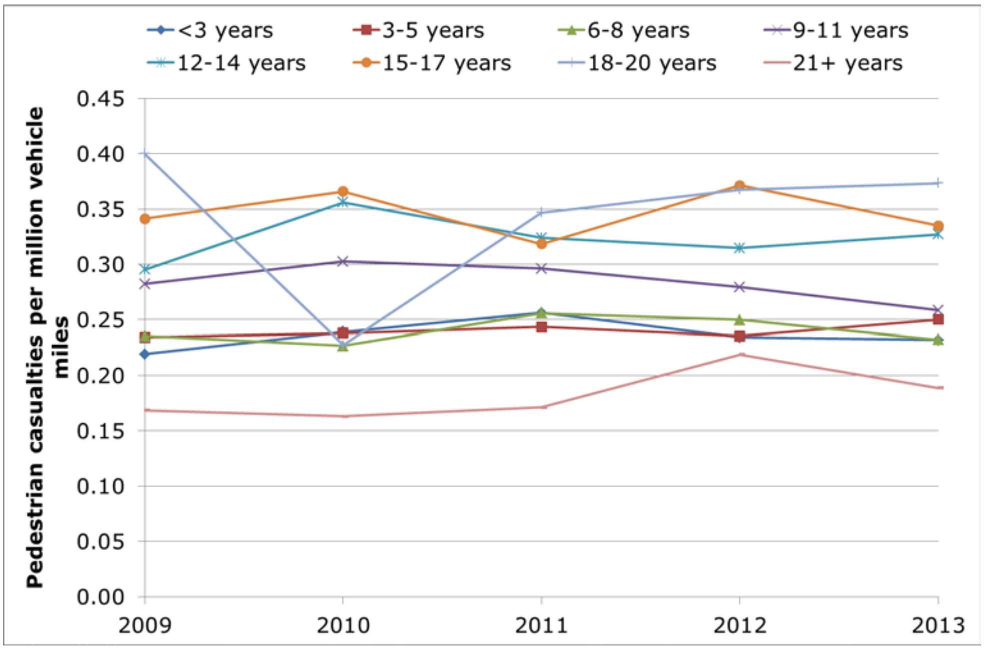


Figure 5.6: Pedestrian casualty rate in London (per million vehicle miles) by vehicle age and year (2009-13)

The trend in casualty rate is less clear in this graph than in the previous graph due to the smaller casualty numbers for pedestrians. However, the overall picture is similar to that for car driver casualties: the older cars (aged 12-20 years) have a higher casualty rate than the newer cars (aged 0-8 years).

As shown in this section there are a number of possible reasons for differences between the segments and car ages. These include:

- Differences in the level of primary or secondary safety
- Differences in the types of people that drive these cars (young drivers are more collision involved and older people are more frail)
- Differences in the size of car (larger cars protect their occupants better but cause different interactions with pedestrians and resulting movements than smaller cars)
- Differences in the way or location in which the vehicles are driven (e.g. urban areas where pedestrians are frequently found)

The secondary safety modelling (see Section5.4) aims to control for some of these differences in order to estimate how improvements to secondary safety have influenced casualties in London.

5.3 Primary safety

Primary safety refers to systems such as brakes and steering which help to avoid collisions. Primary safety is notoriously difficult to evaluate as it involves predicting collisions which have not occurred because of the presence of technologies.

As seen in Section 5.2 and the analysis in Appendix F, there are a number of factors which influence the collision risk of cars. These factors include:

- differences in the types of people that drive the cars and their driving behaviours

- differences in the size and types of cars
- differences in the location where and times when the vehicles are driven
- differences in the vehicles with and without vehicle fitments – for example vehicles without ESC are typically older (see Appendix F.1)

To evaluate primary safety these factors must be controlled for so that any trend in collision risk is evident. In the United States, NHTSA have developed a methodology to model crash avoidance relative to miles travelled (NHTSA, 2012). However, in order to estimate the impact of improvements in vehicle safety on collision risk, this method relies on the assumption that environmental conditions do not change dramatically over the period studied.

In Britain we do not believe that this assumption is valid as we know that there have been changes to environmental conditions over the period 2009 to 2013, for example there was a reduction in speeding and drink driving during the recession (2007-2010) (Lloyd et al, 2012).

One other methodology considered as part of this project, involved using the fitment information to estimate collision risk for vehicles fitted with and without a certain technology, holding all other factors constant in the model. Unfortunately, since the primary safety features present in the London fleet are relatively new to the market and are only installed in a relatively small proportion of traffic (see Figure 4.6 to Figure 4.8), the casualty numbers were too small for this method to provide robust results.

As a result, it has not been possible to evaluate the effect of primary safety on casualty numbers in London.

However, based on effectiveness estimates from the literature (see Appendix A), we would expect primary safety features to have a positive effect on various collision types or on the involvement of certain casualty groups in London in the future.

Vehicle occupant protection is, for example, expected to improve due to:

- The increasing fleet fitment rates of ESC, which is now mandatory on new vehicles; ESC could reduce loss-of-control collisions that result in hitting roadside objects or oncoming traffic.
- The introduction of lane keeping assist systems, which are expected to reduce sideswipes and run-off-road collisions.
- The increasing uptake of AEBS, which could reduce front-to-rear collisions.

The protection of vulnerable road users is also expected to improve due to:

- A likely increasing availability and uptake of pedestrian-capable AEBS, which have the potential to prevent or mitigate certain pedestrian impacts.
- Advanced front lighting concepts, which could enhance visibility and thereby reduce vulnerable road user collisions in dark conditions.

Other primary safety systems will address behavioural contributory factors to collisions:

- Alcohol interlocks could help reduce the prevalence of alcohol-related collisions.
- Distraction and drowsiness monitoring systems could potentially address the related collisions in the future.

- ISA systems show a high potential to reduce excessive driving speeds and reduce the occurrence and casualty outcome of a variety of collision types, including those with vulnerable road users.

A number of these systems (pedestrian AEBS, alcohol interlocks and ISA) are assessed in more detail in section 6 to determine the likely casualty saving in London if these technologies were legislated for within the next few years.

5.4 Secondary safety modelling

Secondary safety refers to the protection offered by a vehicle in the event of a collision. This section examines how car secondary safety for drivers, pedestrians, pedal cycles and PTW casualties has improved in London in recent decades.

Logistic regression is used to model the proportion of car driver casualties who were killed or seriously injured by registration year. Four variables are included in the model:

- Registration year of the vehicle
    - Car registration year is used to estimate the reduction in the severity of drivers' injuries linked to developments in the car fleet. Each year new vehicles are introduced which represent the most advanced car design; other vehicles, although new, are not fitted with the latest technologies. Therefore the benefits of secondary safety are only gradually realised in the fleet.
- Collision year
    - Year of collision will be included in the model to account for the fact that changes to other road safety measures and conditions may have affected the severity of collisions.
- Age and sex of the casualty
    - Age and sex of the casualty is included in the model for several reasons: younger and older drivers tend to have different driving behaviours; older drivers tend to be more seriously injured than younger drivers for physiological reasons; and, young (under 20 years) and older (60+ years) drivers are also more likely to drive older cars which have fewer secondary safety features and therefore severity of car driver's injury may be linked to this.
- Vehicle type of striking car
    - Driver casualty rate falls markedly with size of car; larger cars tend to protect their occupants more than smaller vehicles (Broughton, 2008). Larger cars also tend to cause more injury to pedestrian casualties than smaller vehicles. For this reason, vehicle type (classified in to the seven segments described in Section 3.1) was also included in the model to examine whether secondary safety improvements have benefitted some sizes of car more than others.

In addition to the four variables outlined above an interaction term between vehicle type and registration year was included in the model for car driver casualties to allow for the fact that improvements in secondary safety may have been quicker in certain types of car. Inclusion of this term did not improve the fit of the models for pedestrians, pedal cyclists or PTW users.

The year of registration is known for approximately 83% of the cars involved in injury collisions between 2009 and 2013. Excluding casualties on the basis of missing information for the other key variables leaves between 64% (pedestrian casualties) and 80% (car driver casualties) of the total number of casualties for use in the modelling. It will be assumed that excluding those vehicles where the data are unknown does not bias the results of the model.

Separate models for car driver casualties, pedestrian casualties, pedal cycle casualties and PTW casualties were used to examine changes in occupant and VRU secondary safety respectively. The models can then be used to predict the number of casualties which would have occurred if secondary safety had not improved.

Appendix G considers the link between fitment information and collisions for three secondary safety features (chest and head side airbags and seat belt reminders). Attempts were made to include this fitment information in the models to assess their impact on casualties; unfortunately the models developed did not fit the data well and the influence of other technologies confounded the results. As a result, this section examines the overall impact of secondary safety on casualties; the impact of individual secondary safety features cannot be disaggregated from the results.

5.4.1 Statistical models

5.4.1.1 Car driver casualties

Figure 5.7 shows the modelled proportion of male car driver casualties killed or seriously injured by registration year. Although the model estimates the coefficients for all of the variables, this graph displays only the results for only one set of factors: males aged 25-59 in small family cars in collisions in 2013. By fixing factors at a reference level the general trend in the proportion of casualties killed or seriously injured can be examined; the trend for other casualty groups (e.g. females aged 60+ in small family cars in 2013) is the same (as the main effects are modelled) but will be lower or higher on the graph, depending on the groups selected.

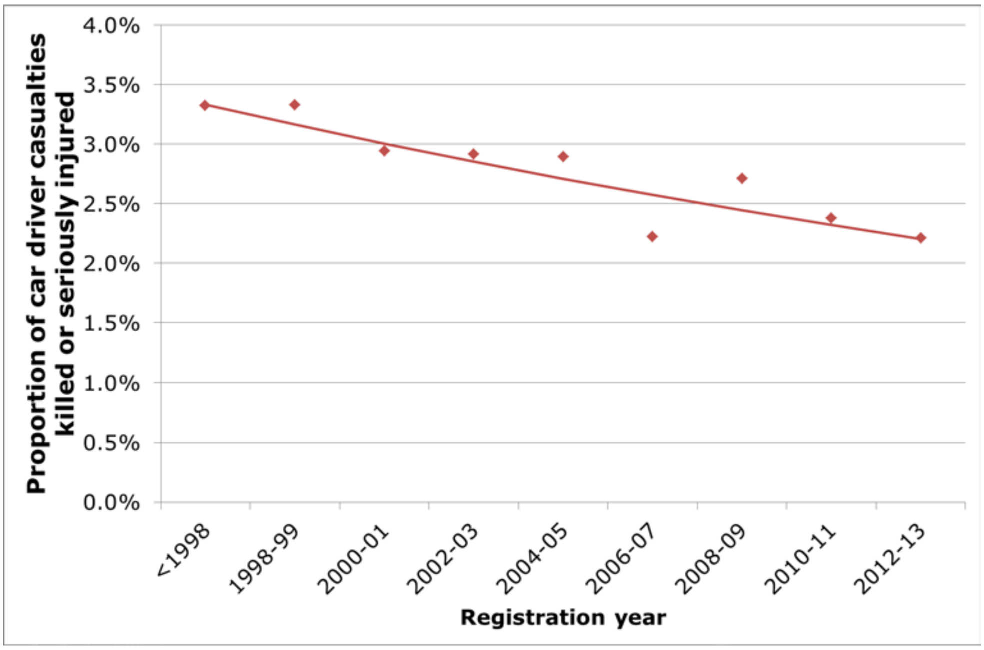


Figure 5.7: Modelled proportion of car driver casualties killed or seriously injured by registration year (Reference levels: males 25-59, small family car, 2013)

The downwards trend shows that improvements to car secondary safety have reduced the proportion of car driver casualties killed or seriously injured in collisions in London.

The interaction between registration year and vehicle type was included in the model to allow for the fact that improvements in secondary safety may have been quicker in certain types of car. The inclusion of an interaction term means that the gradient of the trend is allowed to vary by vehicle type with a steeper negative gradient implying a faster improvement in secondary safety. Figure 5.8 shows how secondary safety improvements have benefitted each of the different segments.

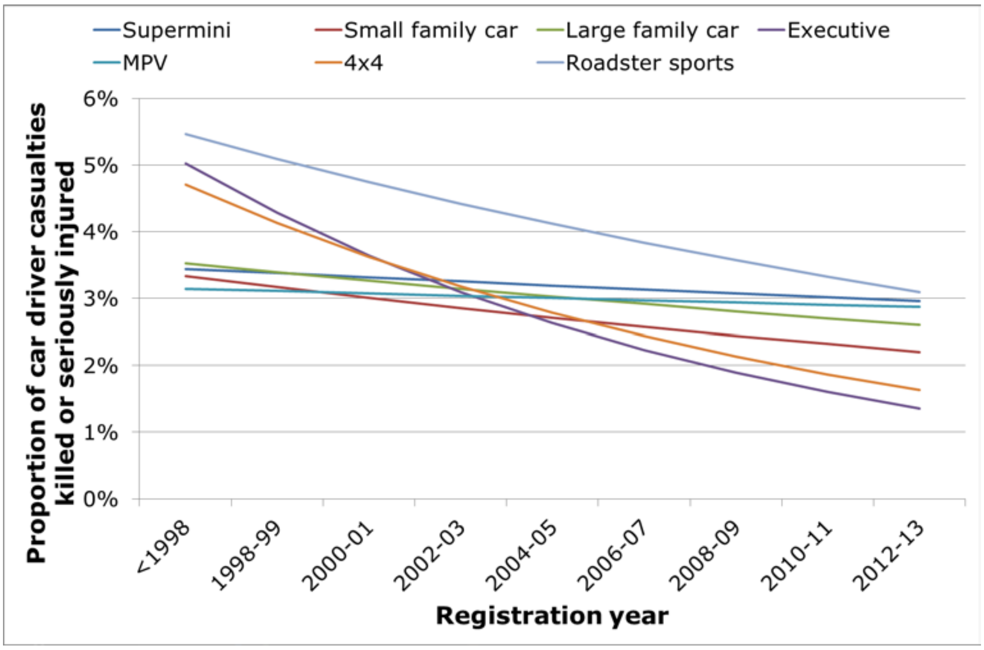


Figure 5.8: Modelled proportion of car driver casualties killed or seriously injured by segment and registration year (Reference level: males 25-59, 2013)

The graph shows that improvements to secondary safety for car occupants have been quicker in the more expensive, luxury cars (i.e. 4x4s and executives) than the smaller, more family orientated car market.

Sports cars have a higher proportion of driver casualties killed or seriously injured than the other segments. This could be because these cars are typically driven faster and in different situations (i.e. this difference may be due to differences in the driver characteristics which cannot be controlled for using age/sex).

5.4.1.2 Pedestrian casualties

The pedestrian model shows the proportion of pedestrian casualties killed or seriously injured in collisions where the pedestrian was hit by a car. Similarly to the car driver casualty results presented in Figure 5.7, Figure 5.9 shows how secondary safety has changed for a set of fixed reference levels (i.e. males aged 16-59, hit by small family cars in 2013).

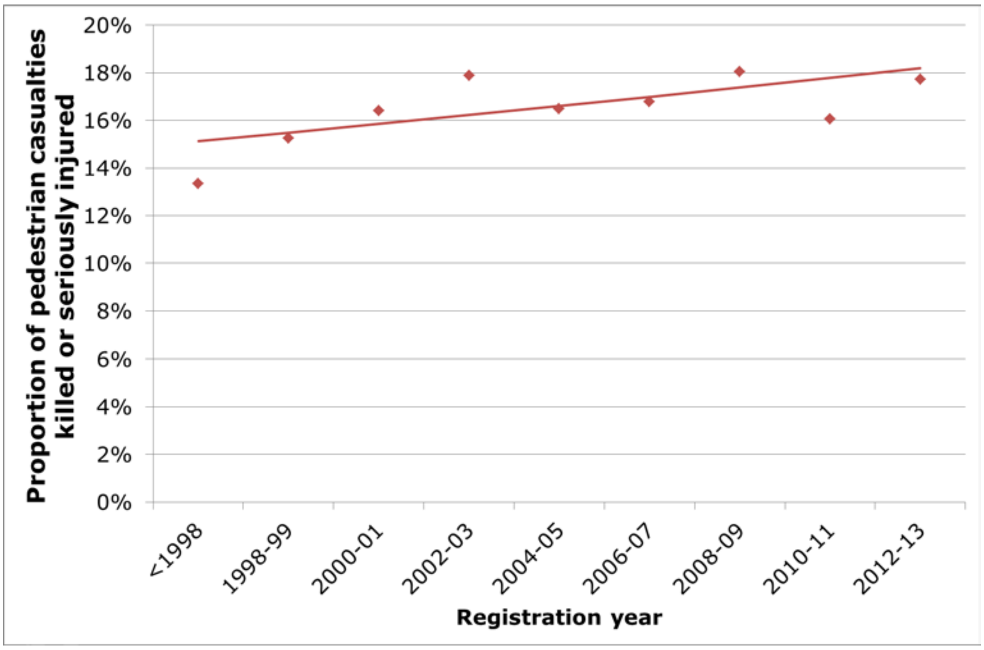


Figure 5.9: Modelled proportion of pedestrian casualties killed or seriously injured by registration year (Reference level: males 16-59, small family car, 2013)

In contrast to the car driver casualty model, the proportion of pedestrians killed or seriously injured increases as registration year increases i.e. secondary safety appears to have worsened slightly for pedestrians. There are a number of possible explanations for this, for example: it could be that cars with a newer registration year have a different exposure to potentially fatal or serious injury collisions with a pedestrian, in a way that is not included within the statistical model (e.g. if they were driven more aggressively around peak pedestrian movement times).

It is possible that vehicle changes in the period analysed have not created the benefits conventionally expected for pedestrians. This was predicted by Lawrence et al. (2006) as a saving of about 4% of fatal casualties and 12% of seriously injured casualties throughout Europe.

It is plausible that improved bumper profiles and stiffness and softer bonnets do indeed improve the outcome for struck pedestrians, but that they are still categorised as being a casualty of at least serious injury severity. A serious injury is defined in STATS19 as the following: “An injury for which a person is detained in hospital as an “in-patient”, or any of the following injuries whether or not they are detained in hospital: fractures, concussion, internal injuries, crushings, burns (excluding friction burns), severe cuts, severe general shock requiring medical treatment and injuries causing death 30 or more days after the accident.” This covers a broad range of injuries and severities when ranked according to other systems (e.g. the Abbreviated Injury Scale). Using this definition for the minimum boundary of the killed or seriously injured severity, a person could have avoided a potentially fatal injury or one expected to cause life-changing disability and sustain only a simple closed fracture, a concussion or a severe cut and still be categorised as KSI. Clearly this scale of change would have a huge influence on society. Yet it would not be evident from the results presented above. As such, it is possible that Figure 5.9 does a disservice to pedestrian secondary safety improvements to vehicles in recent years.

Also of importance is that the pedestrian secondary safety assessments do not include all potentially injurious contact regions of a car, so the unassessed regions of the latest vehicles could still be causing exactly the same number of fatal and serious injuries as in earlier vehicle models. Both the European legislation and Euro NCAP consumer information testing adopted pedestrian tests originally proposed by the European Enhanced Vehicle-safety Committee (EEVC) Working Group 17, and previously 10. These tests provided a robust means of assessing pedestrian contacts with the front of a vehicle via sub-system tests to the bumper, bonnet leading edge and bonnet top surface. However, only about 64 percent of pedestrian cases within STATS19 involve the front of a car. The improvements to the tested areas would be of limited benefit in non-frontal collisions.

Restricting collisions to cars where the first point of impact was the front of the car and modelling the impact on pedestrian casualties shows a slightly flatter trend than all collisions (see Figure 5.10).

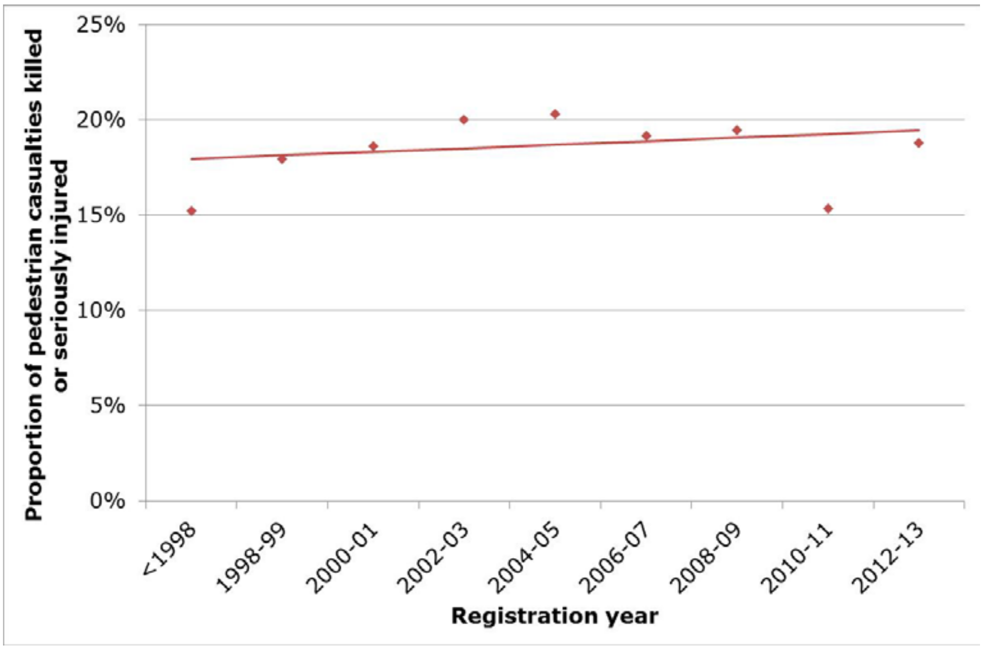


Figure 5.10: Modelled proportion of pedestrian casualties killed or seriously injured by registration year in frontal collisions only (Reference level: males 16-59, small family car, 2013)

This suggests that the secondary safety changes to the front of cars have had little benefit for pedestrian casualties hit by the front of a vehicle. Although the trend in this line is slightly upwards, the main effect of registration year is not significant for this model, which indicates that the gradient of the line is not significantly different from zero. Hence, this suggests that although this modelling has not demonstrated any benefit of the secondary safety changes targeted at pedestrians in frontal collisions, it has not demonstrated any significant disbenefit either. As discussed above there may be other changes which the model cannot observe or control for which may have occurred, including a change in severity of serious injuries observed.

The EEVC pedestrian protection test methods are designed around the representation of a car to pedestrian collision at 40 km/h (25 mph). Impact speeds up to this point account for about 5-25 % of the pedestrians killed and 20-70 % of those seriously injured (e.g. EEVC, 2002; Fredriksson et al., 2010). If speed limits were to change (i.e. be reduced from 30 mph to 20 mph), then it would be expected that a greater proportion of seriously injured pedestrians would be struck at lower speeds and there would be fewer casualties overall. To represent these casualties better, it may be advisable to review the impact conditions of the pedestrian tests. For instance, lower contact speeds could allow a softer tuning of the energy absorbing structures to make better use of the available crushable depth on the car, helping to shift more seriously injured pedestrians to a slightly injured outcome. Of course, care would need to be taken in making such a change, so as to ensure that protection for those casualties struck at higher speeds isn't compromised due to optimisation at lower speeds. Without this review it could be that the impact conditions for a large proportion of casualties is moved away from the test speed and the conditions for which the existing protection has been optimised.

5.4.1.3 Pedal cycle casualties

The pedal cycle model is restricted to pedal cycle casualties in two vehicle collisions (i.e. where one pedal cycle and one car were involved). This eliminates the possibility that a secondary impact by another vehicle will have influenced the pedal cyclist's injuries. However, it does assume that the pedal cycle and car actually made contact with each other.

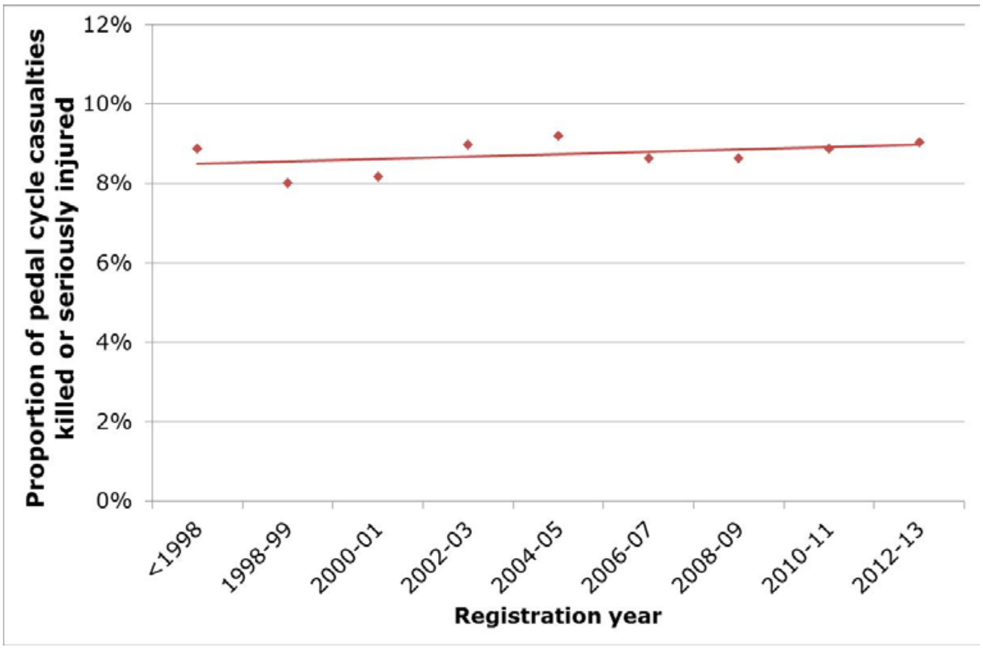


Figure 5.11: Modelled proportion of pedal cycle casualties killed or seriously injured by registration year (Reference level: males 16-59, small family car, 2013)

Figure 5.11 shows that the proportion of male 16-59 year old pedal cyclists that were killed or seriously injured in collisions involving a small family car in 2013 has remained fairly stable by registration year. This indicates that changes to the structure of the car appear to have not noticeably improved or reduced the risk of injury for pedal cycles[18].

5.4.1.4 Powered two wheeler casualties

Finally, the powered two wheeler model is restricted to PTW casualties in two vehicle collisions (i.e. where one PTW and one car were involved). This is for similar reasons to those outlined above for pedal cyclists.

[18] The main effect of registration year is not significant for this model which indicates that the gradient of the line is not significantly different from zero.

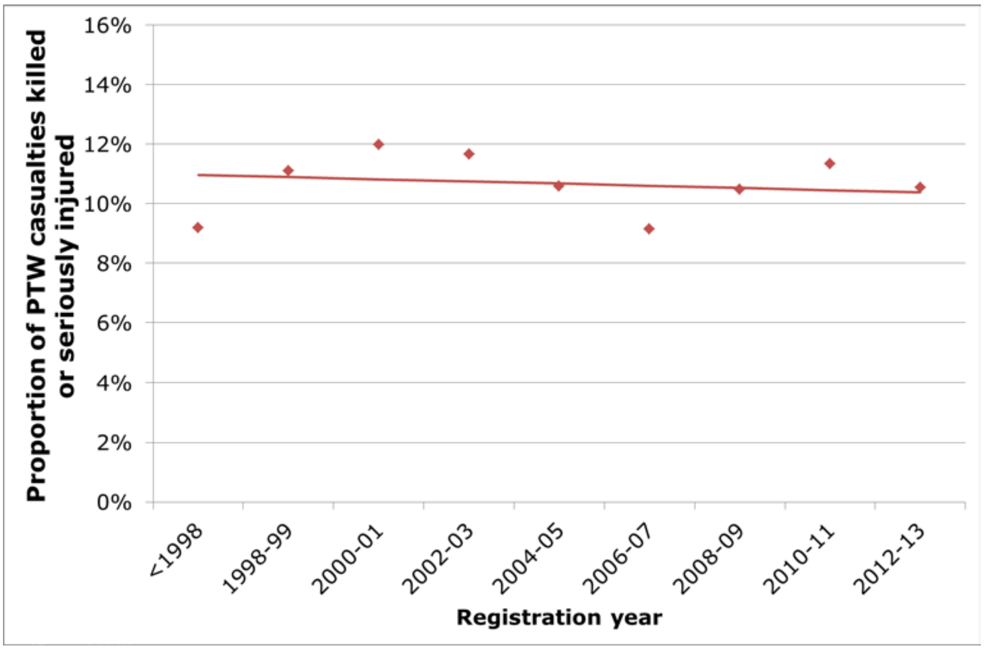


Figure 5.12: Modelled proportion of PTW casualties killed or seriously injured by registration year (Reference level: males 25-59, small family car, 2013)

Figure 5.12 shows that, for PTW riders, changes to cars over the past decade or so have been modelled as having very little effect on the proportion killed or seriously injured[19].

5.4.2 Estimated casualty benefits

The models described above can be used to estimate the number of KSI casualties eliminated by improvements to the secondary safety of cars, following the methodology outlined in Broughton (2003). For example, it is possible to determine if the safety of cars had remained at the level of the 2000-01 registered cars how many additional KSI car driver casualties would have occurred in 2013.

The overall effectiveness of secondary safety can be estimated by calculating the proportion of the potential number of KSI casualties that were not injured by the improvements:

i.e. $estimated\ effectiveness = \frac{estimated\ change\ in\ KSI}{estimated\ change\ in\ KSI + actual\ number\ of\ KSI}$

These calculations assume that the total number of collisions remains unchanged. The model is used to adjust the severity proportions of the modern cars to match with those registered in 2000-01. Casualties in collisions involving cars registered before 2000-01 are assumed to remain unaffected.

Improvements to secondary safety are likely to have reduced the total number of casualties as some casualties who would have previously been slightly injured in the collision are not injured in more modern cars. Additionally the reduction in severity of some casualties may be real but not sufficient to re-classify them from serious to slight. As a result, the casualty estimates presented in Table 5.2 are an underestimate for the actual casualty benefit.

[19] The main effect of registration year is not significant for this model which indicates that the gradient of the line is not significantly different from zero.

Similar calculations have been performed for pedestrians (all collisions and frontal collisions only), pedal cyclists and PTW riders. A positive change in casualties (e.g. for pedestrians) in Table 5.2 suggests that the model estimates that there would have been fewer KSI casualties had cars not changed since 2000-01, however as the trends in Figure 5.9 to Figure 5.12 are not significant, the changes in KSI casualties should also be treated with caution as these are subject to random fluctuation.

Table 5.2: Actual and estimated car driver KSI casualty numbers in London in 2013 if secondary safety had remained at level of 2000-01 registered vehicles

Casualty type	Actual KSI casualty numbers (2013)	Estimated KSI casualty numbers if secondary safety had not changed (2013)	Change in KSI casualties in 2013 due to secondary safety improvements	% change in KSI
Car drivers	263	292	-29	-10%
Pedestrians (all collision types)	535	490	45	9%
Pedestrians (frontal collisions only)	352	334	18	5%
Pedal cyclists	335	335	0	0%
PTW riders	316	320	-4	-1%

The table shows that if secondary safety had not changed since 2000-01 the model estimates that there would have been 29 more KSI car driver casualties, exactly the same number of KSI pedal cyclists and 4 more KSI PTW riders in 2013. However, there would have been 45 fewer KSI pedestrians (18 of which were in frontal collisions). There are a number of possible explanations for this counter-intuitive result; these are discussed in Section 5.4.1.2. These calculations suggest that overall there was a net gain of 12 KSI casualties due to changes in cars and the circumstances of their casualty-causing collisions since 2000-01, although this total includes values which are not statistically significantly different from zero and therefore some caution should be applied when interpreting these results.

In 2013 the estimated effectiveness of improvements in secondary safety since 2000-01 registered vehicles was a 10% reduction for KSI car driver casualties. Very little change was observed for pedal cyclists and PTW riders (0% and 1% reduction respectively) but pedestrians KSI were estimated to have increased by 9% due to the changes captured by the modelling. When frontal collisions only are considered the change is much smaller (5%) but this is still positive indicating a slight increase in pedestrian casualties.

5.5 Compatibility of cars in collisions

Aggressivity relates to the damage one car inflicts upon another in the event of a collision. Analysis of collision data from STATS19 has shown that the size and age of the two cars affects the amount of damage, and the subsequent injury outcome. This section summarises the results from the paper 'Car driver casualty rates in Great Britain by type of car' (Broughton, 2008).

This analysis uses STATS19 data from 2001 to 2005 to evaluate the protection offered by car models to their occupants when involved in a collision, and to look at the impact these cars have on the occupants of other vehicles when they collide.

Generalised Linear Models were fitted to the number of drivers injured in cars of type[20] I and registration year K who are injured in collisions with cars from type J and registration year L. To account for the changing composition of the car fleet, the model also included exposure data i.e. the number of registered cars of type I and registration year K and number of registered cars of type J and registration year L.

The modelling results demonstrated that:

- The mean risk of death for a driver of a mini or supermini was 4 times the risk of death for a driver of a 4x4 or MPV.
- The mean risk of death for a driver in a collision with a 4x4 or MPV was over twice the risk when in a collision with a mini or supermini. Drivers of older cars are at greater risk than drivers of newer cars i.e. newer cars protect their occupants better.
- The risk of death for a car driver in a collision with a newer car is greater than the risk of death in a collision with an older car, i.e. newer cars are more aggressive than older cars.

5.6 Summary

Between 2009 and 2013, 81% of collisions on London's roads involved a car. In these car-involved collisions there were 116,511 casualties with nearly half being vulnerable road users.

Additionally whilst the proportion of car driver casualties killed or seriously injured has been declining since 2009, the proportion of pedestrian and pedal cyclist casualties killed or seriously injured has remained fairly static.

Modelling was carried out to control for some of the factors which influence these casualty rates in order to estimate how improvements to secondary safety may have influenced casualties in London.

5.6.1 Secondary safety – car occupants

In terms of car occupant secondary safety technologies, collision data for cars with and without head and chest side airbags were examined. This showed that the drivers of vehicles without chest airbags fitted, which were involved in side impact collisions, were slightly more severely injured than those of vehicles with chest airbags and that the same was true for vehicles equipped with head airbags.

[20] i.e. segment of the car. This is classified into six categories (minis/superminis, small saloons, medium saloons, large/luxury saloons, sports cars and 4x4s/people carriers) which broadly align with the seven used in this report.

Whilst it was not possible to control for differences in vehicle and driver age in order to estimate the effectiveness of side airbags, the overall effectiveness of secondary safety features was estimated. This showed that improvements to car secondary safety have reduced the proportion of car driver casualties killed or seriously injured in collisions in London.

5.6.2 Secondary safety - VRUs

The secondary safety model indicated that the proportion of pedestrians killed or seriously injured in a collision increases as the registration year of the striking car increases. This would tend to suggest that secondary safety improvements to vehicles have not been effective for pedestrians in London in recent years. However, when the model was restricted to frontal collisions only (to account for the fact the pedestrian secondary safety tests only assess the front of the car) the model suggests that developments in vehicle safety have shown no significant benefit or disbenefit.

For pedal cycle and PTW riders, the modelling indicated that changes to cars over the past decade or so have had very little effect on the proportion killed or seriously injured.

Given these findings, the model was used to determine that if secondary safety had not changed since 2000-01 there would have been 29 more KSI car driver casualties, exactly the same number of KSI pedal cyclists and 4 more KSI PTW riders in 2013. However, there would have been 45 fewer KSI pedestrians (18 of which were in frontal collisions). These calculations suggest that overall there was a net gain of 12 KSI casualties due to changes in cars since 2000-01, however these numbers should be treated with caution as they are based on statistically insignificant trends. It seems extraordinary that efforts by the automotive industry to improve secondary safety since 2000 would have resulted in a net negative change in safety. Given that this is unlikely to represent the true influence of secondary safety changes, it could instead give a useful indication that other attributes contributing to the incidence and outcome of car to pedestrian collisions in London need to be considered also.

6 Predicting the impact on casualties of changes to the car fleet in London in 2020 and 2030

Previous sections have described current trends in the car fleet in London (Section 4) and the associated casualty trends (Section 5). In this section these trends have been used to inform predictions about possible future trends in the car fleet in London. Predictions about future levels of traffic (provided by TfL) are used to predict the casualty trends if safety trends continue at a baseline level, or if additional changes occur in the fleet. The aim of this analysis is to determine what technologies it would be beneficial to encourage in order to speed up the casualty reductions in London.

The analysis has shown that:

- If ISA, Alcohol interlocks, pedestrian secondary safety and pedestrian AEBS were legislated then the proportion of car traffic in London by 2030 with these technologies fitted would be 77%, 81%, 74% and 78% respectively.
- The estimated effectiveness in terms of a reduction in KSI casualties in collisions where they are designed to have an impact is 21%, 70%, 9% and 9% respectively.
- Given the fleet take up and estimated effectiveness, the reduction in KSI casualties from 2015-2030 is predicted to be 649, 108, 183 and 328 respectively.

6.1 Selected technologies

The impact of the growth of four new technologies into the fleet has been evaluated:

- Intelligent Speed Assistance
- Alcohol Interlock (Alcolocks)
- Pedestrian secondary safety measures
- Pedestrian AEBS

Within London, there is a lot of uncertainty in the predicted casualty rate trend for pedal cyclists over the next few decades. There are a number of reasons for this: TfL are planning to introduce a number of measures including segregated Cycle Superhighways which should reduce the chance of cyclists colliding with a car quite substantially; there is also some uncertainty over how pedal cycle traffic is likely to grow as these measures are introduced.

Car manufacturers have introduced a range of technologies which are designed to reduce car occupant and, more recently, pedestrian casualties. Although some of these technologies may provide some benefit for other vulnerable road users, including pedal cyclists and PTW users, the effectiveness of these technologies for these casualties is unknown. In addition, there are no current car features or technologies aimed specifically at these road user groups. For these reasons, pedal cyclists and PTW users have not been included in the prediction modelling as the uncertainties listed above would impact greatly on the reliability of the predictions obtained. The modelling is restricted to car occupants and pedestrian casualties, for whom traffic predictions and technology effectiveness estimates are more informed.

6.2 Method

In order to estimate the impact of these new technologies on a changing fleet, first the baseline casualty trend is established. This is the trend in each of the casualty groups given that road safety and vehicle safety developments 'continue as normal'. The assumption here is that road safety efforts such as educational campaigns and infrastructure changes continue at the same rate as seen in previous years and that vehicle safety continues to develop with the same impact seen previously (Sections 5.3 and 5.4).

Additional interventions are then added to this baseline model to predict the effect on casualty trends if these countermeasures were introduced at a faster rate than would be expected from the current fleet trends. These calculations are based on evidence from previous effectiveness research. Baseline models are applied to the casualty group that the intervention is intended to affect. These are:

- Intelligent Speed Assistance – all car occupants and pedestrian casualties involved in a collision with a car.
- Alcolocks – all collisions involving a drunken car driver.
- Pedestrian secondary safety measures - all pedestrians involved in a collision with a car[21].
- Pedestrian AEBS – all pedestrians involved in a collision with a car[21].

Baseline models are derived from the current casualty and traffic trends. The traffic and associated casualty rate are predicted forward to 2030 using a log-linear regression and the associated casualty numbers are calculated from these models. Estimates of traffic take into account the current TfL forecasts of car and vulnerable road user traffic.

In order to understand the impact of the additional technologies, predictions have been made as to the uptake of these technologies in each segment based on previous technology uptake, and the predicted estimate of effectiveness, as described in Section 6.4. The uptake and effectiveness values are used to estimate the possible reduction in casualties due to these technologies.

6.3 Baseline predictions

The baseline predictions are based on the current casualty trends and the current and predicted traffic trends for cars (split by segment) and pedestrians. Traffic predictions, where available, are based on the traffic modelling results (provided by TfL[22]). These are shown (indexed to 100% in 2011) in Figure 6.1.

[21] We assume that pedestrian AEBS and pedestrian secondary safety improvements only benefit pedestrian casualties. In practice, these technologies may also provide some benefit to other vulnerable road users (for example pedal cycles) in collisions with cars. Therefore, the casualty benefit estimated by the model may underestimate the true benefit of these technologies.

[22] TfL prediction modelling estimates that the number of walking trips per day will be 7.4m, in 2031, and car vehicle km will grow by 6.5% (an average of the lower and upper limits: 1.3% and 11.8%) from 2011 to 2031.

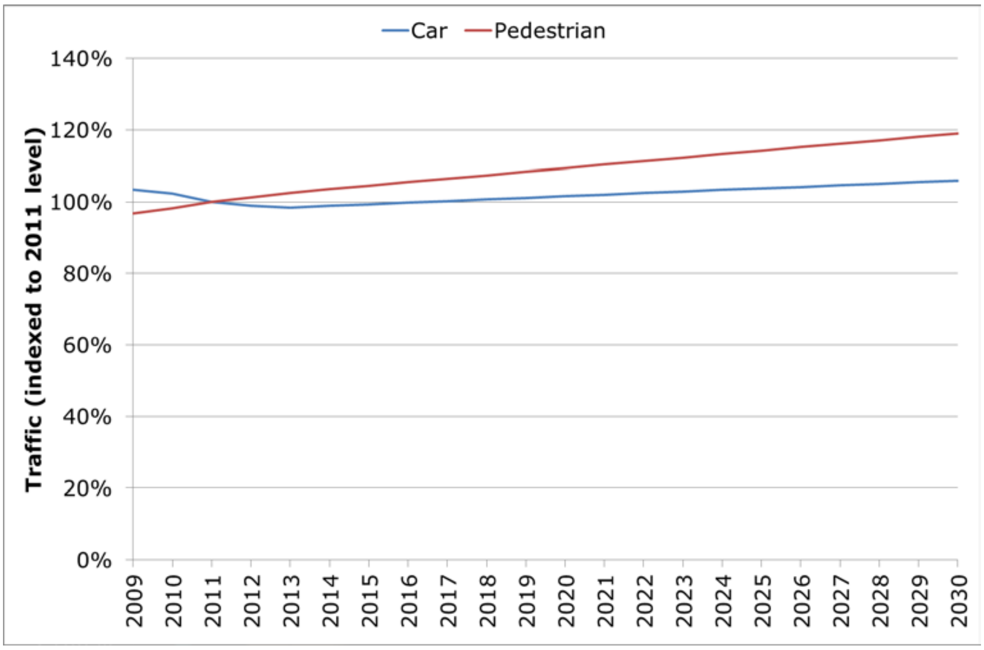


Figure 6.1: Traffic trend and prediction for cars and pedestrians in London to 2030

Based on these traffic predictions and the trend in casualty rate for each road user group between 2009 and 2013, the predicted number of KSI casualties in each of the baseline groups (shown in bullet points in Section 6.2) is estimated (see Figure 6.2).

These predictions are based on an average of two scenarios. The first assumes that the background trend in casualty rate continues as it has done between 2009 and 2013; this incorporates the assumption that road safety interventions continue and that these interventions do not change the current casualty rate trends.

The second scenario assumes that the casualty rate remains constant from 2013 onwards; this generally leads to larger predictions of the number of casualties than assumption 1. The resulting baseline predictions are effectively an average of these two scenarios.

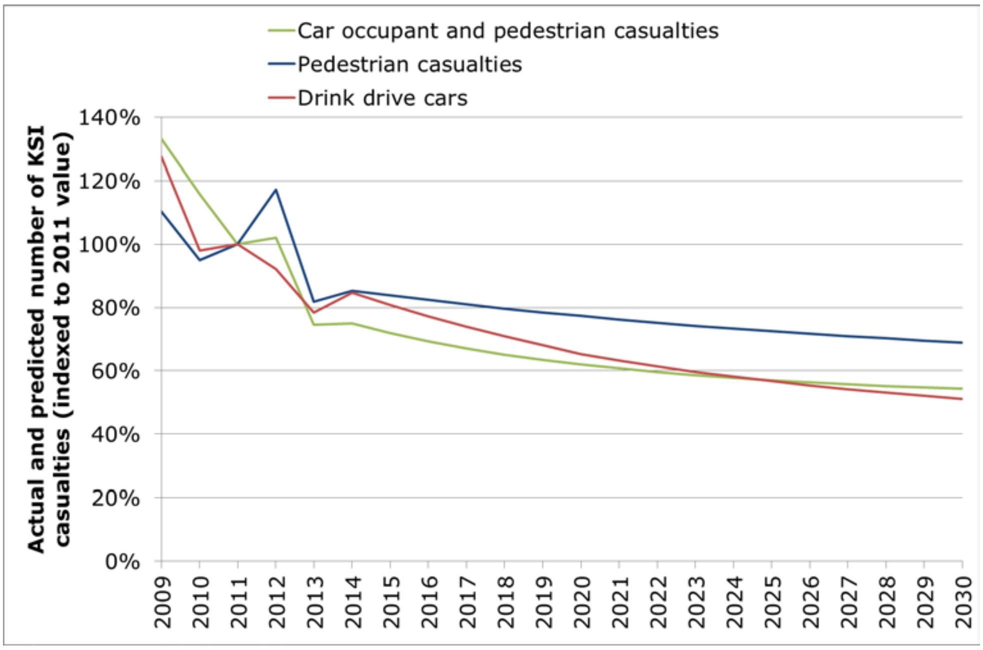


Figure 6.2: Casualty trend and prediction for car occupant and pedestrian KSI casualties, pedestrian KSI casualties and vehicles with a drunk driver in KSI collisions in London to 2030, indexed to 2011 value

The number of car occupant casualties, pedestrian casualties and collisions involving a drunken car driver are all predicted to fall between 2015 and 2030.

6.4 Vehicle technologies

When examining the introduction of new safety features to cars in London it is necessary to highlight both the emerging technologies of most interest and scenarios under which they might integrate into the fleet.

Four of the technologies discussed in Appendix A have been selected; these are:

- Intelligent Speed Assistance (see Section A.2.9)
- Alcohol Interlocks (see Section A.2.10)
- Improved pedestrian secondary safety (see Section A.1.2)
- Pedestrian AEBS (see Section A.2.5)

These technologies were selected because they are well developed systems that have shown promise in reducing collisions and/or casualty severity, but are not yet widely available on most cars.

In addition, since 77% of fatal and serious collisions in London involve a vulnerable road user casualty, with pedestrians being the most common, in order to reduce the number of KSI casualties improving pedestrian safety must be a key aim. Pedestrian AEBS and improved pedestrian secondary safety were selected for this reason.

6.4.1 Scenarios defining technology propagation

The potential propagation of these technologies into the car fleet is considered for three different scenarios. The first scenario (Scenario 1, the baseline scenario) assumes that the adoption of technologies continues along the current trend. There are no fundamental changes in consumer information testing or legislation that promote a different response from the automotive industry or the rapid adoption of the four technologies considered. In this scenario technologies not explicitly tested by Euro NCAP do not appear on new vehicles; hence intelligent speed assistance systems and alcohol interlocks will not be fitted and pedestrian safety slowly propagates from the segments adopting it already.

In the second scenario, Euro NCAP testing will proceed in future years according to the current roadmap (Euro NCAP, 2015) and this will promote the gradual inclusion of associated technologies on new cars. With respect to the highlighted safety features this means that cars with pedestrian AEBS and improved pedestrian secondary safety will gradually become more common in the coming years, as associated tests are planned for inclusion by Euro NCAP in 2015 and 2016. Furthermore, it is anticipated in this scenario that legislation will follow in the future, supporting the work of Euro NCAP by implementing a minimum performance requirement for all cars when it is shown to be feasible and reasonable to do so.

The second scenario also assumes that intelligent speed assistance systems and alcohol interlocks gain traction within the market and that Euro NCAP starts to consider them within their evaluation of a car's safety credentials. Therefore the gradual increase in the prevalence of (voluntary) intelligent speed assistance systems is assumed to follow closely behind improved pedestrian safety and alcohol interlocks, which are assumed to be retro-fitted to the cars of drink drive offenders for a period of 3 years.

The third scenario highlights the potential impact on road related casualties in London of the introduction of legislation mandating the use of the highlighted technologies for new vehicles in the coming years. In this case it is assumed that such legislation is announced in the next two years and mandates the use of these technologies for new cars after a further seven years. In this case, one would also expect consumer information testing to include some promotion of and advanced requirements for the technologies. However, unlike Scenario 2 where legislation followed consumer information testing; in Scenario 3, the legislation is the fundamental driver of the response by the automotive industry and the increased levels of fitment throughout the car fleet.

A summary of these scenarios and what they mean for the highlighted technologies is given in Table 6.1.

Table 6.1: Model scenarios for new safety technologies

	ISA	Alcohol Interlock	Pedestrian Secondary Safety	Pedestrian AEBS
Scenario 1 (baseline)	None	None	Slow fleet penetration estimated from current trend	Slow fleet penetration estimated from current trend
Scenario 2 (NCAP)	NCAP (2016)	NCAP (2016)	NCAP (2015)	NCAP (2016)
Scenario 3 (legislation)	All new cars (2023)	All new cars (2023)	All new cars (2024)	All new cars (2024)

In order to model the impact on casualties of these scenarios it is necessary to understand what fraction of the traffic in London will be equipped with each of the technologies as well as the potential of each of the technologies to either reduce certain types of crashes or to reduce injury severity in the event of a crash and the derivation of these estimates is discussed below.

6.4.2 Fitment rates for scenarios modelled

Estimates of how common each of these technologies will be in the car fleet in London in the future have been based on the proliferation of previous safety systems into the fleet. These predictions, which have been split by segment, take account of the current use of these technologies, their adoption by new vehicle model versions (informed by the adoption rates of existing mandatory technologies, such as ESC, and described in detail in Appendix H), as well as the trend in the proportion of new cars in the whole fleet.

Evidence suggests that it can take the order of a decade for newly introduced technologies to appear on the majority of newly registered cars even if these technologies are promoted and/or tested through NCAP. It then takes a few more years of vehicle turnover before such technologies are common place amongst the fleet which highlights the medium to long term nature of measures designed to encourage or mandate new safety technology.

The estimates of the proportion of car traffic that will have each of the safety features fitted by 2020 and 2030 are shown in Table 6.2. Figure 4.8 showed that less than 0.5% of car traffic in the fitment database has pedestrian AEBS or pedestrian secondary safety features fitted as standard in 2013 and for simplification this has been assumed as zero for 2013.

Table 6.2: Proportion of London car traffic with each safety fitted in 2020 and 2030 (based on predictions)

		ISA	Alcohol Interlock	Pedestrian Secondary Safety	Pedestrian AEBS
Scenario 1 (baseline)	**2020**	0%	0%	0%	1%
	2030	0%	0%	4%	4%
Scenario 2 (NCAP)	**2020**	1%	0%	4%	6%
	2030	36%	1%	57%	65%
Scenario 3 (legislation)	**2020**	9%	9%	7%	9%
	2030	77%	81%	74%	78%

6.4.3 Effectiveness

A literature review of the effectiveness of the chosen technologies is summarised in Appendix A. For the purpose of modelling the potential future reduction in casualties from road collisions in London the referenced studies are surmised as follows:

Intelligent Speed Assistance. For ISA systems estimates for the reduction in the number of crashes resulting in fatal, serious or slight injury are taken from Carston and Tate (2005). Their analysis resulted in estimates of crash savings for fixed, variable and dynamic speed limits and for advisory, voluntary (driver select) and mandatory systems. In the absence of data on speed limit type the figures for the various speed limit types are taken as upper and lower bounds of an estimate on effectiveness.

In the second scenario, in which ISA systems are promoted by NCAP but not mandated, the systems are assumed to be advisory (i.e. the driver is warned about the speed limit for the road but the actual speed of the car is not limited). In the third scenario, in which ISA systems are mandated by legislation, the system is assumed to be intervening but voluntary (i.e. the system does restrict the car to the speed limit of the road but it can be deactivated by the driver). Mandatory systems, in which the speed of the car is always restricted by the speed limit, were not considered in the analysis since it is highly unlikely such a system could be enforced within the time frame of interest.

Alcohol Interlocks. The effectiveness of alcolock programmes was found to vary with location and alcolock type. Elder *et al.* (2011) reviewed a range of studies, from which an estimate was made that the fitment of alcolocks reduced reoffending by between 50% and 90%; this was used as an estimate within the model. In the second scenario alcohol interlocks are assumed to be retro-fitted to the cars of drink drive offenders for around 3 years. The European Transport Safety Council (ETSC) quote Langford (1998) and Popkin (1994) to state that 20-30% of drink drivers go on to reoffend and NHTSA quote around 33% (Fell, 1995) updated in 2014 to 25% (Warren-Kigenyi and Coleman,2014). Therefore the overall effectiveness of the technology, if only applied to re-offenders, would be to reduce drink drive collisions by around 10-30%.

Improved pedestrian secondary safety. By combining the data reported in A.1.2 on the head protection provided by pop-up bonnets and A-pillar bags (Fredriksson and Rosen, 2014) with the estimation of serious and fatal pedestrian injuries which are to the head (Crandall *et al.*, 2002) an overall effectiveness of these technologies may be estimated as a reduction of 8-11% in fatal and serious pedestrian injuries. Whilst this ignores the benefits these technologies would have for thorax injuries it is optimistic when compared to research estimating the impact of current legislation (Lawrence *et al.*, 2006) which estimated a 4% reduction in pedestrian fatalities.

Pedestrian AEBS. The potential reduction in pedestrian casualties is taken from the Aspecss study (Edwards *et al.*, 2013) with second generation systems assumed to be fitted from 2018. Further technological developments may result in future generations of AEBS that have an increased effectiveness in preventing collisions occurring. These future systems have not been modelled in this study.

Table 6.3 presents the weighted average of these effectiveness estimates for each of the four technologies. The figure for alcohol interlocks is an estimate of their effectiveness in situations in which they are fitted; in the second scenario they are only fitted to re-offenders and therefore their effectiveness across all drink drive collisions is reduced, but this is accounted for within the fitment rates included within the model.

In the case of pedestrian secondary safety it may be expected that there is a small increase in slight casualties given that the casualties which are no longer KSI may be considered slight due to an improved outcome. Equally, some of the slight casualties may be considered uninjured. Therefore this group would see both increases and decreases in size due to improvements in pedestrian secondary safety. These increases and decreases in slight casualties, which are likely to be small, are assumed to cancel each other out in the model.

Table 6.3: Modelled average effectiveness of selected technologies

		KSI	Slight
ISA	**Advisory**	16.2%	11.5%
	Voluntary	20.7%	14.0%
Alcohol Interlock		70%	70%
Pedestrian Secondary safety		9.3%	0 % (assumed)
Pedestrian AEBS	**Generation 1**	4.3%	3.3%
	Generation 2	9.3%	6.1%

6.5 Impact of new technologies

The primary objective in being able to estimate the impact of new technologies is predicting the reduction in the number of casualties as a result of the integration of these technologies into the fleet.

The proportion of the fleet that is equipped with the technology was calculated, taking into account the age distribution of the vehicles. This accounts for the aging population of vehicles with the technology that are already in the fleet and for new vehicles with the technology entering the fleet every year.

Using the predicted baseline number of casualties shown in Section 6.3, the proportion of the fleet equipped with the technology and the effectiveness of the technologies, the predicted numbers of casualties were calculated by technology and scenario. These counts are either equal to or less than the baseline counts as a result of having effectiveness values greater than or equal to zero. The reduction in the number of casualties due to the introduction of new technologies can then be estimated by calculating the difference between the predicted number of casualties for each technology/scenario and their respective baseline measures.

The resulting reduction in casualties between 2015-2020 and 2015-2030 for each scenario can be found in Table 6.4 and Table 6.5 broken down by casualty severity and technology.

The proportional savings relative to casualty totals for each group are also reported in these tables. 'Pedestrian AEBS' and 'Improved pedestrian secondary safety' were compared to the number pedestrian casualties without the technology; 'Alcohol interlocks' were compared with the total number of casualties involved in drink drive collisions and 'Intelligent speed assistance' was compared with the total number of car occupant and pedestrian casualties.

Table 6.4: Impact of new technologies with NCAP compared to the baseline measure (scenario 2 compared to baseline)

		ISA		Alcolocks		Pedestrian secondary safety		Pedestrian AEBS	
		2015-2020	2015-2030	2015-2020	2015-2030	2015-2020	2015-2030	2015-2020	2015-2030
Casualty saving	KSI	2	154	0	1	4	123	5	145
	Slight	18	1,997	1	4	0	0	20	634
Proportional saving relative to casualty group	KSI	<0.1%	1.3%	<0.1%	<0.1%	0.1%	1.6%	0.2%	1.8%
	Slight	<0.1%	0.9%	<0.1%	<0.1%	0.0%	0.0%	0.1%	1.3%

Table 6.5: Impact of new technologies with legislation compared to the baseline measure (scenario 3 compared to baseline)

		ISA		Alcolocks		Pedestrian secondary safety		Pedestrian AEBS	
		2015-2020	2015-2030	2015-2020	2015-2030	2015-2020	2015-2030	2015-2020	2015-2030
Casualty saving	KSI	26	649	5	108	7	183	12	328
	Slight	330	9,003	29	695	0	0	48	1,499
Proportional saving relative to casualty group	KSI	0.6%	5.7%	1.9%	18.5%	0.2%	2.3%	0.4%	4.2%
	Slight	0.4%	4.1%	1.9%	19.5%	0.0%	0.0%	0.3%	2.9%

Of the four technologies, ISA shows the biggest potential to reduce casualties with an estimated 649 KSI and 9,003 slight casualties being saved between 2015 and 2030 if ISA legislation was announced in 2016 and was mandated in all new cars from 2023 (scenario 3).

The casualty group considered for Alcolocks includes all casualties involved in drink drive collisions. The number of casualties involved in these collisions is quite low (287 KSI between 2009 and 2013); however, due to the high effectiveness of the technology (70%) it is estimated that installation of these devices could reduce the number of these casualties by just less than 20% between 2012 and 2030.

Pedestrian AEBS is estimated to save 328 KSI casualties between 2015 and 2030 if legislation was announced in 2016 and was mandated in all new cars from 2024 (scenario 3). Similarly, pedestrian secondary safety features could save 183 KSI. Although these two technologies apply to the same casualty group the number of pedestrians saved cannot be summed as it is likely the two technologies would be fitted to the same vehicles.

Figure 6.3, Figure 6.4 and Figure 6.5 illustrate the annual casualty savings which could be achieved if each of the technologies were introduced via legislation. The solid lines show the baseline trend in KSI (if technologies were left to infiltrate the market at the current expected rate) and the dotted lines show the trend in KSI if legislation were introduced to mandate the technology in all new cars.

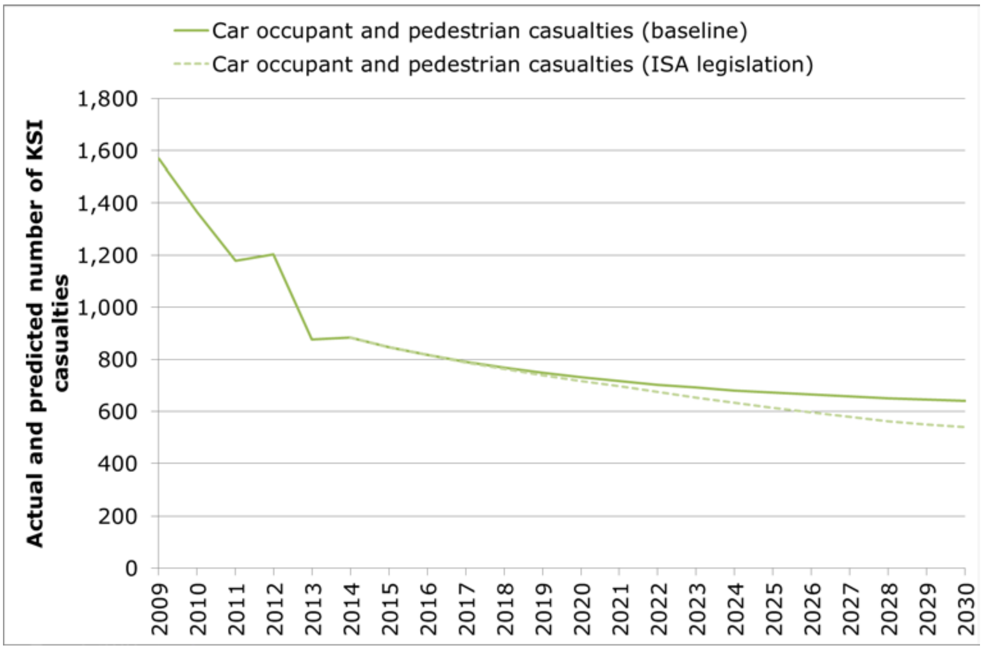


Figure 6.3: Casualty trend and prediction for all KSI car occupant and pedestrian casualties in London comparing the baseline and introduction of ISA via the legislation scenario (scenario 3)

Figure 6.3 shows that if ISA legislation was announced in 2016 and was mandated in all new cars from 2023 then in 2030 there would be 101 fewer KSI car occupant and pedestrian casualties (i.e. a saving of nearly 16% from the predicted figure if legislation had not been introduced). In addition, it is likely that the introduction of ISA would provide some benefit for other vulnerable road users, including pedal cyclists and PTW users; however these have not been included in the modelling due to the uncertainty in the growth of these modes.

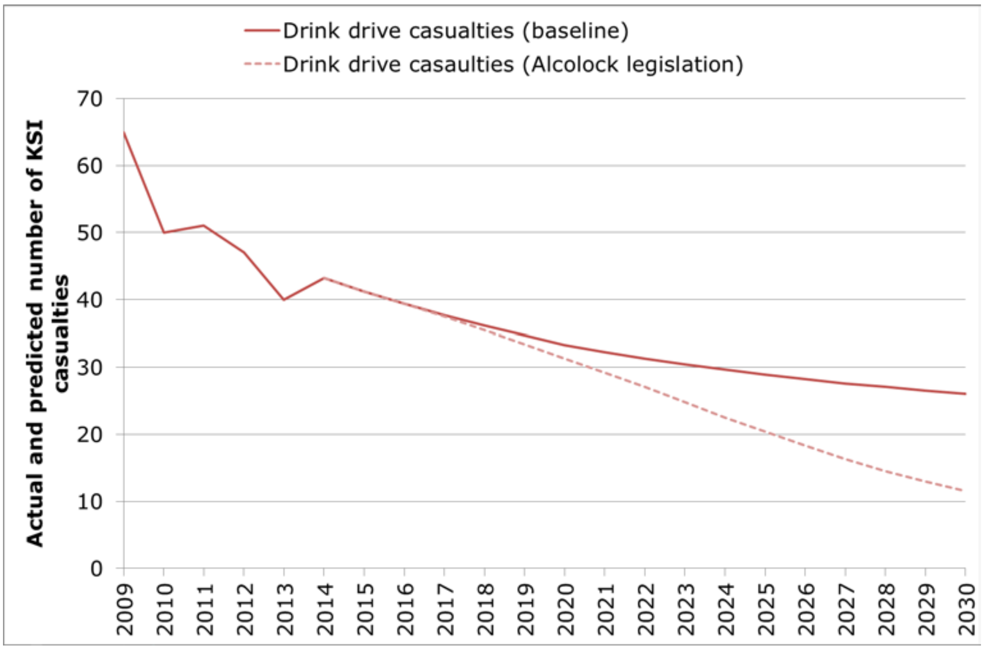


Figure 6.4: Casualty trend and prediction for casualties in drink drive collisions in London comparing the baseline and introduction of alcolocks via legislation scenario (scenario 3)

Figure 6.4 suggests that if alcolock legislation was announced in 2016 and was mandated in all new cars from 2023 then by 2030 the annual casualty saving compared to the baseline scenario would be 16 KSI casualties (i.e. a saving of over 50% from the predicted figure if legislation had not been introduced).

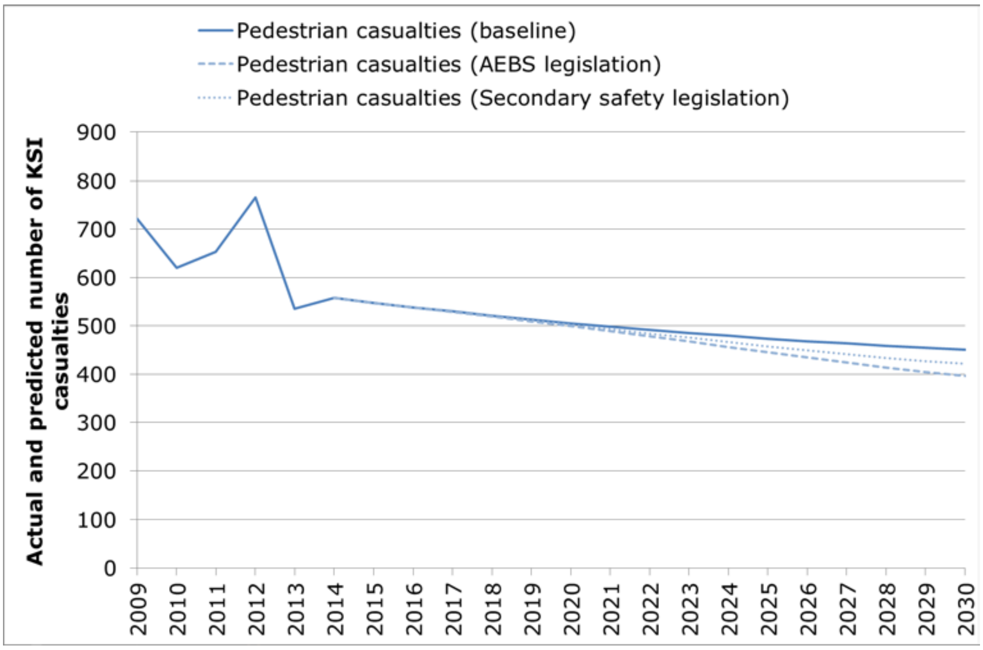


Figure 6.5: Casualty trend and prediction for pedestrian KSI casualties in London comparing the baseline and introduction of pedestrian AEBS and pedestrian secondary safety improvements via legislation scenario (scenario 3)

Table 6.2 shows that if pedestrian AEBS was mandated for in all new vehicles there would be 55 fewer KSI pedestrian casualties in 2030 than if no legislation was introduced and manufacturers continued to introduce the technology at the current rate. This is a saving of 12%. The annual saving for pedestrian secondary safety is 29 KSI casualties in 2030 (i.e. a 6% saving).

6.6 Summary

In summary, this section aims to predict the number of casualties in London in future years for a number of different scenarios. The first scenario (the baseline scenario) assumes that road safety and vehicle safety developments 'continue as normal'. The other scenarios assume that new technologies are introduced into the fleet, either by NCAP or legislation mandating their use in all new vehicles, on top of the developments which will have occurred anyway. The four technologies evaluated were:

- Intelligent Speed Assistance
- Alcohol Interlock (Alcolocks)
- Pedestrian secondary safety measures
- Pedestrian AEBS

The modelling used traffic predictions (provided by TfL), trends in the casualty rate from 2009 to 2013 and estimates of the effectiveness of the four different technologies to predict the number of casualties in each scenario. Casualty numbers are compared to the baseline scenario to determine what additional casualty savings could be achieved if the technologies were introduced at a faster rate than assumed by the baseline scenario.

There are a number of limitations of the models:

- The casualty rate trend for each road user group is based on a relatively short term trend (2009-13).
- The effect of legislation on the fitment of the four technologies to new vehicles is assumed to follow a similar pattern to that seen for other technologies in the past (as described in Appendix F); if the uptake of the technologies is faster (or slower) the casualty savings will be higher (or lower).
- The effectiveness estimates originate from a number of sources, some of which are controlled laboratory experiments. These models assume that the estimates apply to real world collisions, in particular the types that occur in London.
- The relative number of interactions between cars and vulnerable road users does not change as the traffic changes. For example, as pedestrian traffic increases the proportion of pedestrian collisions involving cars remains constant, irrespective of how car traffic is changing.
- We assume that pedestrian AEBS and pedestrian secondary safety improvements only benefit pedestrian casualties and that ISA only benefits car occupants and pedestrians. In practice, these technologies may also provide some benefit to other vulnerable road users (for example pedal cycles) in collisions with cars. Therefore the casualty benefit estimated by the model may underestimate the true benefit of these technologies.

Of the four technologies evaluated, intelligent speed assistance shows the biggest potential to reduce casualties if legislation was announced in 2016 and was mandated in all new cars from 2023.

For the other technologies, the additional casualty saving which can be achieved if legislation were to be introduced is smaller. There are a number of reasons for this; firstly the pedestrian AEBS, pedestrian secondary safety and Alcolock interventions are applicable to a smaller subset of all KSI casualties that ISA and therefore the saving is much smaller. Secondly, pedestrian technologies are only estimated to be about half as effective as ISA.

At the European level, the General Safety Regulation (EC) 661/2009 requires that the Commission report to the European Parliament every three years with proposals for amendment to the Regulation or other relevant Community legislation regarding the inclusion of further new safety features that meet the CARS 2020 and the Policy Orientations on Road Safety 2011-2020 criteria. As part of these requirements, a recent report by TRL provided the Commission with an overview of the feasibility and cost-benefit for a wide range of candidate measures for inclusion in the General Safety Regulation (Hynd et al., 2015). Based on the evidence reviewed, ISA was listed in the measures considered to be likely to be cost-beneficial as was enhanced AEBS. Additionally, in regard to AEB it was noted that pedestrian/cyclist detection systems may become cost beneficial in the future as system costs come down.

7 Conclusions

7.1 Project overview

Over the past decade London has achieved substantial reductions in road traffic casualties and collisions, however many still occur and there is scope for further improvements in safety. In 2012 TfL set out its plans to reduce KSI casualties by a further 40% by 2020 from the 2005-09 baseline (Transport for London, 2013). This target was achieved in 2014 and a target of a 50% reduction set.

Improvements in vehicle safety have already contributed to reductions in the number of car occupants KSI over the last decade, and with further developments in technology, it is expected that cars will continue to become safer. However, there are some concerns that certain safety improvements have not similarly benefitted vulnerable road users, and given the efforts of TfL to encourage sustainable transport and promote walking and cycling, reducing KSI VRUs is key.

This project had four main aims:

- Understand the current composition of the car fleet in London and the level of fitment of safety features to these vehicles
- Link information on the current fleet to the casualty data to gain a better understanding how vehicle safety features influence casualties
- Explore trends in the fleet and fitment information to predict how changes to the fleet are likely to influence casualties in the future
- Consider what technologies it would be beneficial to encourage in order to speed up the casualty reductions in London.

In order to achieve these aims the project developed a unique dataset which combined STATS19, traffic data and safety fitment data for the purpose of examining the casualty trends by car segments and technology fitment in more detail.

Examining the current composition of the car fleet in London showed a number of interesting trends; for example cars are becoming larger with an increase in MPV and 4x4 traffic. In addition, the average age of vehicles appears to be increasing, but the number of newly registered cars has also been increasing since 2011. Safety technologies are increasingly fitted to the fleet; with executives, large family cars and 4x4s often being the first vehicles to adopt new technologies.

The focus of this report is on vehicle safety developments in cars and therefore the analysis was restricted to collisions involving at least one car; this equates to approximately 81% of all collisions in London. Focus was also restricted to car occupants, pedestrians, pedal cycle and PTW casualties in these collisions; as these make up the majority of casualties, and are the groups most likely to be influenced by changes to the safety of cars. Occupants of LGVs, HGVs and other vehicles were excluded.

The effect of improvements to vehicle safety on the casualty numbers is often masked by other differences in the data for example: differences in the types of people that drive the cars; differences in the size of cars fitted with the different technologies and differences in the way or location in which the vehicles are driven. As a result, statistical modelling is required to disaggregate the effects of vehicle safety from the other factors in the data.

Developments in vehicle safety can be divided into measures which can help prevent the collision from occurring, termed primary safety, and those which are designed to prevent injuries or mitigate injury severity once a crash has occurred, termed secondary safety.

The overall effectiveness of secondary safety features was estimated using a statistical model. This showed that improvements to car secondary safety have:

- Reduced the proportion of car driver casualties killed or seriously injured in collisions in London.
- Had very little effect on the proportion of PTW and pedal cycle riders killed or seriously injured.
- Had no significant impact on pedestrians involved in frontal impacts with cars.

The final section of the report used predictive models to estimate the number of casualties in London if road safety and vehicle safety developments continue as seen above, or if additional technologies are introduced into the fleet, either by NCAP or legislation mandating their use in all new vehicles. The four technologies evaluated were:

- Pedestrian AEBS
- Intelligent Speed Assistance
- Alcohol Interlock (Alcolocks)
- Pedestrian secondary safety measures

The models have a number of limitations but the results indicate that these technologies have the potential to reduce the number of casualties in London by 2030 if they were mandated on all new cars in the next few years.

7.2 Summary of potential for technologies

The final aim of this project was to consider what technologies it would be beneficial to encourage in order to speed up casualty reductions in London. This section brings together the results from all the previous sections to highlight which technologies it may be beneficial for TfL to promote and encourage amongst vehicle manufacturers, NCAP and European regulators.

Of the four technologies considered in Section 6, intelligent speed asisstance shows the biggest potential to reduce casualties if legislation was announced mandating its use on all new cars. This technology is designed to aid drivers in observing the speed limit. The predictive modelling estimates the potential benefit of this technology to both car occupant and pedestrian casualties, although it is recognised that there may also be some benefit to other road user casualties including pedal cycles and PTW users (this has not been quantified in this report). ISA is likely to provide both a primary safety benefit (by reducing the likelihood of a collision due to more appropriate speeds being selected) and a secondary safety benefit (by reducing injury severity due to reduced impact speeds). TfL should consider encouraging manufacturers to adopt this technology; although further consideration should be given to the format that this takes, for example:

- Advisory - alert the driver to when their speed is too great;
- Voluntary - the driver chooses whether the system can restrict their vehicle speed and/or the speed it is restricted to; or
- Mandatory - the driver's speed selection is physically limited by the ISA system.

As discussed in Section A.2.9, consideration also needs to be given to public attitudes to ISA and the practical implementation of the technology.

Although this report shows that vehicle safety improvements have benefitted car occupant casualties more than VRU casualties over the past decade, car occupant casualties still make up the majority (52%) of casualties in collisions in London. As a result, manufacturers, Euro NCAP and the European regulators should still be encouraged to continue developments which will reduce the number of all road casualties.

The casualty group considered for Alcolocks includes all casualties involved in drink drive collisions. The number of casualties involved in these collisions is quite low (287 KSI between 2009 and 2013); however, due to the high effectiveness of the technology (70%) it is estimated that installation of these devices could reduce the number of these casualties by just less than 20% between 2012 and 2030.

The results in Section 5.5 indicate that vulnerable road users, in particular pedestrians, could benefit from future improvements to the secondary safety of cars, as vehicle changes to date have not resulted in the casualty benefits conventionally expected for pedestrians. The predictive modelling in Section 6.5 suggests that if improvements to pedestrian secondary safety were legislated for then, between 2015 and 2030, 183 KSI casualties could be saved.

Other pedestrian safety features such as pedestrian AEBS, which aim to reduce the risk of a car colliding with a pedestrian, have also begun to be introduced and predictive modelling suggests that legislating for this technology could also provide some casualty benefit (predicted to be 328 KSI casualties between 2015 and 2030). Given TfL's focus on vulnerable road user casualties, consideration should be given to promoting these technologies to consumers; particularly those living in London (as we have seen in Appendix E that vehicles from London are less likely to be equipped with technologies than those from outside). Manufacturers, Euro NCAP and European regulators should be encouraged to develop and prioritise these technologies so that the casualty savings estimated from the predictive modelling can be realised.

Thus far, vehicle manufacturers have focused on technologies designed to reduce car occupant and pedestrian casualties; less focus has been given to developing technologies specifically targeted at other vulnerable road users, including pedal cycle and PTW users. Although some technologies designed for pedestrian casualty prevention or protection in the event of an impact may provide some benefit for other VRUs, the effectiveness for these road user groups is unknown. As a result, the prediction modelling is limited to car occupant and pedestrian casualties. However, as cycling is set to become more popular with the introduction of TfL's segregated Cycle Superhighways, technologies which are aimed at preventing cyclist collisions, or reducing the injury severity for cyclists in the event of a collision, will play a key part in reducing these casualties.

To conclude, between the years 2015 to 2030 in London, the KSI casualty savings which could be achieved if all new passenger cars were mandated to fit the selected technologies from 2023/24 are:

- Intelligent Speed Assistance: 649 car occupant and pedestrians
- Alcohol Interlock (Alcolocks): 108 car occupants
- Pedestrian secondary safety measures: 183 pedestrians
- Pedestrian AEBS: 328 pedestrians

In addition, there are many more slightly injured casualties which could be eliminated with these technologies (quantified in Section 6.5) and far more damage-only collisions which could be avoided (not quantified in this report).

Although a full cost-benefit analysis was not part of this project, estimates at a European level (Hynd et al., 2015) included ISA in a list of cost-beneficial candidate measures for inclusion in the General Safety Regulation. It was also noted that pedestrian/cyclist AEB detection systems may become cost beneficial in the future as system costs come down.

The benefit of mandatory legislation of these technologies is clear. However, developments in vehicle safety should not be considered a quick solution as penetration in the fleet is not immediate. Neither should it replace improvements to other road safety measures, including to driver education and infrastructure. These developments are implicit within the baseline scenario and therefore to ensure the potential casualty savings are realised, it is important to ensure that both general road safety and vehicle safety should be developed hand in hand.

8 Recommendations

In order to further reduce casualties in London, it is recommended that TfL:

1. Encourages manufacturers to develop and implement safety features that will reduce vulnerable road user casualties as a priority, including new technologies and designs that will reduce pedal cyclist KSIs
2. Supports Euro NCAP in developing new test protocols and revising the criteria for achieving a 5 star rating, with the further inclusion of AEB systems and ISA to increase the availability of consumer information on safety technologies available on cars
3. Encourages European regulators to rapidly announce legislation to bring in mandatory requirements for pedestrian AEB and ISA in new cars to maximise the penetration of these technologies into the vehicle fleet

References

Baum H and Geißler T (2009). Cost-benefit analysis of Xenon Headlights in Germany and in EU 27. Institute for Transport Economics, University of Cologne.

BASt (1988). Das Unfallgeschehen bei Nacht (187).

Biding T and Lind G (2002). Intelligent speed adaptation (ISA), Results of large-scale trials in Borlänge, Lidköping, Lund and Umeå during 1999-2002. Swedish National Road Administration, Publication 2002:89E.

Broughton, J. (2003). The benefits of improved car secondary safety. Accident Analysis & Prevention, Volume 35, Issue 4, 527-535.

Broughton, J. (2008). Car driver casualty rates in Great Britain by type of car. Accident Analysis and Prevention, 40, 1543-1552.

Dang J.N. (2007). Statistical Analysis of the Effectiveness of Electronic Stability Control (ESC) Systems – Final Report. Washington DC, National Highway Traffic Safety Administration. DOT HS 810 794. July 2007.

Department for Transport (2014). Reported Road Casualties Great Britain, 2013. Retrieved from gov.uk https://www.gov.uk/government/statistics/reported-road-casualties-great-britain-annual-report-2013.

Elder R.W., Voas R., Beirness D., Shults R.A., Sleet D.A., Nichols J.L., Compton R. (2011). Effectiveness of ignition interlocks for preventing alcohol-impaired driving and alcohol-related crashes: a Community Guide systematic review. Am J Prev Med. 2011 Mar;40(3):362-76. doi: 10.1016/j.amepre.2010.11.012.

Carsten O and Tate F (2005). Intelligent speed adaptation: accident savings and cost–benefit analysis. Accident Analysis and Prevention 37 (2005) 407–416.

COWI (2006). Cost-benefit assessment and prioritisation of vehicle safety technologies - Final report. Framework Contract TREN/A1/56-2004; Lot 2: Economic assistance activities. ECORYS, COWI, ECN, Ernst & Young Europe and Consultrans.

Cuerden R., Cookson R. & Richards D. (2009). Car rollover mechanisms and injury outcome. The 21st International Technical Conference on the Enhanced Safety of Vehicles Conference (ESV); Stuttgart, Germany. Dragutinovic, N., et al. (2005). Behavioural effects of advanced cruise control use: a meta-analytic approach. In: European Journal of Transport and Infrastructure Research, vol. 5, nr. 4, p. 267-280.

Department for Transport (a). (2013). Traffic by local authority (TRA89). Retrieved from gov.uk: https://www.gov.uk/government/statistical-data-sets/tra89-traffic-by-local-authority

Department for Transport (b). (2013). Vehicle mileage and occupancy (NTS09). Retrieved from gov.uk: https://www.gov.uk/government/statistical-data-sets/nts09-vehicle-mileage-and-occupancy

Department for Transport (c). (2013). Cars (VEH02). Retrieved from gov.uk: https://www.gov.uk/government/statistical-data-sets/veh02-licensed-cars

Department for Transport (d). (2013). Travel by age and gender (NTS06). Retrieved from gov.uk: https://www.gov.uk/government/statistical-data-sets/nts06-age-gender-and-modal-breakdown

Department for Transport (e). (2013). Driving licence holding and vehicle availability (NTS02). Retrieved from gov.uk: https://www.gov.uk/government/statistical-data-sets/nts02-driving-licence-holders

DVLA. (2013). Anonymised MOT tests and results. Retrieved from data.gov.uk: http://data.gov.uk/dataset/anonymised_mot_test

Edwards M, Nathanson A and Wisch M (2013). Benefit estimate and assessment methodologies for pre-crash braking part of forward-looking integrated pedestrian safety systems. EC FP7 Aspecss project Deliverable D1.3. http://www.aspecss-project.eu/downloads/

Elephant. (2009). The six ages of driving. Retrieved from Elephant: http://www.elephant.co.uk/pressReleases/49/The-six-ages-of-driving-

EEVC (2002). Improved test methods to evaluate pedestrian protection afforded by passenger cars (December 1998 with September 2002 updates). European Enhanced Vehicle-safety Committee: www.eevc.org.

Euro NCAP (2015). 2020 Roadmap - European New Car Assessment Programme; March 2015. Retrieved from http://euroncap.blob.core.windows.net/media/16472/euro-ncap-2020-roadmap-rev1-march-2015.pdf, 20 April 2015.

Euro NCAP (2013). AEB Fitment Survey, http://www.euroncap.com/en/vehicle-safety/safety-campaigns/2013-aeb-fitment-survey/

eSafety Forum (2005). Final Report and Recommendations of the Implementation Road Map Working Group. eSafety Forum.

Fell, J. (1995). Repeat DWI offenders in the United States. Traffic tech: Technology transfer series. Washington, DC:National Highway Traffic Safety Administration. Retrieved from www.nhtsa.gov/people/outreach/traftech/1995/TT085.htm.

Ferguson S., W. K. (2007). Effectiveness and Driver Acceptance of the Honda Seat Belt Reminder System. Traffic Injury Prevention, pp. 123-129.

Fredriksson R., Rosen E. and Kullgren A. (2010). Priorities of pedestrian protection--a real-life study of severe injuries and car sources. Accident Analysis & Prevention, 42 (6), 1672-1681.

Fredriksson R., R. E. (2014). Head Injury Reduction Potential of Integrated Pedestrian Protection Systems Based on Accident and. IRCOBI Conference 2014. IRC-14-69.

Grover C., Knight I., Okoro F., Simmons I., Couper G., Massie P. & Smith B. (2008). Automated Emergency Braking Systems: Technical requirements, costs and benefits. TRL Published Project Report PPR 227. Crowthorne: TRL.

Grover C, Knight I, Okoro F, Simmons I, Couper G, Massie P and Smith B (2008). Automated Emergency Brake Systems: Technical Requirements, Costs and Benefits. TRL Published Project Report PPR227.

Hardy BJ, Lawrence GJL, Knight IM and Carroll JA (2006). A study on the feasibility of measures relating to the protection of pedestrians and other vulnerable road users - Final 2006. Project Report UPR/VE/045/06. Wokingham, Berkshire, United Kingdom: TRL. October 2006.

HLDI (2012a). Volvo collision avoidance features: initial results. Highway Loss Data Institute Bulletin Vol. 29, No. 5: April 2012. http://www.iihs.org/research/hldi/crash_avoidance/29.5-Volvo.pdf

HLDI (2012b). Mercedes-Benz collision avoidance features: initial results. Highway Loss Data Institute Bulletin Vol. 29, No. 7: April 2012.

http://www.iihs.org/research/hldi/crash_avoidance/29.7-Mercedes.pdf

HLDI (2012c). Crash avoidance features reduce crashes, insurance claim study shows; autonomous braking and adaptive headlights yield biggest benefits. News Release July 3, 2012. http://www.iihs.org/news/rss/pr070312.html

Hobbs C. A. & McDonough P. J. (1998). Development of the European New Car Assessment Programme (Euro NCAP). 16th international technical conference on the Enhanced Safety of Vehicles (ESV); Windsor, Ontario, Canada: Volume 3 of 3, 2439-2461.

Hummel T, Kuhn M, Bende J and Lang A (2011). Advanced Driver Assistance Systems. An investigation of their potential safety benefits based on an analysis of insurance claims in Germany. German Insurance Association, Insurers Accident Research, Berlin.

Hynd D, McCarthy M, Carroll J, Seidl M, Edwards M, Visvikis C, Tress M, Reed N and Stevens A (2015) Benefit and feasibility of a range of new technologies and unregulated measures in the fields of vehicle occupant safety and protection of vulnerable road users. TRL Client Project Report CPR 2023. Brussels: European Commission. Retrieved from http://bookshop.europa.eu/en/benefit-and-feasibility-of-a-range-of-new-technologies-and-unregulated-measures-in-the-field-of-vehicle-occupant-safety-and-protection-of-vulnerable-road-users-pbNB0714108/;pgid=Iq1Ekni0.1lSR0OOK4MycO9B00005RxjsFsg;sid=bWoc4U7

Ingenie. (2013). Most popular cars for young drivers. Retrieved from Ingenie: http://www.ingenie.com/cheaper-to-insure-cars

Jermakian J (2011). Crash avoidance potential of four passenger vehicle technologies. Accident Analysis and Prevention 43:732–740.

Kallberg V (1993). Reflector posts—signs of danger? Transportation Research Record 1403, 57–66.

Kullgren A., Lie A., & Tingvall C. (2010). Comparison Between Euro NCAP Test Results and Real-World Crash Data. Traffic Injury Prevention, 11(6), 587-593.

Kullgren A, Stigson H, Achterburg F and Townsend E (2005). In-car enforcement technologies today. European Transport Research Council.Lai F, Carsten O and Tate F (2012). How much benefit does Intelligent Speed Adaptation deliver? - Analysis of its potential contribution to safety and environment. Accident Analysis and Prevention, Vol. 48, pp. 63-72.

Lai F and Carsten O (2008). I Want to Go Faster, So Get Out of My Way – An Analysis of Overriding of the ISA System. Proceedings of the 7th European Congress and Exhibition on Intelligent Transport Systems and Services, 3-6 June 2008, Geneva, Switzerland.

Langford, J. (1998): Alcohol ignition interlocks: A background paper. Proceedings of the Road Safety Research, Policing, Education Conference, New Zealand.

Lawrence G J L, Hardy B J, Carroll J A, Donaldson W M S, Visvikis C and Peel D A (2006). A study on the feasibility of measures relating to the protection of pedestrians and other vulnerable road users – Final 2006. Updated by Hardy B J, Lawrence G J L, Knight I M and Carroll J A. TRL Limited unpublished Project Report UPR/VE/045/06 under Contract No. ENTR/05/17.01 to the European Commission.

Li G., Braver E. R. & Chen L.-H. (2003). Fragility versus excessive crash involvement as determinants of high death rates per vehicle-mile of travel among older drivers. Accident Analysis & Prevention, 35 (2), 227-235.

Lie A., K. A. (2007). Intelligent seatbelt reminders: Do they change driver seat belt use in Europe? Enhanced Safety Vehicles (ESV).

Liers H. (2009). Benefit estimation of the Euro NCAP pedestrian rating concerning real world pedestrian safety. 21st international technical conference on the Enhanced Safety of Vehicles (ESV); Stuttgart, Germany.

Lind, G., Lindqvist, E., and Persson, S. (2003). Short descriptions of ITS safety applications and their potential safety benefits. Published by Stratega and Transek.

LLoyd, L. K., & Forster, J. J. (2014). Modelling trends in road accident frequency - Bayesian inference for rates with uncertain exposure. Journal of Computational Statistics and Data Analysis, 73, 189-204.

Lloyd, L., Reeves, C., Broughton, J., & Scoons, J. (2013). Investigating the reduction in fatal accidents in Great Britain from 2007-2010. Crowthorne: TRL.

Newstead S., Delaney A., Cameron M. & Watson L. (2006). Study of the relationship between injury outcomes in police reported crash data and crash barrier test results in Europe and Australia (Report of Sub-Task 2.1/2.2). Monash University Accident Research Centre: CEA Insurers of Europe.

NHTSA (2012). An analysis of recent improvements to vehicle safety. NHTSA Technical report, DOT HS811 572, Washington.

McCarthy M, Barrow A, Reeves C and Muirhead M (2012). ASSESS: Assessment of Integrated Vehicle Safety Systems. Final report. Client Project Report RPN2527. TRL Limited, Crowthorne, UK.

McKeever BB (1998). Working paper: Estimating the potential benefit of intelligent transport systems. Mitretech Systems, USA.

Mitsopoulos E, Regan MA and Haworth N (2002). Acceptability of in-vehicle intelligent transport systems to Victorian car drivers. Australian Road Safety Research, Policing and Education Conference Proceedings 2002.

Page Y, Foret-Bruno J-Y and Cuny S (2005). Are expected and observed effectiveness of emergency brake assist in preventing road injury accidents consistent? Paper number 05-0268, Proceedings of the 19th International Technical Conference on the Enhanced Safety of Vehicles, Washington DC, June 2005.

Popkin, C.L. (1994): The deterrent effect of education on DWI recidivism, Alcohol, Drugs and Driving.

Reagan IJ, Bliss JP, Van Houten R and Hilton BW (2013). The Effects of External Motivation and Real-Time Automated Feedback on Speeding Behavior in a Naturalistic

Setting. Human Factors: The Journal of the Human Factors and Ergonomics Society, February 2013, Vol. 55 Issue 1, pp. 218-230.

Regan MA, Triggs TJ, Young KL,Tomasevic N, Mitsopoulos E, Stephan K and Tingvall C (2006). On-road evaluation of Intelligent Speed Adaptation, Following Distance Warning and Seatbelt Reminder Systems: final results of the TAC SafeCar project.

Regan, M.A, Oxley, J., Godley, S. & Tingvall, C. (2001). Intelligent Transport Systems: Safety and Human Factors Issues. Royal Automobile Club of Victoria Literature. Report No. 01/01. Melbourne, Australia: RACV Ltd.

Schöttler T, Nehmzow J and Otte D (2010). Influence of headlamps for accident avoidance, comparing Halogen to Xenon. In-Depth Study of German In-Depth Accident Study GIDAS. Accident Research Unit, Medical University Hannover.

Smith L, Lawton B, Beard G, Durrell L, Scoons J and Lloyd L (2015) The effectiveness of roads policing strategies. Crowthorne:TRL, PPR731.

Sugimoto Y and Sauer C (2005). Effectiveness Estimation Method for Advanced Driver Assistance System and its Application to Collision Mitigation Brake System. Proceedings of the19th ESV Conference. Washington DC, USA. Paper 05-148-O.

The Media Team, Gumtree. (2013). Men are from Maserati, Women are from Volkswagen? The Most Popular Cars for Women and Why. Retrieved from Gumtree: http://blog.gumtree.com/men-are-from-maserati-women-are-from-volkswagen-the-most-popular-cars-for-women-and-why/

Thomas P. and Frampton R. (2007). Effectiveness of Electronic Stability Control Systems in Great Britain. http://www.chooseesc.eu/download/studies/uk_esc_vsrc_study.pdf.

Transport and Mobility Leuven (2013). Ex-post evaluation of Directive 92/6/EEC on the installation and use of speed limitation devices for certain categories of motor vehicles in the Community, as amended by Directive 2002/85/EC. Transport & Mobility Leuven, Diestsesteenweg 57, 3010 Leuven – Belgium.

Transport for London. (2013). Safe Streets for London: The Road Safety Action Plan for London 2020. London.

Ward H, Shepherd N, Robertson S and Thomas M (2005). Night-time accidents: a scoping study. Report to The AA Motoring Trust and Rees Jeffreys Road Fund. Centre for Transport Studies, UCL (University College London): London, UK.

Weekes A., Avery M., Frampton R., Thomas P. (2009). ESC Standard Fitment and Failure to Protect Young Drivers. Paper Number 09-0278. ESV 2009.

Van Twuuijver M., Pol M. (2004). Car Owner's Experiences with In-car Speed Controlling Systems in the Netherlands. Association for European Transport 2004.

Warren-Kigenyi N., Coleman, H. (2014). DWI Recidivism in the United States: An Examination of State-Level Driver Data and the Effect of Look-Back Periods on Recidivism Prevalence. Traffic Safety Facts Research Note. DOT HS 811 991. NHTSA.

Wilkie SM and Tate FN (2003). ISA UK – Intelligent Speed Adaptation. Implications of travel patterns for ISA. University of Leeds and MIRA Ltd.

Young KL, Regan MA, Triggs TJ, Jontof-Hutter K and Newstead S (2010). Intelligent speed adaptation—Effects and acceptance by young inexperienced drivers. Accident Analysis and Prevention, 42(3), 935-943.

Zydek B, Schiller C, Polin D, Wagner M and Khanh TQ (n.d.). Summary: Evaluation of Adaptive Headlamp Systems. Technische Universität Darmstadt, Laboratory of Lighting Technology.Williams A., W. K. (2002). Effectiveness of Ford's belt reminder system in increasing seat belt use. Injury Prevention, pp. 293-296.

Appendix A Vehicle safety technologies

This Appendix presents a description of the vehicle safety technologies reviewed for this project. The review included, where possible, consideration of the effects of the technology on reducing incidence or casualty severity for primary and secondary safety features respectively, for a casualty population.

A.1 Secondary safety

One measure of general secondary safety levels is the evaluation provided by Euro NCAP. It was the intention of Euro NCAP that those cars which receive a high star rating would be 'safer' than those receiving a lower star rating in the real world (Hobbs and McDonough, 1998). This premise was investigated by Kullgren *et al.* (2010) who found the largest difference in injury risk between 2- and 5-star rated cars for fatal crashes, indicating that car manufacturers have focused safety on performance in serious crashes.

A.1.1 Seat belt reminders

Seat belts are one of the most effective secondary safety systems and consistently provide a highly protective effect in all vehicle types. Seat belt reminders produce a warning to the driver that the belt is not used.

Ford and Honda introduced enhanced SBRs in their passenger cars in 2002 and 2004 respectively. Subsequently, in early studies, belt wearing rates of small groups of drivers arriving for service at dealerships in the USA were observed. For the Ford system, an increase from 71% to 76% for those with SBR was reported (Williams, *et al.*, 2002); for Honda, an increase from 84% to 90% was reported (Ferguson, *et al.*, 2007).

For M1[23] vehicles, UN Regulation 16 has required SBRs for the driver's seat position since 2009 for new types of vehicles (for all new vehicles from 2014). Euro NCAP has rewarded SBRs for the driver's seating position since 2002 and all seat positions since 2009. This has been effective at encouraging SBRs to be equipped: In 2013, the percentages of vehicles tested by Euro NCAP equipped with SBRs were 100% on driver's seat, 95% on the front passenger's seat, and 77% on rear seats.

SBRs are an effective way of encouraging the seat belt to be worn. SBR effectiveness studies on M1 vehicles show that, based on an extensive study into the effect of enhanced SBR in seven EU countries with a sample of 11,160 passenger cars, reminders that comply with Euro NCAP requirements result in 80% of non-wearers becoming wearers, independent of the initial wearing rate (Lie *et al.*, 2007).

Seat belt wearing rates are already very high in Great Britain (95% for the driver in 2013: IRTAD[24]) and so fitment of seat belt reminders to new cars is also high (probably near to 100% for driver's seat and approaching this number for the front passenger seat).

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[23] Category M1:Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat

[24] International Road Traffic and Accident Database

A.1.2 Improved pedestrian secondary safety

In legislative and consumer information testing, the injury causing potential of pedestrian contacts with the front of cars is assessed via a series of component tests. These include firing a full legform impactor at the bumper of the vehicle, an upper legform at somewhere near to the bonnet leading edge or front of the bonnet (Euro NCAP only) and headforms at the bonnet. In each case measurements from the impactors are used to judge the injury causing nature of the car and give it a points' score.

Liers (2009) used real world pedestrian collision details from Germany to estimate the relationship between the potential measurements from these tests and potential injury mitigation in the real world. They found that a change in Euro NCAP pedestrian protection score of 6 points, from 18 to 24, could be expected to prevent between 1 and 5 percent of pedestrian injuries of at least moderate severity.

It is generally accepted that gains in this passive protection will diminish as designs reach the limit of potential within the packaging constraints for cars. As additional countermeasures, deployable solutions such as a pop-up bonnet or pedestrian airbag are now available on some of the latest car models.

A.1.3 Active (pop-up) bonnet

Pedestrian pop-up bonnet systems have been equipped to some cars where the redesign of the vehicle was not feasible for a given price and within styling constraints. Instead, the OEM opted for this solution to enable the amount of deformable crush space to be increased should a pedestrian strike the bonnet of the vehicle.

Together with an airbag to protect the windscreen scuttle, (Fredriksson and Rosen, 2014) suggested that a pop-up bonnet can be protective in 47 % of impacts with a car resulting in a serious or fatal (AIS ≥ 3) head injury, based on GIDAS data. The effectiveness in these impacts would be to mitigate the most severe injury, reducing the pedestrian injury severity to slight, rather than fatal or serious. This would be possible for 20 to 30 % of the AIS ≥ 3 injured pedestrians. A general expectation is that around 80 % of serious and fatal pedestrian injuries are to the head. Therefore combining these factors leads to an expected effectiveness for a combined active pedestrian secondary safety system to be in the region of 8 to 11 % for fatal and seriously injured pedestrian casualties that were struck by the front of the car.

A.2 Primary safety

A.2.1 Electronic Stability Control

ESC was first introduced in production cars in the mid 1990's and, as with many new technologies, began with fitment mainly to expensive luxury vehicles. The system builds on the functions provided by Antilock Braking Systems (ABS) and Traction Control. Sensors are added that measure parameters such as the yaw rate, lateral acceleration and the drivers steering inputs. These allow the system to calculate the path that the driver intends the vehicle to follow and to measure the path that the vehicle is actually following. Where the two paths do not match, that is the vehicle is under or over steering or beginning to rollover, the system intervenes to restore stability.

Predictive studies of effectiveness reported consistently high effectiveness (expressed as a percentage of the target population of relevant collisions). Because fitment rates of ESC were high and manufacturers voluntarily equipped the system, there was sufficient collision data for retrospective case-control studies to confirm the predictions based on case by case analysis. These statistical retrospective studies showed that ESC reduced all car injury collisions in Great Britain by 7% (9% slight and 25% for fatal collisions) (Thomas and Frampton, 2007) and 8% for all car injury collisions (14% for fatal collisions) in the US (Dang,2007).

Fitment of ESC was enabled because evidence on its effectiveness was consistent in the message that it provided a benefit, and importantly, cars equipped with ABS had the hardware required to facilitate ESC. Therefore, this was the main factor that increased fitment. By the time ESC was made mandatory in 2014 (mandated on all vehicle categories from 01/11/14 except M2, which will be from 11/07/15), fleet fitment was already high, probably nearing 100%.

Weekes *et al.* 2009 examined the percentage of models fitting ESC as standard in the Thatcham ratings (availability model) and survey data from Bosch based on 9 European countries (registrations model) to predict the increase in fitment of ESC to meet the regulatory requirements in 2014.

Based on these fitment predictions, Weekes *et al.* modelled the effect on fitment in the vehicle fleet, which showed 100% penetration by 2021.

A.2.2 Collision warning systems

Obstacle and collision warning systems warn the driver when there is a risk of a collision. Basic systems function by monitoring the area in front of the vehicle and warning the driver if certain criteria are met. These criteria usually relate to the proximity of other vehicles or obstacles in the driver’s lane of travel.

Most obstacle and collision warning systems are based around radar sensors to detect the presence of other vehicles or obstacles, although camera, infra-red and ultra-sonic sensors may also be used. Two-stage warnings are usually recommended in the literature: the first stage is reserved for cautionary warnings where there is a low likelihood of a collision. The second stage is a separate, imminent warning where there is a high likelihood of a collision. Visual, audio or haptic warnings may be issued; however, visual warnings are recommended for low priority information only because they depend on the driver looking at the warning display. In contrast, auditory warnings and haptic warnings can attract the driver’s attention irrespective of where they are looking and are therefore suitable for imminent warnings.

Current collision warning systems are included as a component of the functionality of automatic braking systems on a few high-end vehicles (see brake assist plus, AEBS and pedestrian detection systems). Examples of these are the Daimler Pre-Safe brake and systems by Ford/Volvo that provide collision warning information.

Collision warning has the potential to reduce the risk of a range of collision scenarios. However, the effectiveness of collision warning in this respect depends on the functions and capabilities that are offered by each individual system.

Estimates for the percentage of rear-end crashes that could be avoided with forward collision warning vary; Regan *et al.* (2001) report 7% of rear-end crashes, Kullgren *et al.* (2005) report 57%. The eSafety Forum (2005) estimated that 3.1% of all crashes could be prevented. Estimates from the USA report that fatal rear end crashes may be reduced by around 48% (McKeever, 1998).

The market penetration of obstacle and collision warning systems is currently very low. The Road Map Working Group of the eSafety Forum estimated that between 0 and 5 percent of vehicles were equipped with a system in 2005.

A.2.3 Brake assist

Brake Assist is a function that interprets the manner in which a driver presses the brake pedal and, if it is computed to be in a manner typical of responding to an emergency situation, the vehicle will boost the braking to a level higher than that demanded by the driver's pedal application. The aim of this is to help the driver to reach maximum braking in as short a time as possible. This assistance is intended to help the driver come to a stop before a collision, or at least to reduce the collision speed. It should be noted that BAS does not influence the maximum deceleration that a vehicle can achieve only the ability of a "typical" driver to reach that maximum level quickly. BAS will not, therefore, offer any assistance to a skilled driver who responds correctly to an emergency event by pressing the brake pedal very hard and fast. All vehicles equipped with BAS will also be fitted with ABS such that the vehicle does not become unstable when BAS helps the driver to reach maximum deceleration.

Brake Assist was developed in the mid-1990s. In preceding years the maximum deceleration that passenger vehicle brakes were capable of had significantly increased but collisions where vehicles "failed to stop" were still common. Research showed that ordinary drivers are rarely able to utilise the full potential of the brakes in an emergency situation. Typically drivers initially press the pedal quickly but not sufficiently hard and then subsequently increase the brake pedal force as they realise that a collision is likely. This means that they do not reach the maximum deceleration capability of the vehicle as quickly as they could and in some cases never reach maximum deceleration. These findings led to the development of Brake Assist.

A voluntary agreement within the automotive industry in the EU-25 required that all new passenger cars be fitted with ABS as of July 2006. The EC subsequently mandated the use of BAS on all new passenger cars produced from 2011 as part of the Phase II Pedestrian Protection Directive.

Research into the second phase of the pedestrian protection Directive (Lawrence et al, 2006) reviewed the estimated benefits of BAS. This research cited Hannewald and Kauer (undated) who used predictive collision analysis to estimate that BAS would reduce pedestrian fatalities and serious injuries by approximately 5-6% given full fleet penetration of BAS. The assumptions used in this analysis were considered by Lawrence et al (2006) to be flawed, although it was noted that some of the flaws would influence the results in opposite directions such that their effects may cancel out. Lawrence et al (2006) also reviewed research conducted by Page et al (2005). This study also estimated the effects of BAS using a predictive technique but in this case the assumptions used to generate the estimate appeared to be more robust. The results were an expected reduction in vehicle occupant fatalities of 6.5-9% and a slightly higher value for reduction of pedestrian fatalities at 10-12%. Page et al (2005) also carried out a retrospective analysis to assess the observed effectiveness of BAS by comparing the actual collision involvement of two models of car with and without BAS. This analysis resulted in an estimate that BAS would reduce the overall probability of involvement in a casualty collision by approximately 11%. However, the analysis was limited by a small sample size and thus was not statistically significant. Lawrence et al (2006) found that there was strong evidence that BAS would have a beneficial effect on pedestrian fatalities of between 0% and 12% but stated that the exact proportion could not be estimated with confidence. A cost benefit analysis was based on the mid-range values of 5%-6%. A cost-benefit analysis of BAS has also been conducted by COWI (2006) and this estimated that if the entire vehicle fleet was fitted with BAS than there would be a reduction in collision probability of 8% for fatal, serious and slight injury collisions.

A.2.4 Autonomous Emergency Braking System (AEBS)

An Autonomous Emergency Braking System (AEBS) combines sensing of the environment ahead of the vehicle with the automatic activation of the brakes (without driver input) in order to mitigate or avoid an collision. The level of automatic braking varies, but may be up to full ABS braking capability.

AEBSs are fitted to some current vehicles and are capable of automatically mitigating the severity of two-vehicle, front-to-rear shunt collisions (on straight roads and curves dependent on sensor line of sight and environment "clutter") as well as some collisions with fixed objects and motorcycles. Second generation systems are also appearing (on high-end vehicles) and have improved functionality in curves, functionality at greater speeds, and incorporate the detection of pedestrians and improved detection of other objects. They are particularly applicable to situations in which the driver is distracted from the driving task.

There are essentially three AEBS groups aimed at different collision circumstances:

- Urban AEBS, which typically uses LIDAR sensors, is designed to function in low speed traffic and is primarily aimed at avoiding low-speed shunts. An example system is the Volvo 'City Safety' fitted to some vehicles since 2010. These systems have major benefits for vehicle damage costs and whiplash injury.
- 'Inter urban' AEBS, which typically uses a combination of radar and a camera, is aimed at avoiding, or more likely, mitigating the severity of higher speed impacts. Currently, the functionality of these systems is limited to shunt collisions that are at higher speed than those mitigated by urban AEBS.
- Pedestrian AEBS, which typically uses camera and radar/LIDAR data, is intended to detect pedestrians in critical situations and activate the brakes autonomously. As with urban systems, functionality is typically limited to low speeds because of the time required to detect and reduce the vehicle's velocity.

AEBSs are voluntary on M1 and N1[25] vehicles, although there fitment is incentivised via Euro NCAP. An AEBS is fitted by 12 manufacturers in Europe, with six offering it as standard equipment on at least one model. Volvo fit the system as standard to seven models. Fitment tends to be to vehicles at the higher end of the market. There has been strong support from the insurance industry for low-speed AEBS to avoid damage-only collisions and whiplash injuries. For M1 vehicles, AEBSs are optional on approximately 20-50% of 2013 vehicle models depending on the type of AEB system. However, it is

[25] Category N1: Vehicles designed and constructed for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes.

standard fitment on 90% of Volvo models, 49% of Mercedes models, 42% of Infiniti, 32% of Mazda models and 12% of Lexus models (Euro NCAP, 2013). Fitment rates to new vehicles are expected to rise in response to greater consumer awareness and acceptance of AEBS. Current system fitment in the fleet is unknown because of the large percentage of vehicles to which fitment is optional. For this reason, it is considered that current fitment in the fleet is still very low (probably below 3%).

Particular M1 fleets (such as taxis, hire cars etc.) have the potential to adopt AEBS and attain the benefits, although purchasing decisions probably exclude the more expensive options or packages of options.

Regulation (EU) No 347/2012 made the fitment of AEBS mandatory for new types of N2/N3[26] and M2/M3[27] vehicles in 2014, and this will become mandatory for new vehicles in 2015. Some N2/N3 and M2/M3 vehicles are excluded from the requirements. Fitment to goods vehicles should therefore increase rapidly as new vehicles penetrate into the fleet. Some vehicle manufacturers have been fitting AEBSs for some time; for example, Volvo offered all N2/N3 vehicles with AEBS in 2013 (Volvo, 2013).

The literature reveals wide variations in the effectiveness and casualty benefits because of the predictive nature of the estimates and the wide variety of assumptions made. For example, Sugimoto and Sauer (2005) estimate that automatic braking systems could prevent 38% of front-to-rear crashes in the U.S., and reduce the probability of fatality in rear-end crashes by 44%. McKeever (1998) estimated that the system could reduce fatal rear-end crashes in the U.S. by 48% and Kullgren *et al.* (2005) estimated a greater reduction of 57% of fatal rear crashes in the U.S.

Estimates from other countries also result in different values. For example, Mitsopoulos *et al.* (2002) estimated a reduction of 7% of rear-end crashes in Australia. Grover *et al.* (2007) estimated that the benefit of automatic braking systems on passenger cars in Europe could be the same as for trucks – reducing the severity of 25-75% of front-to-rear crashes in Europe, with these (admittedly wide) estimates compatible with US data. Hummel *et al.* (2011) found that of the real word safety potential of AEBS was 13.9% of all collisions and that 2.2% of fatal, 9.4% of serious, and 35.7% of slight casualties could be avoided.

In terms of all crashes/casualties the eSafety Forum (2005) estimate that 3.1% of all crashes could be prevented. Furthermore, COWI (2006) estimated that such a system could reduce at least 8% of fatalities, 10% of serious injuries, and 10% of slight injuries in all types of collision in Europe. These figures demonstrate the wide variation in predictive estimates and the uncertainty regarding the actual real world effectiveness of the systems.

A predictive case-by-case analysis of 412 On-The-Spot (OTS) collision cases used engineering judgement combined with knowledge of test results from two current AEBS to determine whether AEBS would have influenced the outcome. It was found that approximately 30% (21%-38% for full range of estimate) of serious casualties in front-

[26] Category N2/N3: Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes/having a maximum mass exceeding 12 tonnes.

[27] Category M2/M3: Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass not exceeding 5 tonnes/having a maximum mass exceeding 5 tonnes.

to-rear collisions could be avoided and 68% (58% to 77% for full range of estimate) of slight casualties could be avoided (McCarthy *et al.*, 2012). There were no fatal collisions in the sample.

Combining these effectiveness estimates with the earlier target population estimates suggests that, if these are accurate, AEBS would be expected to bring about an overall reduction in casualties of approximately 11%; 1% (0.6%-1.1%) for serious casualties and 10% (9%-12%) for slight casualties.

Retrospective evidence from the US that indicates that AEBS (particularly the 'City Safety' systems) are more effective than these estimates suggest, perhaps because a proportion of collisions recorded in insurance claim data are not recorded in the reported road casualty data.

Recent insurance data from the US showed that Mercedes vehicles with collision warning and brake assist were involved in, on average, 3.1% fewer collisions (6.1% to 0%) compared with the same vehicles without the system (HLDI, 2012b). US insurance data for vehicles from two manufacturers (Mercedes and Volvo) suggest that systems that involve automatic braking are more effective than warning alone (HLDI, 2012c).

These data also help to confirm the effectiveness of 'city safety' systems, with collision frequencies 15% lower (Volvo XC60) and 9% lower (Volvo S60) than control vehicles (HLDI, 2012d). Frequency of bodily injury was also 33% lower (XC60; 95% confidence interval: 29% to 38%) and 18% lower (S60; 95% confidence interval: 4% to 30%), although injury benefits are probably limited to the prevention of whiplash injury.

Cars with 'city safety' might also have an AEBS system targeted at the avoidance or mitigation of more injurious collisions. These systems are fitted in fewer numbers than the 'city safety' functions, although increasingly, the vehicle may have 'merged' systems using data from different sensors to address the full speed range of collisions. It is considered likely that the effectiveness for 'higher speed' AEBS is lower than for 'city safety' and probably more in the region of the predictive estimate of 11% of all casualties (McCarthy *et al.*, 2012).

Initial retrospective data provides effectiveness values slightly lower than that predicted. For example, US insurance data shows that Mercedes cars fitted with Distronic Plus have on average 7.1% fewer claims (95% confidence interval: 12.8% to 1% fewer claims) than those not equipped with the system (HLDI, 2012b). This data also shows average reductions for property damage and injury claims, although the 95% confidence limits span zero meaning that with the data available, the true value may also be increased with system fitment. For Volvo vehicles, the trend is similar, although the magnitude of the collision reduction is smaller with an average 2.9% reduction, with 95% confidence interval of -13.8% to 9.3% (HLDI 2012a). Overall losses (including injuries) show on average much larger reductions (up to around 50%), but in all cases the confidence limits cross zero meaning that there could be a disbenefit if the data available thus far happened by chance to be biased in favour of collisions in which the system provided high benefits.

Systems that can function in head-on and side impacts will provide a great casualty benefit, but these might not be possible to detect without vehicle-to-vehicle communication or significantly improved car-based sensing performance. Similarly, systems that can reliably cope with objects off the road and pedestrians will also provide a significant increase in benefit.

A.2.5 Pedestrian alert and AEBS

Pedestrian AEBS are a further advancement whereby the presence of pedestrians/cyclists in the path or periphery of the vehicle is detected and can be used to provide a warning signal and/or can be linked to automatic braking functionality.

Pedestrian detection and night vision systems are currently fitted by approximately 5% of manufacturers: BMW, Mercedes-Benz, and Audi. These systems typically use infra-red sensing which may be linked with other data, for example radar and camera data to detect and track pedestrians. These systems are offered as optional systems. Volvo currently offers a pedestrian AEBS on the Volvo V40, S60, V60, XC60, V70, XC70 and S80 models (system was launched in May 2013); some current AEBS systems may detect cyclists, but they are not specifically designed to do so.

The functionality of warning and automatic braking could be linked to other systems that may already be on the vehicle, such as FCW or AEBS. In this respect, adding pedestrian functionality to an AEBS system is another step in the development of this system type but requires additional sensors (the Volvo system uses radar and camera) and additional processing of the sensed information. Therefore, the costs of pedestrian systems are greater than that of standard AEBS.

Two test procedures for pedestrian AEBS have been developed by the European AsPeCSS project (www.aspecss-project.eu) and may be used in the future by Euro NCAP. It should be noted that if either methodology is adopted by Euro NCAP, further work would be required (e.g. by other research initiatives or the Euro NCAP Primary safety group) to develop and verify the detailed aspects of the procedure and rating system.

Edwards *et al.* (2013) reported on benefits of three car pedestrian systems (with AEBS functionality) from research carried out by the European AsPeCSS consortium. This analysis (based on in-depth data from GB and Germany) found that current AEB systems could reduce fatal pedestrian casualties by 2.9-6.2%, serious casualties by 4.2-4.4% and slight casualties by 2.2-4.4% (Edwards *et al.* 2013). An analysis by Hummel *et al.* (2011), predicted more optimistic casualty reductions of 21% for fatal, 15% for serious, and 44.5% for slight casualties in collisions involving cars and pedestrians.

Edwards *et al.* predicted improved benefits for second-generation systems and estimated that these could reduce fatal pedestrian casualties (compared to no AEBS) by 6.7-14.1.%, serious casualties by 8.8%-9.7% and slight casualties by 3.6%-8.6% (Edwards *et al.* 2013).

Benefits for other vehicle types have not been well studied and require further analysis, but pedestrian and cyclist collisions with larger vehicles tend to be associated with low speed manoeuvres and so more specific, targeted solutions may be more appropriate (e.g. presence sensors, improved direct/indirect visibility).

A.2.6 Lighting systems

Collisions at night are significantly overrepresented in collision statistics; therefore, any improvement in visibility represents a significant opportunity to reduce fatalities. For example, analysis of UK collision data by Ward *et al.* (2005) showed that 40% of fatal and serious injuries occur during the period 19:00 and 08:00, despite only a quarter of car journeys being between these times. Similarly, in Germany the collision risk at night is three times greater: 28% of injury collisions and 42% of fatal collisions occur at night, despite 20% of the distance travelled being at night (BASt, 1988).

There are a range of lighting technologies available; light sources such as Xenon or LED have been shown to provide increased detection distances at night compared to Halogen sources: e.g. Zydek *et al.* (n.d.), Baum and Geißler (2009). An examination of German night-time collisions using GIDAS data showed that fitment of Xenon lights could avoid around 16% of these collisions (Schöttler *et al.*, 2010)

Adaptive Front-lighting Systems (AFSs) are designed to provide drivers with a better field of view when driving at night; static, front-facing headlights offer the same performance in curves, on motorways and in urban environments, despite the different illumination pattern requirements for these environments. AFS offers optimal carriageway illumination patterns depending on a variety of driving parameters (steering angle, speed, activation of indicators, etc). From these inputs a series of algorithms predict the vehicle's road environment and adjust the performance of the headlamps accordingly. Future systems will incorporate GPS information to select illumination patterns based on a prediction of road conditions (the need for which has been demonstrated empirically; drivers prefer lighting angles to be changed in advance of a corner, rather than in response to steering inputs when in the corner).

Different AFSs produce similar lighting patterns across a range of driving environments, these environments that typically include: curves, motorways, adverse weather, overhead traffic signs, country roads, and towns. These lighting patterns have been investigated across a range of studies that examined drivers' preferences for headlamp swivel angle and light pattern distributions. A large European project funded by the EUREKA inter-governmental initiative attempted to reach a consensus as to which lighting patterns were most appropriate in various environments and these standards seem to have be adopted by the majority of manufacturers.

Several manufacturers fit AFS as standard to some models; for example Lexus, BMW, Honda etc. When AFS is available as an optional extra, AFS is typically packaged with other systems such as bi-xenon headlights, beam levelling etc. AFS is standard equipment on some, mainly high-end makes or higher specification models. For Intelligent Adaptive Forward Lighting (AFL) incorporating bi-xenon headlights with dynamic beam levelling, high beam assist and high-pressure headlight washers, the package is £890 on some Vauxhall/Opel models and standard on higher models in the range.

Data from the USA suggests roughly 1 in 40 pedestrian fatalities (2.5%) could be prevented annually by improvements to vehicle headlights. Jermakian (2011) estimated that approximately 2.3% of US crashes (142,000 of 6 million crashes) could be prevented with AFS. While the reductions in fatalities from AFS are yet to be comprehensively estimated in Europe, AFSs are being offered by an increasing number of major motor manufactures, typically on high to mid-range vehicles. The systems are supplied by several suppliers, including Valeo, Hella, and Automotive Lighting.

Baum and Geißler (2009) predicted (in an assessment of Xenon lights) that there are 1,084,924 relevant collisions in the EU27 annually, resulting in 35,869 fatalities, 275,457 serious and 1,171,178 slight casualties. These authors present an effectiveness of Xenon lights of 60%, although no evidence for this is provided, and state that this only applies to rural roads.

US Insurance claim data from HDLI (2012) for one car make shows that High Intensity Discharge headlights (typically Xenon) reduced property damage liability by 5.5% compared to non-equipped (Halogen) vehicles (95% confidence interval: -7.2% to -3.7%). There is also strong evidence that the severity of the collisions were reduced since frequency of all injury claim measures (bodily injury liability, medical payments and personal injury protection) showed reductions between -4.5% to -9.7%. These measures relate to different types of insurance coverage available in the US.

Similarly, systems which alter the beam pattern with the upcoming curve, reduced property damage liability claims by an estimated 4.7% (-7.7% to -1.6%). There was also strong evidence that injuries were significantly reduced; bodily injury liability reduced 9.9% (-17.3% to -1.7%) and medical payments 14.0% (-21.7 to -5.5%), suggesting that crashes involving equipped vehicles were less severe.

Adaptive high beam assist, which activates full beam to utilise the extra lighting available and dips the beam automatically to avoid glare to oncoming cars, showed 5.9% reduction in property damage liability (-16.7% to 6.2%), but a large increase in bodily injury liability of 32.6% (-13.3% to 102.9%) and personal injury protection (12.9%). This suggests that while the frequency of collisions shows a small reduction, the severity of those collisions might be increased (although note that the confidence limits span one in most cases). One possible explanation for this is that the greater beam throw of the high bean encouraged drivers to travel at greater speeds that they would otherwise do, therefore allowing less reaction time should an unexpected event occur. This is in line with previous findings that drivers were found to compensate for the improved vision by increasing their speed, which in some circumstances even led to increased collision risk (Kahlburg, 1993).

Studies such as Zydek *et al.* indicate that HID high beams can create similar levels of discomfort glare than standard HID, showing that improved detection distances without increases in glare are possible for HID “glare-fee” systems. However, information from the DfT suggests that “many thousands” of complaints are received each year about glare from standard HID light sources.

A.2.7 Night vision

Night vision systems are designed to prevent collisions by increasing the detection performance of critical objects such as pedestrians, cyclists, animals, vehicles, and other objects in night, low light or low visibility conditions (i.e. fog).

The systems use these data sources to either display the data to the driver, for them to decide what action to take, or intelligently analyse the data and warn the driver of a potential collision. If linked to an AEB system, braking or manoeuvres could be activated automatically.

A number of companies are currently offering night vision systems: Cadillac since 2000 (General Motors, 2000) (ceasing in 2004), Toyota-Lexus since 2003, Honda since 2004, Mercedes-Benz and BMW since the end of 2005 and Audi since 2010. Night vision systems are currently mostly fitted to executive style higher specification cars. However, this technology is now moving into their medium-to-high end vehicle types, although still as an optional extra.

A.2.8 Adaptive Cruise Control (ACC)

In an extension to the speed management capability of conventional cruise control systems, Adaptive Cruise Control (ACC) maintains a desired road speed if the roadway ahead is unobstructed and a constant time gap from a moving vehicle ahead. The system will automatically control vehicle cruising speed and as necessary, operate the throttle and brakes to maintain a safe distance to the vehicle in front, without the driver having to use the accelerator or brake. The system only brakes if the current pre-selected speed or headway would lead to a likely collision.

Typical systems incorporate laser, radar-based, or LIDAR- (light detection and ranging) based sensors to detect forward objects, as well as curve detection sensors to ensure the vehicle ahead is in the same lane. Currently systems available from a variety of vehicle manufacturers allow up to about 0.3 g (about one third of the available) braking force. This is equivalent to moderate braking in a non-emergency situation and so the functionality is approaching that of a low deceleration AEBS.

Simulation modelling and behavioural studies (in simulators and on-road) have been carried out in an attempt to determine the potential safety benefits of ACC systems. Many studies are reviewed by Regan *et al.* (2001). According to the authors, “On balance the data reviewed suggest that ACC is more likely to enhance the comfort of drivers than to enhance their safety.”

A meta-analytic approach was used by Dragutinovic *et al.* (2005) to analyse the effects of Advanced Cruise Control on driving behaviour reported in seven simulator studies. The effects of ACC on three consistent outcome measures, namely; driving speed, headway and workload were analysed. The mean effect size on driving speed was 0.0956 km/h. From a road safety point of view, an increase in average driving speed of 0.1 km/h is considered negligible. However, the authors noted that the nine individual effect sizes formed clusters around a positive effect of 2.5 and a negative effect of 2.3 km/h. They suggest that there is potential for magnitudes of effect of this size to have an important impact on road safety but needed to be considered alongside other factors.

Adaptive Cruise Control systems have been available on production passenger cars since 1998/1999. Systems such as the Eaton VORAD were already being adopted by the heavy duty trucking industry at that time. However, in 2004, only 0.01 percent of the cars in the Netherlands were equipped with Intelligent Cruise Control (Van Twuijver and Pol, 2004).

A.2.9 Intelligent Speed Assistance (ISA)

Intelligent Speed Assistance (ISA) describes a range of technologies that are designed to aid drivers in observing the speed limit. ISA can achieve this through different degrees of control, the two main forms of which are

- Advisory - alert the driver to when their speed is too great;
- Intervening – the system actively limits the speed. This category can also be further sub-divided:
    - o Voluntary - the driver chooses whether the system can restrict their vehicle speed and/or the speed it is restricted to; and
    - o Mandatory - the driver’s speed selection is physically limited by the ISA system.

The system alerts the driver with audio, visual, and/or haptic feedback or, depending on the type of system, prevents the vehicle from accelerating when the speed exceeds the locally valid legal speed limit. The speed limit information is either received from transponders in speed limit signs (a 'beacon system'), or from a digital road map, which requires reliable positioning information from GPS.

As the cost of technologies have decreased, GPS-based systems have emerged as the preferred solution, mostly due to their superior flexibility, the potential to integrate ISA into a package of wider "intelligent vehicle" technologies, and avoiding the need to set up a costly network of national beacons. Historically there were issues relating to GPS-based ISA systems needing to surmount the difficulties faced by GPS in general, such as interference from weather conditions, the "urban canyon" effect (whereby the GPS signal can be lost between tall buildings in dense urban environments), and so forth. Technical development means that these issues are less significant now, but are still relevant.

Although ISA systems are discussed based on posted speed limits, there is the potential, either for a GPS map system or a local beacon system, to adjust the speed limit based on other factors (e.g. extreme weather conditions, temporary speed limits etc.). Deployment could also be targeted at: particular road types, at specific collision black spots, at particular times of day, or at particular driver groups (e.g. young drivers, commercial fleet drivers).

Although not ISA systems, it should also be noted that many current vehicles are fitted with voluntary speed limiting systems which are can be set by the driver to ensure compliance with a particular speed threshold. However, in this case, the speed limiter is set by the driver and is not linked to any digital map of speed limit information. Goods vehicles are also equipped with mandatory speed limiters but these only apply to maximum speed.

The main benefits of ISA are reduced speeds, which result in fewer collisions and reduce the injury risk for those that do occur.

During a field test of 50 participants, Reagan *et al.* (2013) found that drivers of ISA-equipped vehicles spent more time travelling at 70 mile/h (113 km/h) or lower (54.8%) compared to the control group (48. 8%). This effect would be expected to lead to fewer (and less severe collisions). Many studies support this expectation and have predicted that the availability of ISA will have a positive effect on collisions and injuries:

Carston and Tate (2005) found that "...a simple mandatory system, with which it would be impossible for vehicles to exceed the speed limit, would save 20% of injury accidents and 37% of fatal accidents. A more complex version of the mandatory system, including a capability to respond to current network and weather conditions, would result in a reduction of 36% in injury accidents and 59% in fatal accidents." These estimates were made by combining research from a number of European countries. The predicted percentage decreases in collisions imply savings of over €20 Billion per annum in the EU28.

Biding and Lind (2002) reported that in a trial of several thousand vehicles in Sweden, mean speed, standard deviation of speed, and speed violations were reduced.

Based on data from the UK, Lai *et al.* (2012) predicted that mandatory ISA would reduce the number of fatal collisions by 30% and serious collisions by 25%.

The SafeCAR project in Australia predicted on the basis of data collected from 23 drivers (15 equipped, 8 control) travelling at least 16,500 miles (26,400 km) that there could be 20% fewer road injuries in urban areas (Regan *et al.*, 2006).

Data from field tests in the UK involving 79 drivers over a six-month period showed that a voluntary ISA system reduced driving speed by about 5% (Lai and Carsten, 2008). The authors estimated that this system has the potential to reduce the number of fatalities by 2.1-10.7%, fatal collisions by 1.7% - 8.7%, and serious injury collisions by 0.7-3.6% depending on the expected market penetration between 13-65% in 2016 and the quality of implementation.

Wilkie and Tate (2003) used UK data to predict collision reductions ranging from 8.4% for an advisory-based system, to 30.2% for a mandatory system. These authors also found that a local ISA system with a 15km radius would have 84% of the effectiveness of a national ISA system. Assuming that beacon based ISA systems would have to be introduced region-by-region, this report investigated what safety improvements could be achieved by the use of local systems.

Several studies found that advisory ISA systems were overridden more frequently in urban areas. An eight-week field trial of 44 drivers showed a trend for a voluntary system to be overridden in urban settings. On 20 mile/h roads, ISA was overridden for 13% of distance travelled, while on the 30 mile/h roads and 40 mile/h roads the ISA was overridden for 8% of the distance travelled. It was also shown that the ISA system was overridden more often by male and young drivers than other drivers (Saint Pierre and Ehrlich, 2008). This suggests that mandatory systems might be more effective for young drivers; Young *et al.* (2010) found evidence in a simulator study involving 30 drivers that inexperienced drivers benefited to a greater extent.

A study on the effectiveness of Directive 2002/85/EC (the Speed Limitation Directive) found a positive impact on safety; collision reductions of 9% for fatal collisions on motorways with HCVs involved, 4% of serious injuries, and 3% of injury collisions were estimated (Transport and Mobility Leuven, 2013).

Despite consistent results from various trials, the requirement for a system to be in place to inform on speed limits and also resistance because of fears about public attitudes to ISA mean that ISA has not yet been implemented.

A.2.10 Alcohol interlock

The alcohol ignition interlock device (alcolock) is an electronic device, which is installed in a vehicle. Before the driver is allowed to turn on the ignition he or she has to take a breath test in order to check their blood alcohol concentration (BAC). If the breath test measures a BAC above the predetermined threshold level, the alcolock is activated and it is impossible to start the car. Many states in the US and Canada have introduced the alcolock, using it partly as a substitute for the suspension of a driving licence and partly as a preventive measure. As well as in-vehicle breath tests as above, there are various other interlock systems: key-based breath tests, sniffer systems and skin contact systems. The main benefits are that convicted drivers can continue to drive if they have an alcolock fitted. It has been shown that those who choose to use a lock are less likely to re-offend.

Evidence presented by Kullgren *et al.* (2005) estimated that repeat drink-driving offences could be reduced by 40%-95% in US, Canada and Sweden. The eSafety Forum

(2005) estimated that 25% of alcohol-related crashes could be affected (with 70% fleet fitment, leading to a 17.5% reduction in these crashes. This equates to a 1.1% reduction in all collisions. Other European studies, such as Lind *et al.* (2003) predict a reduction in fatalities of between 1% and 5% (the latter dependent on 100% fitment).

The main barriers to the technology appear to be judicial, lack of mandatory use and public acceptance. In addition, most systems are relatively high cost and may be expensive to maintain/calibrate.

Appendix B Datasets for exposure modelling

B.1 Traffic data

Traffic estimates of London car traffic by borough and year are available from the DfT website[28]. These estimates include car traffic on both major and minor roads in London.

Figure B.1 shows car traffic in London by year from 1993 to 2013.

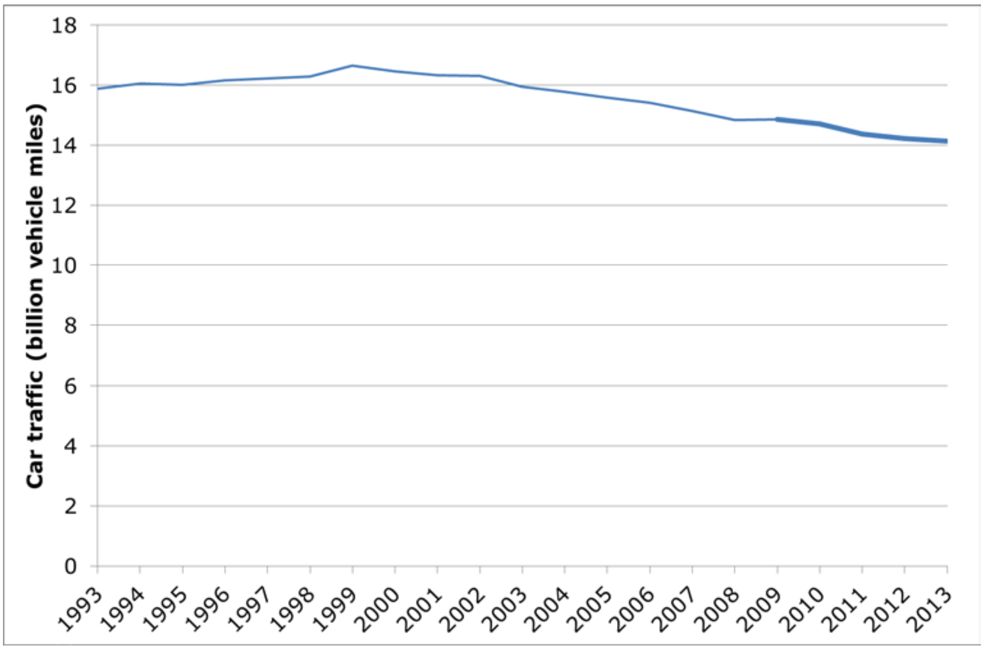

Figure B.1: Car traffic in London by year (billion vehicle miles)

In the period of interest for this project (2009-2013), overall car traffic has been decreasing in London with a 5% change since 2009. The estimates show that traffic has decreased across all boroughs, although some changes have been larger than others: traffic in Newham has decreased by 16% since 2009 whereas the decrease in Barnet was only 1%.

B.2 Registered cars

Upon request, DfT kindly provided data on the number of cars registered in London each year (2009-2013) by make, model and year of first registration.

Figure B.2 shows how the number of cars (and the number of newly registered cars) changes across the period. Values are indexed to the 2009 figure such that a value greater than 100% indicates that there were more registrations in that year than 2009 and a value less than 100% indicates there were fewer.

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[28] https://www.gov.uk/government/statistics/road-traffic-estimates-in-great-britain-2013 - TRA8902

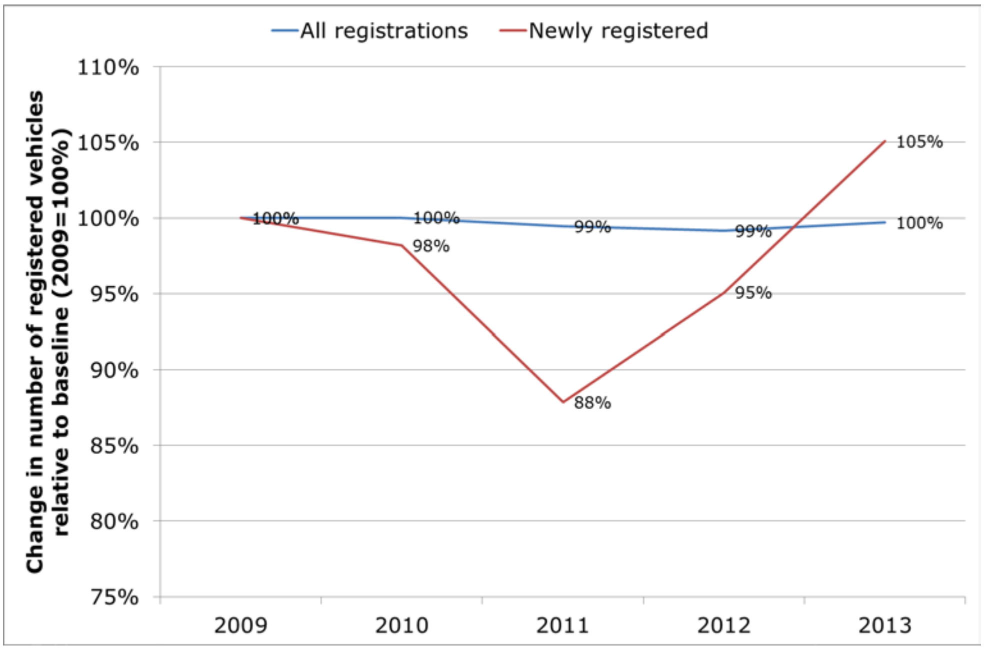

Figure B.2: Cars registered in London by year (split by all cars and newly registered cars)

Figure B.2 shows that the total number of car registrations remained fairly consistent across the period but was slightly lower in 2013 than 2009 (2,556,730 in 2009 and 2,549,275 in 2013).

The number of newly registered cars was higher in 2013 than in 2009 (122,062 in 2009 and 128,241 in 2013). The number has been increasing over the past three years and in 2013 5% of all registrations were new cars.

It is unknown how many of the cars registered in London are registered to business premises in London, but are not actually being driven there or how many cars are registered elsewhere, but are driven in London. Attempts were made to utilise data from the Low Emission Zone (LEZ) cameras which cover most of Greater London to provide further information about the cars being driving in London. Unfortunately, these data were not available in a suitable format for analysis and therefore the decision was made to assume that the cars registered in London are a representative sample of those driven in London.

B.3 MOT data

MOT data contains information on every car registered in Britain that is required to have an MOT test by law (i.e. all cars aged over 3 years), including the make and model, pass or fail, reasons for failure if applicable, number of miles on the milometer at each test, and year of first use. These data are freely available to download from the DVLA website[29].

From the MOT data in 2012 and 2013 we have retrieved the mileages recorded for each car that passed a test with a make and model and year of first registration recorded and a mileage of greater than zero. We have matched cars with mileage values in each of the

[29] http://data.gov.uk/dataset/anonymised_mot_test

2012 and 2013 datasets using a unique identifier and subtracted the mileage recorded in 2012 from that recorded in 2013. We have then factored these figures to take account of slightly different lengths of time between MOT tests. Once aggregated this gives an estimate of the number of miles driven in a year for different ages and segments of vehicles for cars over three years old. For newer cars we have assumed a uniform distribution of miles across the first three years by taking the average annual mileage at first test.

These figures of number of miles driven per year by age and segment of vehicle were then modelled to remove the impact of statistical variation and provide smooth estimates of annual mileage by age, as shown for example in Figure B.3.

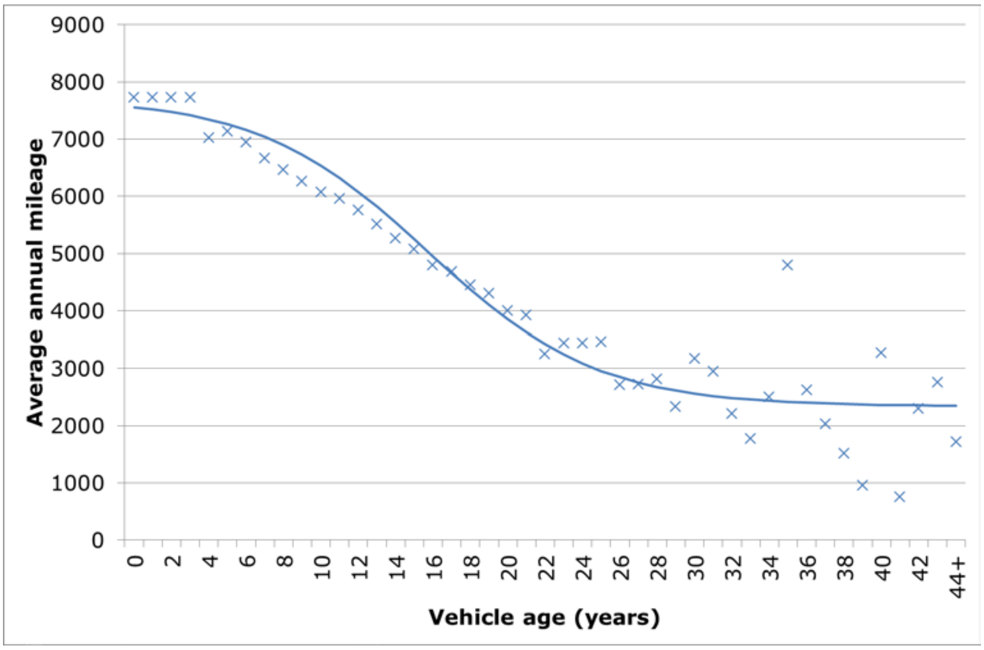

Figure B.3: Modelled annual mileage per car for superminis

These models give us an estimate of the average miles driven each year since registration by car type.

Note that this analysis was based on all MOT tests in Great Britain which meet the criteria above; it was not restricted solely to cars which drive in London. As a result, for the statistical modelling, it is assumed that the relative difference in estimated average annual mileage between the different vehicle ages and segments is representative of the relative differences between cars which drive in London.

In addition, not all of a vehicles average annual mileage will be driven in London. This analysis assumes that the proportion of each vehicle's average annual mileage in London is the same across segments and registration years. It also assumes that the average annual mileage for each segment and age does not change between 2009 and 2013.

Appendix C Differences in car use by gender, age and journey purpose

This appendix summarises what we know about the types of people buying different cars and how these cars are used. Differences in the types of car registered between London and the rest of Great Britain, and within London itself are also presented.

In 2009, in England, 53.9% of car licence holders were men; by 2013 this had dropped to 53.1%. Figure C.1 and Figure C.2 show how the proportion of males and females who hold a full car driving licence differs by age group between 2009 and 2013.

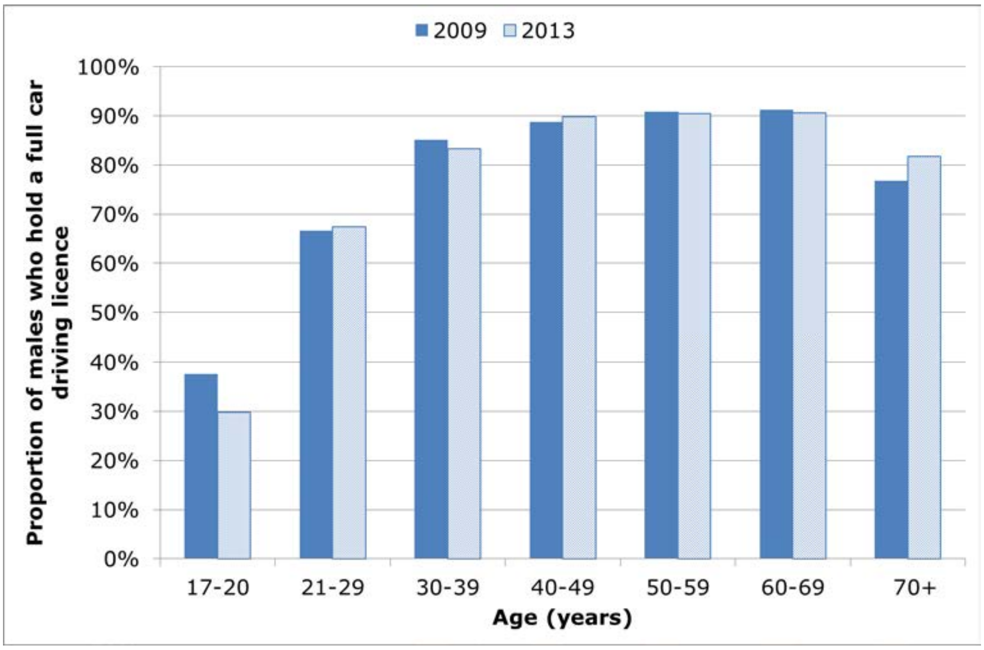

Figure C.1: Proportion of males who hold a full car driving licence by age (England, 2009 & 2013) (data sourced from NTS0201 (Department for Transport (e), 2013))

In 2009 38% of males in England aged 17-20 years had a full car driving licence, but by 2013 this had dropped to 30%. In contrast, the proportion of males aged 70+ with a driving licence increased during the same period from 77% to 82%.

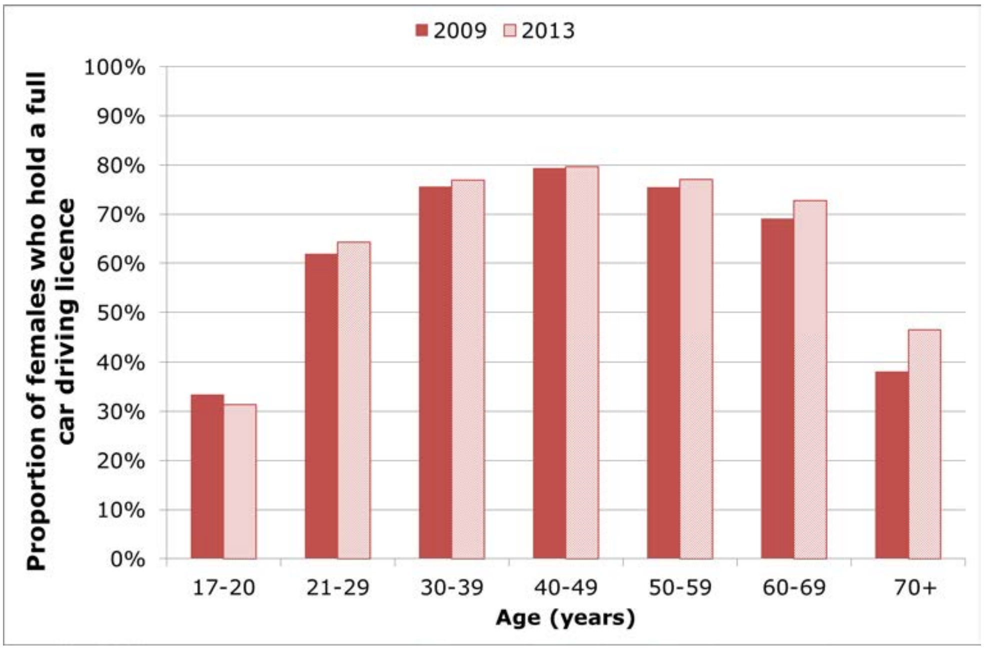

Figure C.2: Proportion of females who hold a full car driving licence by age (England, 2009 & 2013) (data sourced from NTS0201 (Department for Transport (e), 2013))

Females show a similar pattern, with proportionately fewer 17-20 year olds having a full car driving licence in 2013 and more 70+ year olds. These figures suggest that the driving population is getting older, with a particular increase in the oldest group.

Registrations in cars are another way of examining differences between genders. Figure C.3 shows how the distribution of registered keepers has changed over the past 5 years.

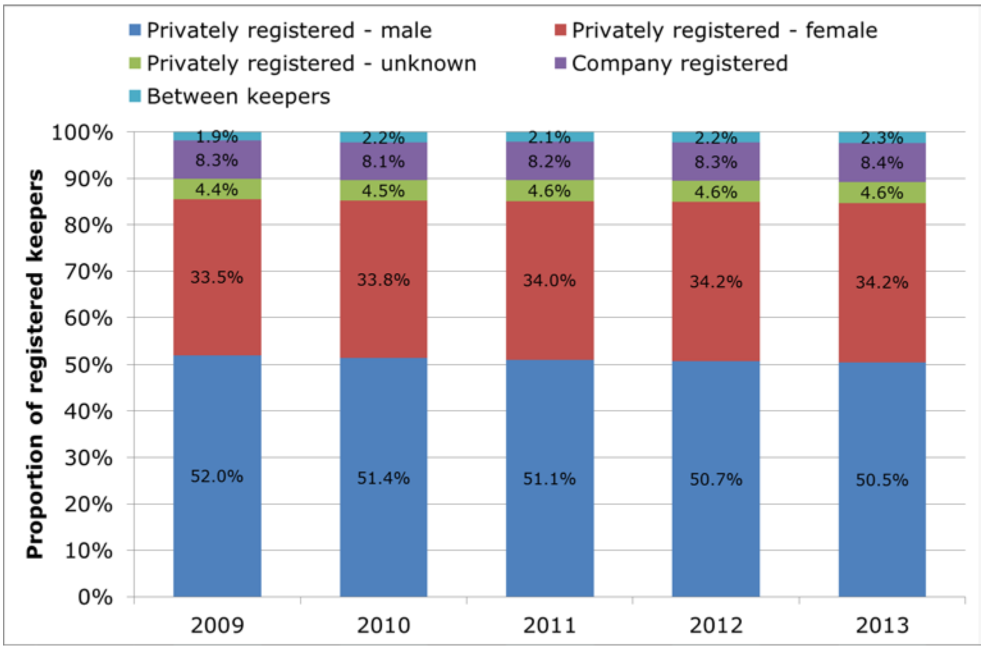

Figure C.3: Proportion of registered keepers of cars by private/company and gender (2009-2013) (data sourced from VEH0202 (Department for Transport (c), 2013))

Between 2009 and 2013 the number of cars licensed has increased from approximately 28.2 million to 29.1 million. The distribution of vehicles licenced by gender shows that fewer cars are registered to males and an increased proportion to females; this matches with the trend in full car licences discussed above.

In addition to differences between genders, age of the motorist also has an effect on car choice. A study by insurance company Elephant (Elephant, 2009), which studied the most popular car choice in each age group, showed a number of differences between the groups. Figure C.4 shows how the average cost, engine size and age of the vehicle differs by age of the motorist.

Figure C.4: Average cost, engine size and age of the most popular car in each age group

Age group	Average cost	Average engine size (cc)	Average age
Under 20	£2,987	1315	7 years, 5 months
20-29	£5,022	1598	6 years, 9 months
30-39	£7,237	1841	6 years, 5 months
40-49	£7,271	1902	6 years, 7 months
50-59	£7,506	1917	6 years, 9 months
60+	£6,589	1947	7 years, 6 months

Motorists under 20 drive the cheapest cars with the smallest engines and these typically tend to be older vehicles. Those aged 60 years and over drive the vehicles with the largest engine size, but these tend to be slightly cheaper and older than the vehicles driven by those in the 50-59 year old age group.

The study also examined differences in the age of vehicle by age and gender of the motorist (Figure C.5).

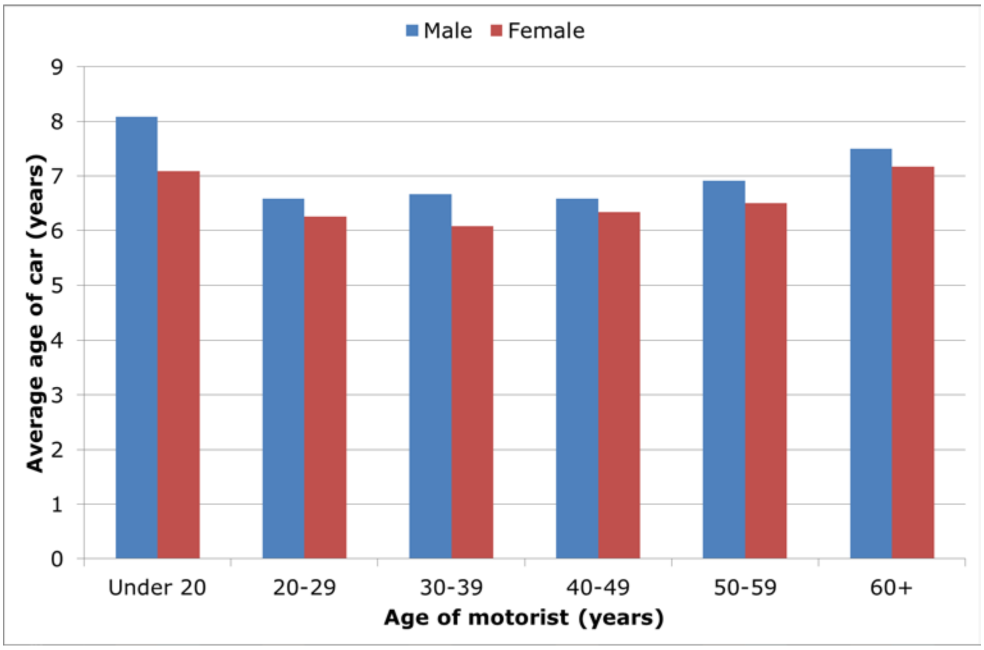

Figure C.5: Average age of cars by age and gender of motorist (2009)

Males in all age groups drive older cars than their female counterparts. As seen above, the oldest vehicles are driven by those under 20 and by those aged 60 and over.

The purpose and length of the journeys taken can differ as vehicles get older. Figure C.6 shows the average annual mileage of cars by age of vehicle and trip purpose.

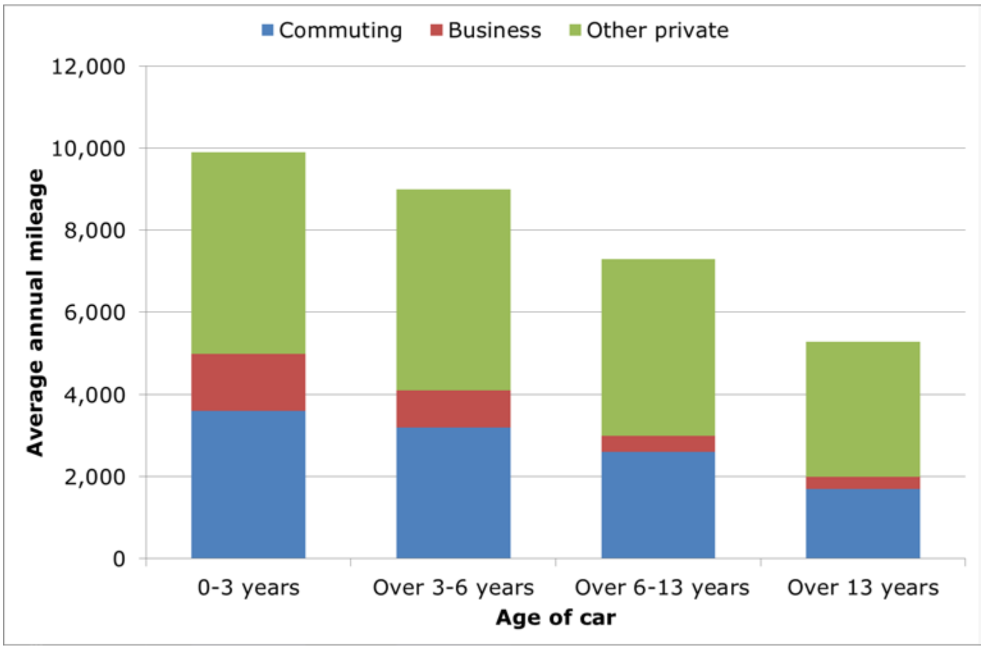

Figure C.6: Average annual mileage of 4 wheeled cars by age of vehicle and purpose (data sourced from NTS0903 (Department for Transport (b), 2013))

As a vehicle gets older, on average, it is driven fewer miles a year and is used less for commuting/business purposes and more for private trips (as a proportion of the annual mileage). For example, 36% of the annual mileage of 0-3 year old car is used for commuting and 14% for business purposes; this compares to 31% and 6% respectively for the mileage of a 13+ year old car. This appears to match with how trip purpose changes as people age: older people commute less and shop/visit friends more than those in younger age groups (NTS0611 (Department for Transport (d), 2013)) and, as we have seen above, older people tend to drive older cars.

Figure C.7 shows how the proportion of registered keepers of new cars has changed from 2009 to 2013.

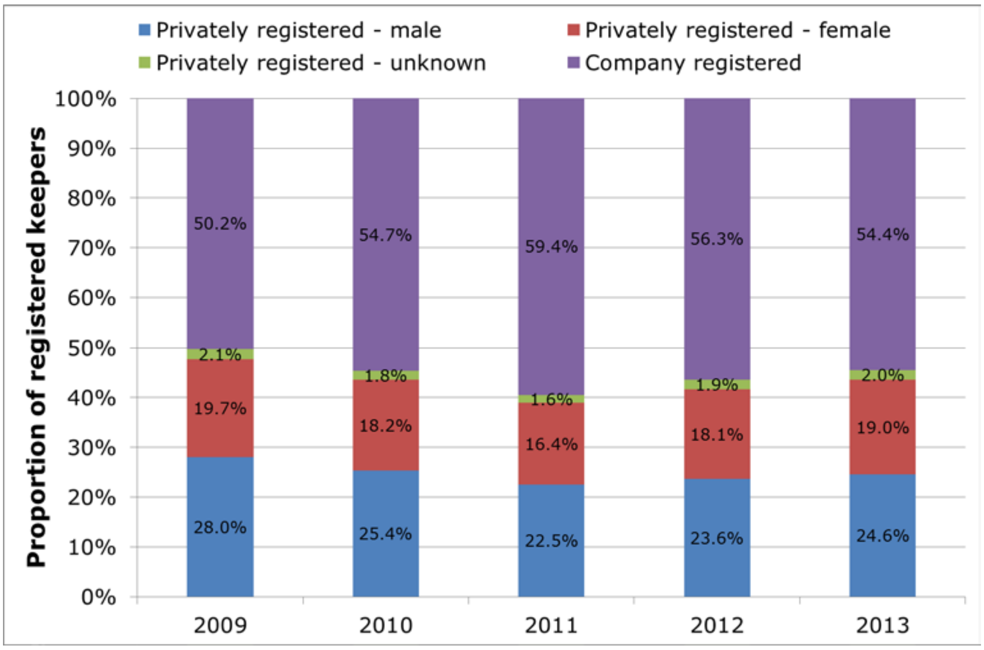

Figure C.7: Proportion of registered keepers of cars registered for the first time by private/company and gender (2009-2013) (data sourced from VEH0260 (Department for Transport (c), 2013))

Over half of all new car registrations are to companies. Since 2009 this has been increasing generally (from 50% in 2009 to over 54% in 2013), with a peak in 2011 at 59%. In contrast, the proportion of cars registered privately to male keepers has been decreasing over the same period, but this is still higher than the proportion of female keepers.

Appendix D Collision involved cars in London by segment and vehicle age

The make and model is known for approximately 80% of cars involved in injury collisions in London. Figure D.1 shows the proportion of collision involved cars in each segment by year.

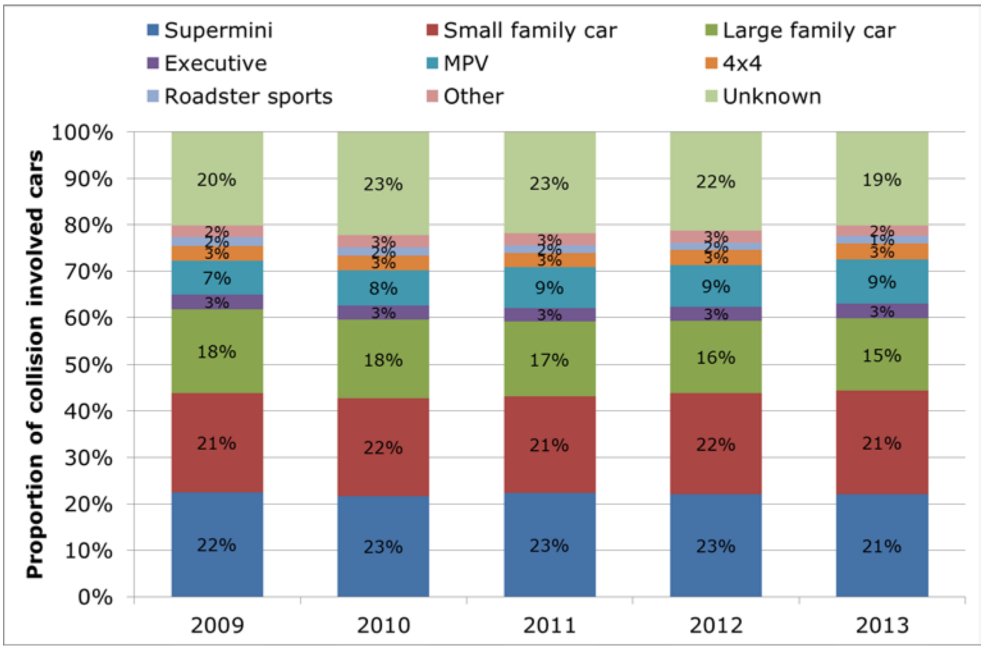

Figure D.1: Proportion of collision involved cars in London by segment and year (2009-13)

The graph shows that the proportion of collisions involving large family cars has been decreasing across the period, whilst the proportion involving MPVs has been increasing. It is not clear at this stage if these trends are due to changes in the way in which the vehicles are driven, the prevalence of these cars within the fleet or to changes in the technologies with which they are fitted.

Collision involvement and subsequent injury in the event of a collision may also be influenced by the age of the vehicle. Figure D.2 shows how the age distribution of collision involved cars has changed between 2009 and 2013.

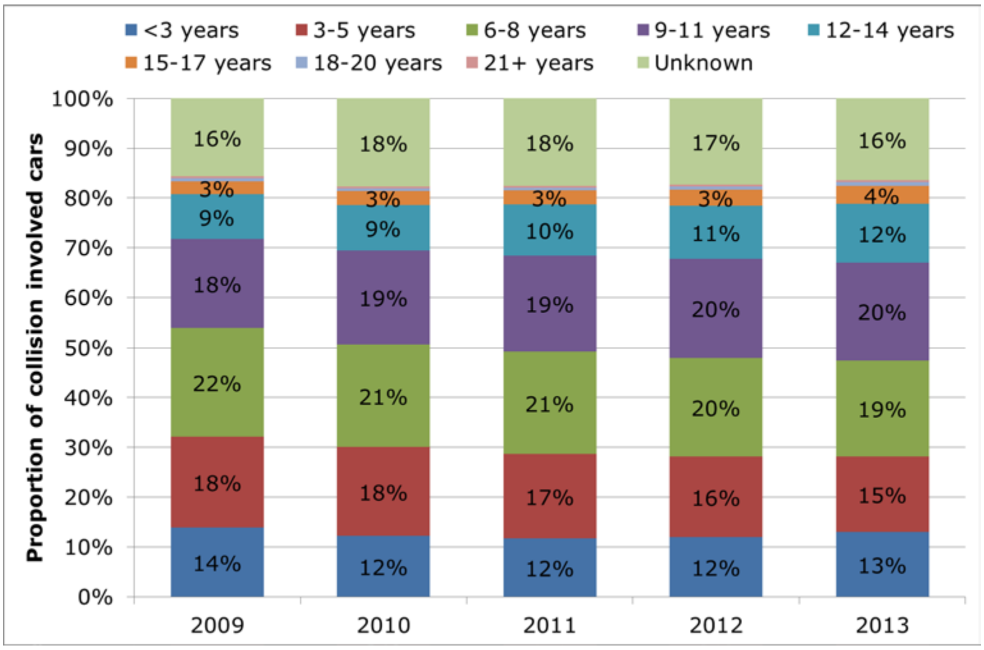

Figure D.2: Proportion of collision involved cars in London by vehicle age and year (2009-13)

The proportion of collisions involving cars less than 8 years old appears to be decreasing, whilst older cars appear to be increasing. This could reflect the observation that cars in London are, on average, getting older (see Figure 4.2) or that the decrease in newer cars in the collision statistics is due to the introduction of more primary safety features into the fleet.

In addition to examining how differences in the fleet affect the collision involvement of cars, it is important to consider how the type of vehicle affects car occupants and vulnerable road users differently. Figure D.3 shows how the distribution of car driver casualties compares to pedestrian casualties by segment.

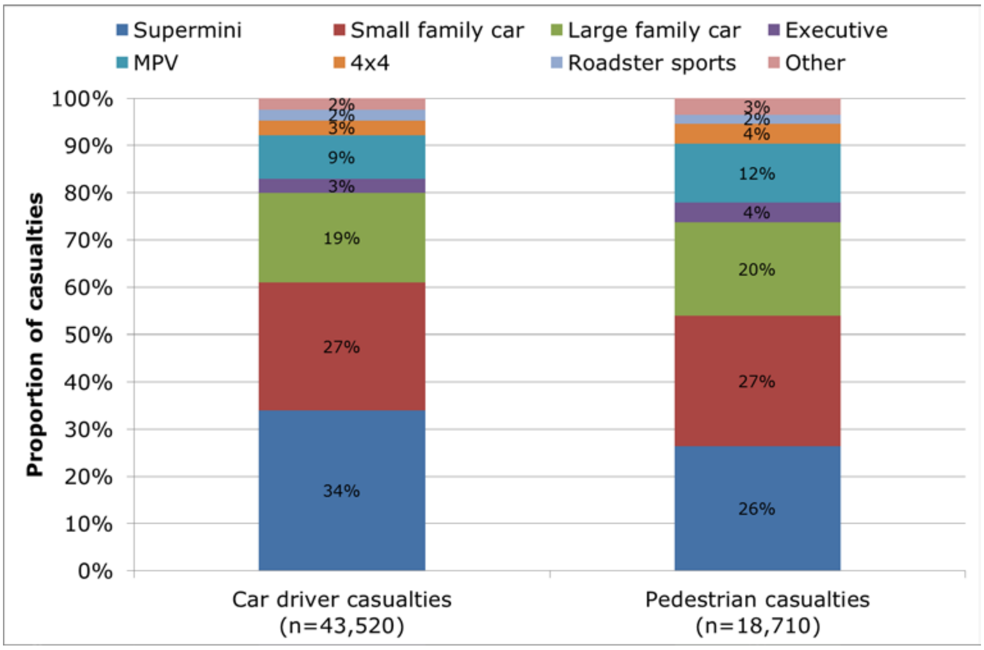

Figure D.3: Proportion of all casualties in collisions in London by casualty type and segment (2009-13)

The results show that a higher proportion of car driver casualties are injured in superminis than the proportion of pedestrians injured by these vehicles; the opposite is true for larger vehicles such as large family cars, executives, MPVs and 4x4s. This difference is likely to result due to the protection offered by the different size and weight of the cars: smaller cars protect their occupants less well than larger cars.

In addition, differences in the types of people that drive these cars and the conditions in which they are driven may also affect the relative distribution amongst the two casualty groups. For example, if MPVs are more likely to be driven in urban areas where there are lots of pedestrians, then this could inflate the proportion of casualties which are hit by these cars and hence explain some of the differences.

Appendix E Comparison between collision involved drivers from London and those from other areas

The home postcodes of the drivers who were involved in collisions within London were examined to ascertain whether the driver was from within London or not.

68% of the car and taxi drivers who were involved in a collision within London (and for which vehicle segment and a valid GB driver home postcode were available) were from inside London.

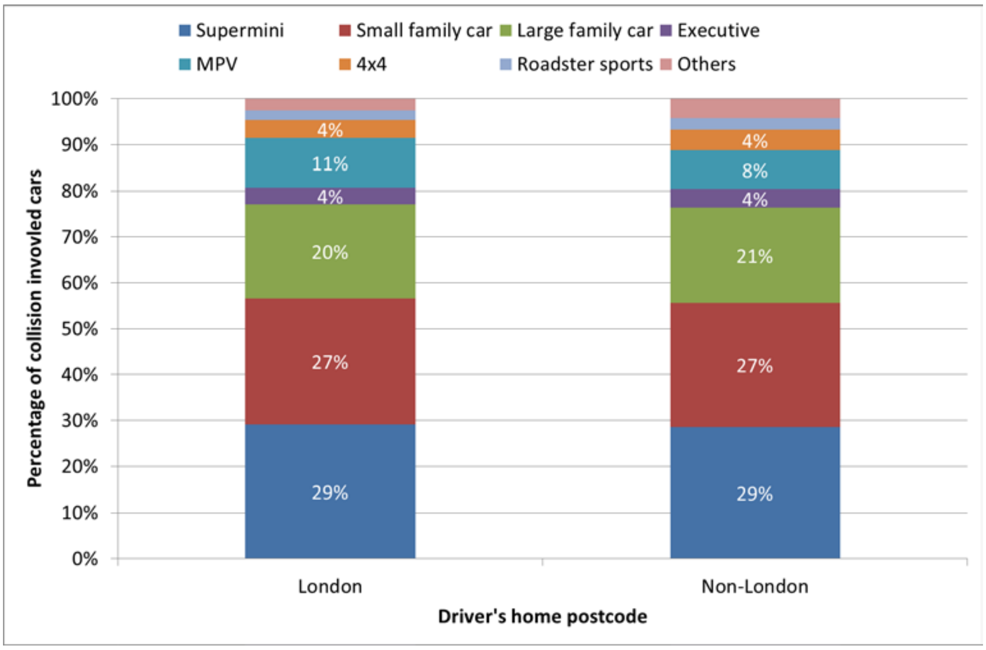

Figure E.1: Percentage of collision involved cars by segment and driver's home postcode

Figure E.1 suggests that the distribution of collision involved cars by segment is similar for those registered inside and outside of London.

All fitments except pedestrian airbags (which were found in very few vehicles) were more commonly found on vehicles where the driver home postcode was outside of London. In particular, head side airbags, ESC and SBR were more commonly found on vehicles (involved in collisions within London) where the driver's home postcode was outside of London.

This might suggest that vehicles from within London are different from those outside London, perhaps that drivers from within London are less likely to pay for additional safety features. In order to reduce casualties, TfL may want to consider educational campaigns to encourage Londoners to purchase vehicles equipped with safety features.

Appendix F Primary safety fitment of collision involved cars

The STATS19 road injury collision database was combined with the fitment database so that the prevalence of vehicle fitments in collisions could be analysed. In particular, this appendix considers two primary safety features: ESC and brake assist.

F.1 Electronic Stability control

Figure F.1 shows the percentage of collision involved cars, for which fitment information was available, that had ESC fitted as standard or as an option by segment.

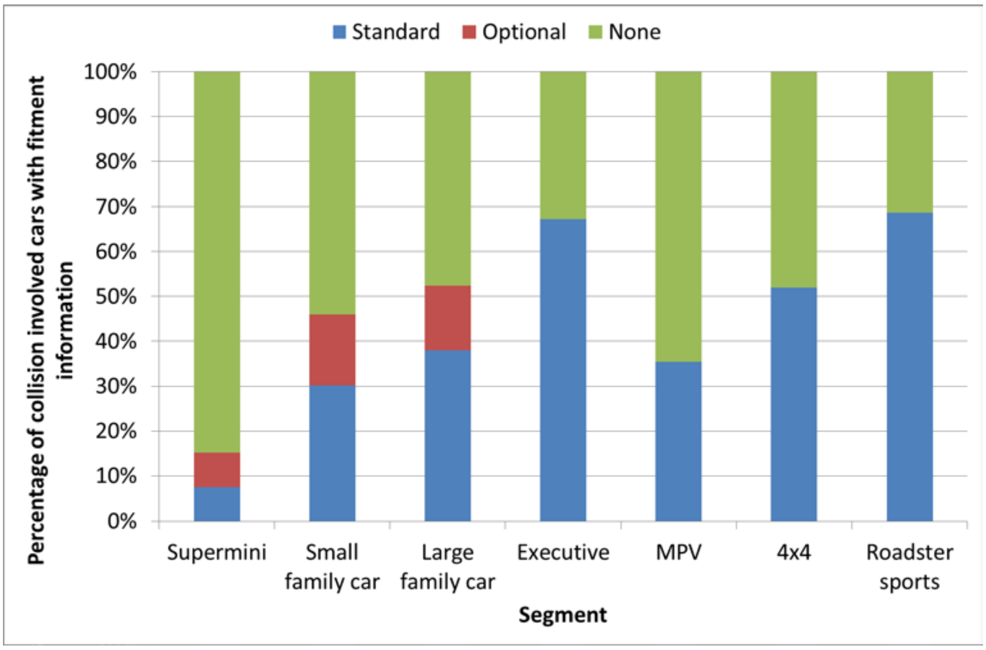

Figure F.1: Percentage of collision involved cars in London with ESC fitted by segment

ESC was more commonly fitted as standard to collision involved roadster sports cars and executive vehicles and less commonly to collision involved superminis. ESC was far less commonly found in collision involved superminis, even as an optional extra. This trend reflects that of the traffic data (Figure 4.9) which shows that a very small percentage of supermini car traffic has ESC fitted and a larger percentage of executive and roadster sport traffic has ESC fitted as standard.

However, the proportion of collision involved cars with ESC fitted is lower than the proportion of traffic with ESC fitted for all segments except roadster sports (which was very similar). For example, 84% of executive car traffic has ESC fitted (Figure 4.9) but 67% of collision involved executive cars had ESC fitted. This might suggest that ESC (a primary safety feature designed to reduce the likelihood of a collision occurring) is effective at stabilising the vehicle and preventing a collision. However, there are a number of other possible reasons for this including:

- Differences in the vehicles with and without ESC – vehicles without ESC are typically older and therefore may be more likely to have defects which result in a collision.

- Given that vehicles without ESC are typically older, there may be differences in the people who drive vehicles with and without ESC (e.g. driver age or gender) – those without ESC may be more prone to collision involvement due the prevalence of risky driver behaviours such as speeding

Table F.1 shows various statistics for vehicles with ESC as standard, ESC as an option and vehicles without ESC available.

Table F.1: ESC comparisons

	ESC as standard	ESC optional	No ESC fitted
Average vehicle age	4	6	9
Average driver age[30]	39	37	38
Percentage of drivers who are male[31]	70%	63%	60%
Percentage of vehicles which skidded	2.3%	2.3%	3.2%
Percentage of drivers who were killed or seriously injured	1.2%	1.4%	1.9%
Percentage of drivers of vehicles which skidded who were KSI	6.2%	6.6%	8.9%

On average, the vehicles with ESC fitted as standard were much newer than vehicles without ESC fitted (4 calendar years since registration, compared with 9 for vehicles without ESC). The drivers of the vehicles with ESC fitted had a similar average age to those of vehicles without ESC, but a higher proportion of these were male (70% compared with 60%).

ESC is designed to prevent vehicles from skidding and overturning in loss of control collisions. A slightly higher proportion of vehicles without ESC skidded or overturned than the proportion of vehicles with ESC as standard which suggests that ESC may be effective at reducing the probability of overturning.

The drivers of the vehicles without ESC fitted were more severely injured in all collisions and those which included the vehicle skidding or overturning. However, since the vehicles without ESC fitted are older on average than the vehicles with ESC fitted as standard, it is unclear whether the fitment of ESC has changed the nature of the collision and therefore reduced the chance of KSI injury or if other differences in the secondary safety of the vehicles is affecting the KSI proportion.

F.2 Brake Assistance

Figure F.2 shows the percentage of collision involved cars, for which fitment information was available, that had brake assistance fitted as standard or as an option.

[30] Not including drivers where age was unknown or recorded as 0.

[31] Not including drivers where the sex was not recorded.

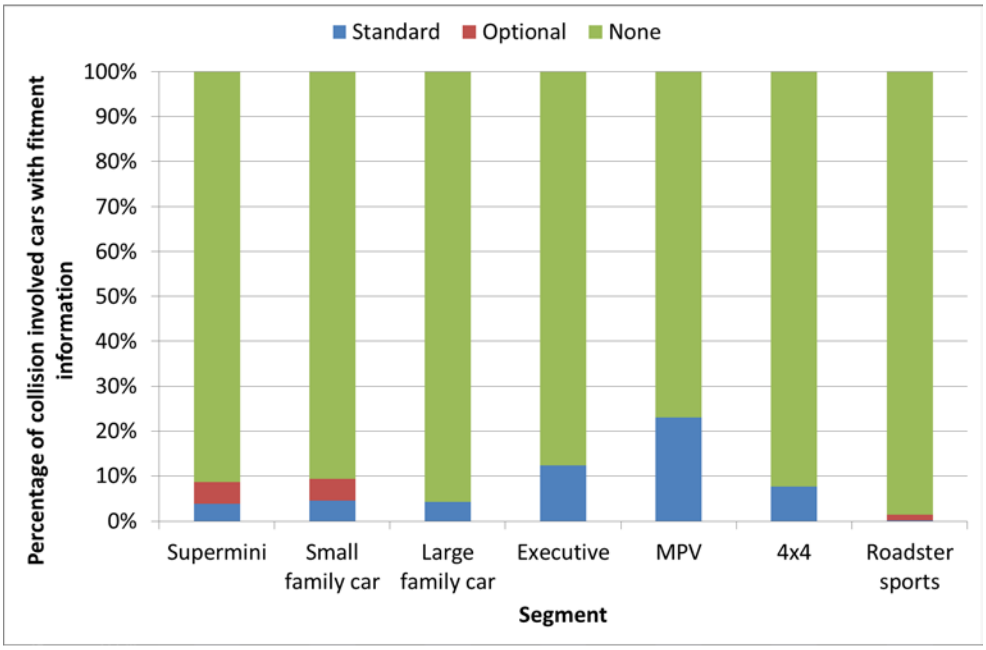

Figure F.2: Percentage of collision involved cars in London with brake assistance fitted by segment

Brake assistance was fitted as to less than 10% of all vehicle segments other than MPVs (24% of which had brake assistance fitted) and executive vehicles (12% of which had brake assistance fitted).

Table F.2 shows various statistics for vehicles with brake assistance fitted as standard, as an option and vehicles without brake assistance available.

Table F.2: Brake assistance comparisons

	Brake assistance as standard	Brake assistance optional	No brake assistance fitted
Average vehicle age	2	2	8
Average driver age[30]	40	35	38
Percentage of drivers who are male[31]	69%	56%	63%
Percentage of vehicles which had a front or rear impact, or no impact	66%	64%	67%
Percentage of drivers of vehicles in non-side collisions who were KSI	0.9%	1.7%	1.8%
Percentage of pedestrians hit in non-side collisions who were KSI	15%	18%	19%

Similarly to ESC, on average, the vehicles with brake assistance fitted as standard were much newer than vehicles without brake assistance fitted (2 calendar years since registration, compared with 8 for vehicles without brake assistance). The drivers of the vehicles without brake assistance fitted were younger on average than those of vehicles which had brake assistance fitted as standard; the 25-29 year old age group accounted for most drivers of vehicles without brake assistance compared with 40-44 year olds for vehicles with brake assistance as standard.

Brake assistance is not expected to have any impact on side collisions; however, it may reduce the number of, or severity of, front and rear impacts and vehicles which don't impact. The STATS19 data showed similar proportions of vehicles being involved in 'non-side' collisions for vehicles with brake assistance as standard and those with no brake assistance fitted (66% compared with 67%). However, the drivers of vehicles without brake assistance that were involved in 'non-side' collisions were slightly more severely injured than those of vehicles with brake assistance. This could suggest that installation of brake assist does not significantly reduce the number of collisions which occur, but that it does reduce the speed and subsequent injury severity of these collisions. On the other hand, since the vehicles without brake assistance fitted are older on average than the vehicles with brake assistance fitted as standard (and the drivers of such vehicles are younger), it is unclear whether the fitting of brake assistance is the reason for these differences.

In addition to influencing car driver casualties, brake assist is likely to have some impact on VRU collisions by reducing the number or speed at which these occur. There were 6,803 pedestrians injured by the 51,623 vehicles which had non-side impacts. Of the 51,623 vehicles with non-side impacts, 6% had brake assistance fitted as standard and 8% of the 6,803 pedestrians were hit by vehicles without brake assistance fitted as standard. This may indicate that the brake assistance helped to prevent some collisions with pedestrians. The severity of the injuries is also lower for the vehicles with brake assistance fitted - 15% of pedestrians hit by a vehicle with brake assistance fitted as standard were killed or seriously injured compared with 19% of pedestrians hit by vehicles without brake assistance fitted.

Appendix G Secondary safety fitment of collision involved cars

The STATS19 road injury collision database was combined with the fitment database so that the prevalence of vehicle fitments in collisions could be analysed. In particular, this appendix considers three secondary safety features: chest and head side airbags and seat belt reminders.

G.1 Side airbags

Figure G.1 and Figure G.2 show the percentage of each vehicle segment that have side chest and side head airbags fitted respectively.

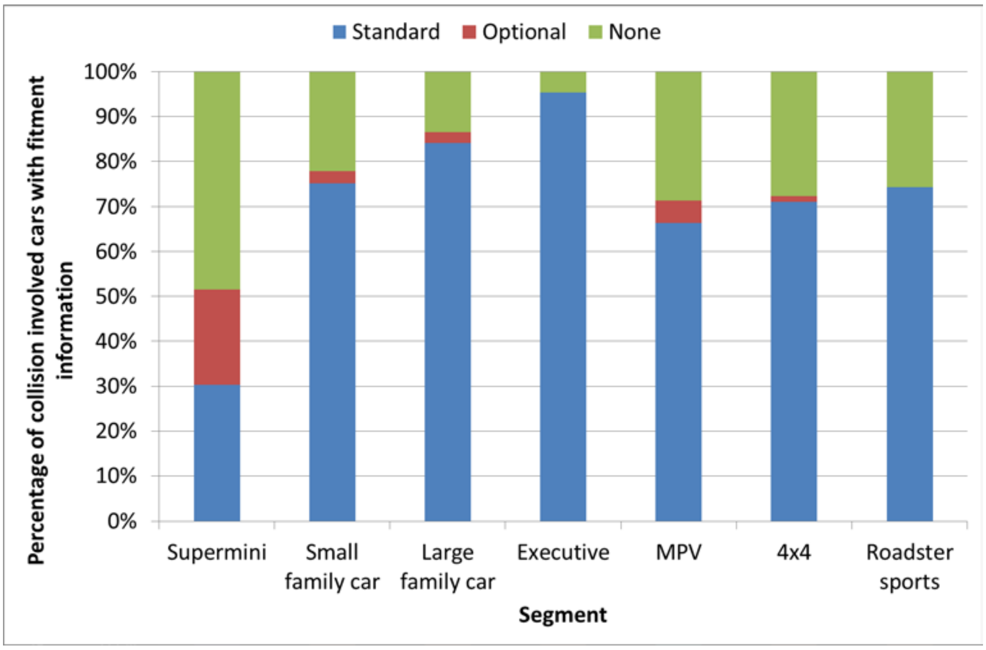

Figure G.1: Percentage of collision involved cars in London with a side chest airbag fitted by segment

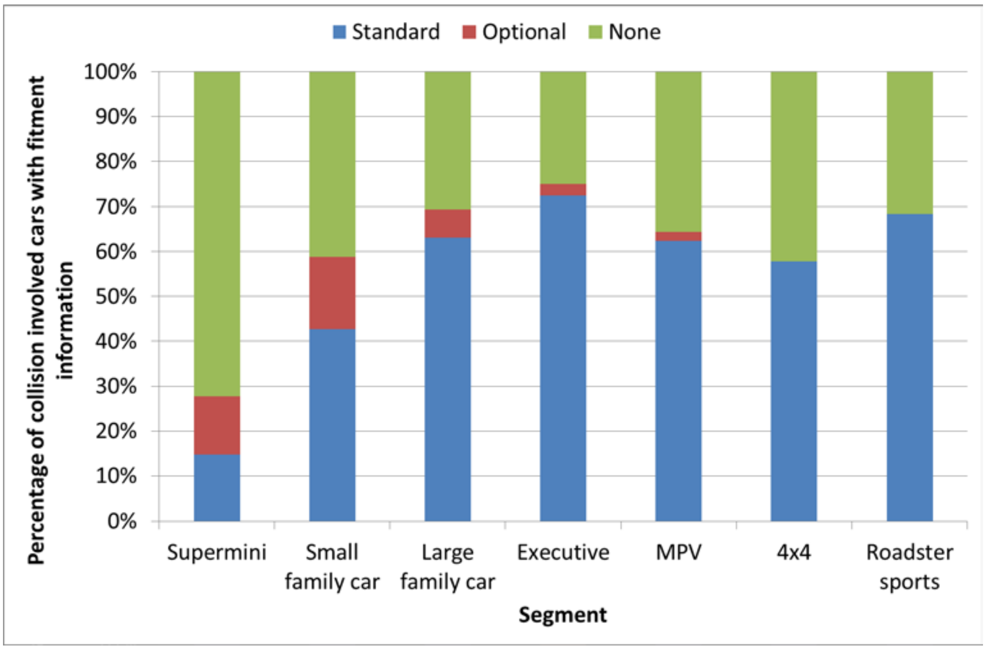

Figure G.2: Percentage of collision involved cars with a head airbag fitted by segment

As with the fitment by traffic data presented in Figure 4.10, chest airbags are more common than head airbags. All segments other than superminis had chest airbags fitted as standard in more than 60% of collision involved vehicles; superminis also had a relatively low proportion of collision involved vehicles equipped with head airbags.

Table G.1 shows various statistics for vehicles with chest and head airbags.

Table G.1: Chest and head airbag comparisons

	Chest airbag as standard	No chest airbag fitted	Head airbag as standard	No head airbag fitted
Average vehicle age	6	11	5	10
Average driver age[30]	39	38	39	38
Percentage of drivers who are male[31]	66%	58%	69%	59%
Percentage of vehicles which had a side impact	34%	32%	34%	32%
Percentage of drivers of vehicles in side impacts who were KSI	1.2%	1.6%	1.0%	1.6%

On average, the vehicles with airbags fitted as standard were newer than vehicles without airbags fitted. The drivers of the vehicles without airbags fitted were slightly younger on average than those of vehicles which had airbags fitted as standard. Drivers of vehicles with chest airbags as standard were more likely to be male than drivers of vehicles without chest airbags fitted.

Side airbags are designed to reduce injury severity in side impact collisions but, they do not reduce the chance of having a side impact collision. The STATS19 data shows that the drivers of vehicles without chest airbags fitted that were involved in side impact collisions were slightly more severely injured than those of vehicles with chest airbags. The same is true for vehicles equipped with head airbags, although it should be noted that many vehicles are equipped with both. Since the vehicles without airbags fitted are older on average than the vehicles with airbags fitted as standard (and the drivers of such vehicles are slightly younger), it is unclear whether the airbags are the main explanatory reason for this difference.

Attempts were made to develop secondary safety models to control for differences in vehicle and driver age in order to estimate the effectiveness of side airbags; unfortunately the models developed did not fit the data well and the influence of other technologies confounded the results. However, the overall effectiveness of secondary safety features can be estimated; these results are presented in Section 5.4.

G.2 Seat belt reminder

Seat belt reminders are a technology that is under-represented in the fitment database. Whilst the presence of seat belt reminders has been noted by Euro NCAP since 2009, this information is not widely reported in either the other sources used to populate the database or Euro NCAP tests prior to 2009. Therefore, for most segments, the percentage of collision involved cars with seat belt reminders is likely to be higher than shown in Figure G.3.

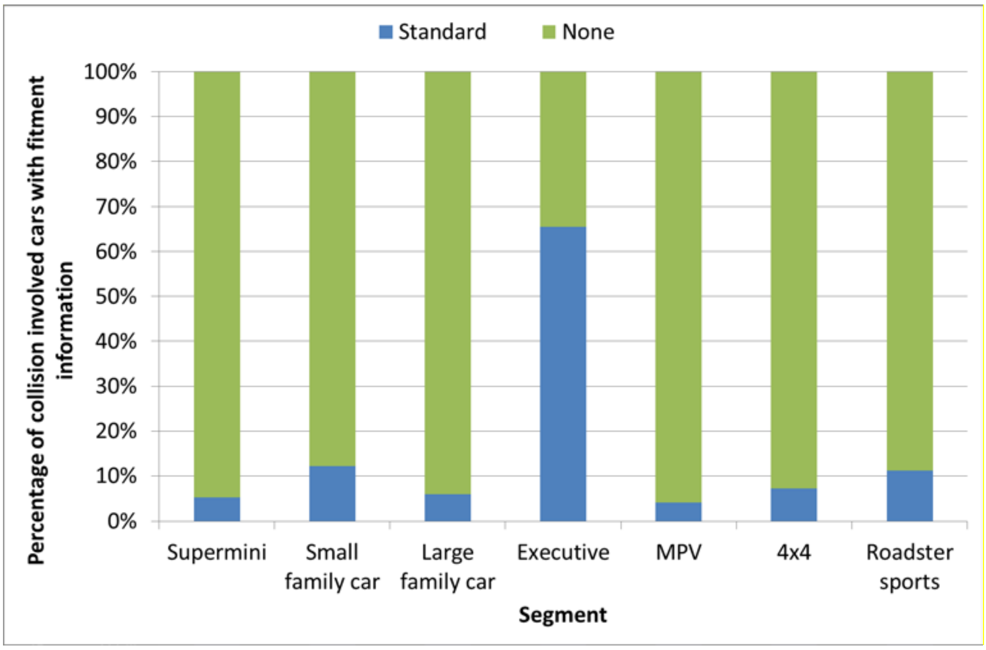

Figure G.3: Percentage of collision involved cars in London with a seat belt reminder fitted by segment

Seat belt reminders were most common in collision involved executive cars; two-thirds of these vehicles had seat belt reminders fitted.

Table G.2 shows the differences between cars in collisions fitted with seatbelt reminders and those that do not.

Table G.2: Seat belt reminder comparisons

	Seat belt reminder as standard	No seat belt reminder fitted
Average vehicle age	3	8
Average driver age[30]	40	38
Percentage of drivers who are male[31]	69%	62%
Percentage of drivers of who were KSI	1.0%	1.7%

Recording of seat belt use is poorly filled in within STATS19 and as a result it is impossible to assess accurately whether a seat belt reminder is influencing the number of people wearing a seat belt from this data. However, we know seatbelts reduce the chance of being killed or seriously injured. The percentage of drivers who were KSI was higher for vehicles without a seat belt reminder fitted (1.7% compared with 1.0% for vehicles with a reminder fitted, see Table G.2). This might suggest that they are having some impact on KSI numbers although it may also be due to the differences in vehicle and driver age and sex.

As with side airbags it has not been possible to model the effectiveness of seat belt reminders in isolated; however the overall effectiveness of secondary safety features are presented in Section 5.4.

Appendix H Fitment rates

Predicting the future penetration of safety technologies is both difficult and subject to errors of unknown magnitude. Fundamentally, predicting the future where there are many complex factors that can influence the fitment rate of systems to vehicles means that any estimate should be suitably caveated.

As background, it is important to identify and understand the main factors that affect the fitment rate, and therefore fleet penetration, of vehicle technologies. These include a range of factors, many of which are interrelated; for example:

- Mandatory regulatory requirements
- The perceived benefit of the system and its reward in consumer testing schemes such as Euro NCAP
- Strategy of the car manufacturer to the fitment of safety systems as standard and the cost of integrating the system into a new model version
- Low additional technical complexity/feasibility required above existing hardware already fitted to the vehicle.

To assist with the formulation of estimates for future system fitment, the proliferation of previous safety systems, collated in the fitment database, was considered. These data were split by car segment type and weighted according to the vehicle mileage data for London in the database. For technologies, such as side airbags and ESC, which have been promoted by Euro NCAP but not mandated (at least until fairly recently in the case of ESC) the analysis revealed that take-up in certain segments can lag years behind the initial take-up of the technology. As an example the increase in new cars fitted with ESC by segment is shown in Figure H.1. In the figure the fitment shown is to be interpreted as the percentage of *newly registered* cars, weighted by vehicle mileage in London, with ESC. Where fitted as standard, this is shown by the solid lines, whereas the dotted lines indicate the fitment including vehicles where ESC may have been fitted as an option. It can be seen that the take-up of ESC within the supermini segment lags approximately 9 years behind the take-up of ESC within the executive segment and that it wasn't until 15 years after the introduction of technology into the fleet that its fitment on the vast majority of new cars was standard.

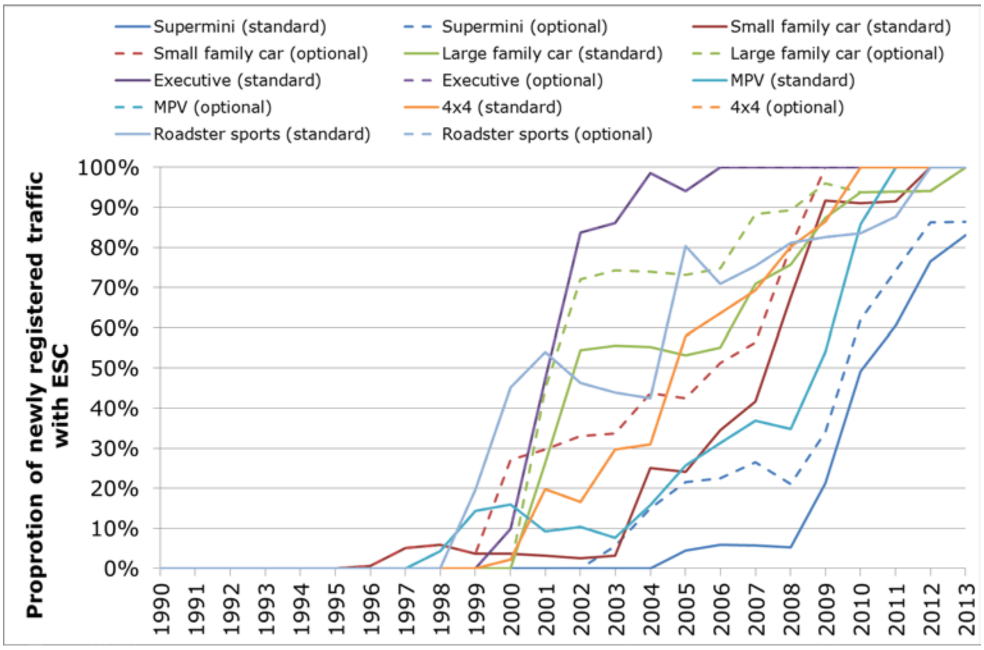

Figure H.1: Estimated proliferation of ESC for new cars in London

These trends in the data for established technologies, which have been tested under Euro NCAP and subsequently legislated, were used to inform the expected increase in the proliferation of the new technologies under scenario 2 in Section 6. An example of the modelled increase in the fitment of pedestrian AEBS is shown in Figure H.2 where it is expected that, despite proposed NCAP testing in 2016, most of the car fleet will not have such systems fitted until well into the 2020s.

It should be noted that the proliferation of alcohol interlocks in scenario 2 is modelled different to this since it is assumed to be required for drink drive offenders only.

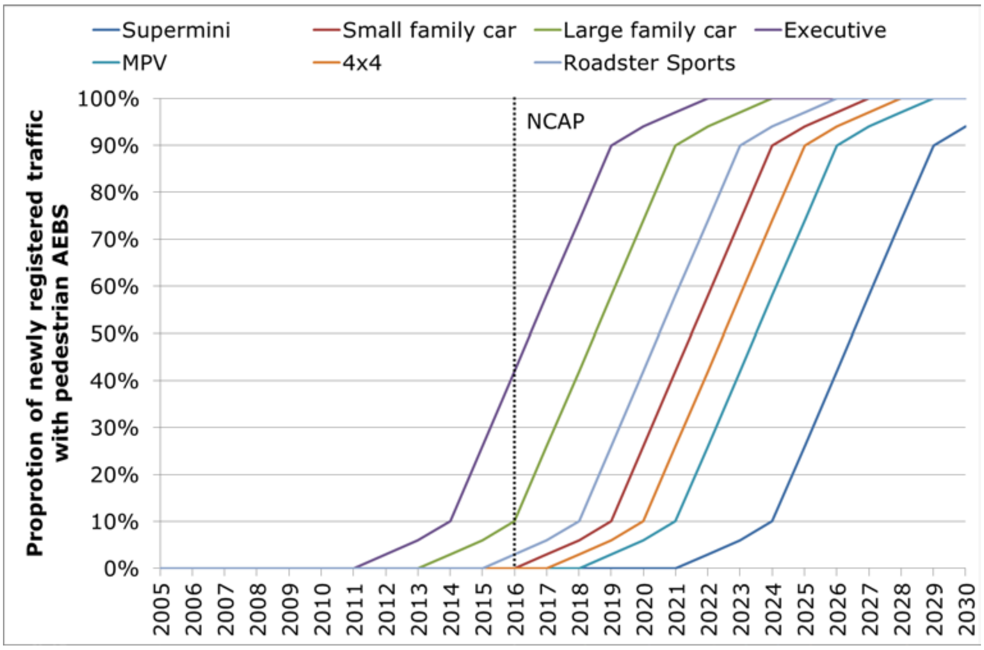

Figure H.2: Modelled take-up of pedestrian AEBS for new cars

In scenario 3 these trends need to be adjusted to react to the modelled introduction of legislation mandating the use of such systems. Again it is possible to get an idea of how the market reacts to such a situation by looking at the data relating to a system, such as brake assist, for which legislation has already been introduced. The estimated take-up of brake assist within the London car fleet is shown in Figure H.3. In this case there is a fairly linear increase in the percentage of newly registered traffic with the technology between 2008 and 2013.

This trend is applied to the take-up of the selected technologies in Table 6.1. In this scenario the increasing prevalence of the technologies initially follows an existing trend, supplemented by some promotion within NCAP, until legislation concerned the mandating of the technology is announced. From this point onwards the percentage of the fleet with such a system fitted as standard is assumed to increase linearly to meet 100% fitment for new cars by the year specified in the legislation[32]. An example of this, for pedestrian AEBS in scenario 3, is shown in Figure H.4.

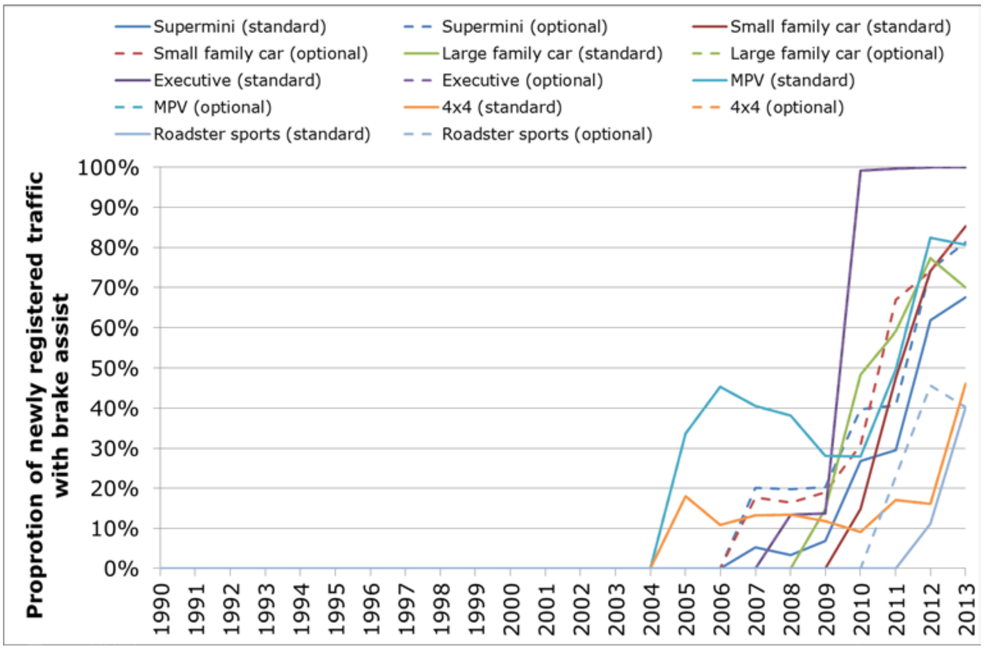

Figure H.3: Estimated proliferation of brake assist for new cars in London

[32] Except in cases where the existing trend would result in 100% fitment prior to the date specified in the legislation, in which case the existing trend is assumed to be unaffected by the legislation.

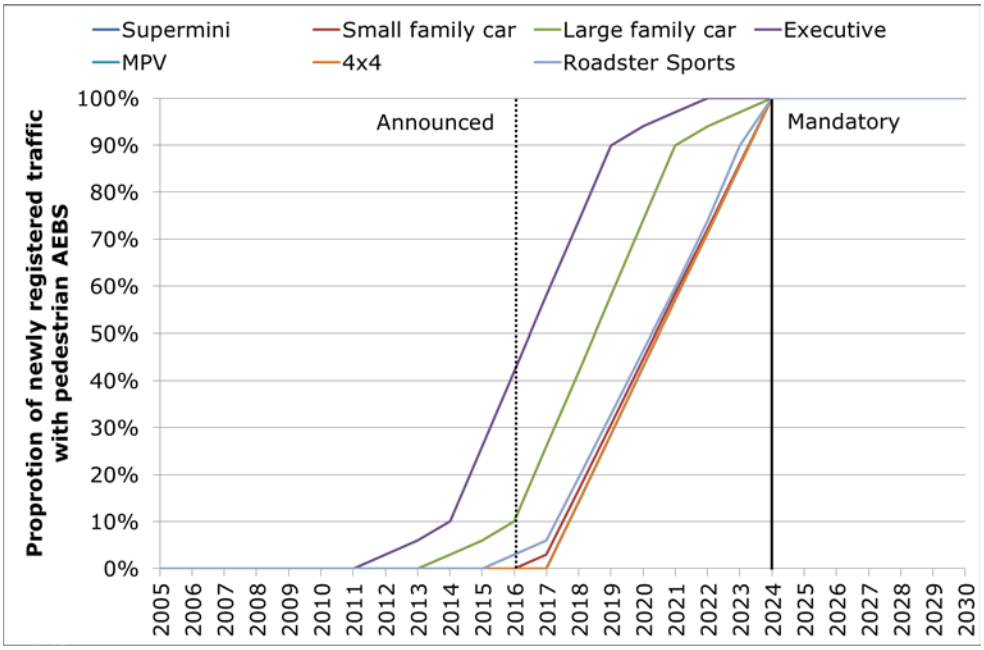

Figure H.4: Modelled take-up of pedestrian AEBS for new cars

For some systems, particularly the active systems, actual fleet fitment rates may be lower than predicted above since a large proportion of systems are offered as optional extras and therefore the fleet penetration depends on the uptake of the system by the consumer, something for which limited data exist.