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The potential for vehicle safety standards to prevent road deaths and injuries in Brazil

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Abstract

Vehicles in emerging markets are not typically regulated to the same extent as in industrialised regions. Casualty rates are considerably higher in these emerging markets, and the lack of vehicle safety regulation is responsible for at least some of the difference. It is estimated that **10,200 car occupants died in accidents on Brazilian roads in 2010**; car user casualties are the focus of this study. With rapid growth in passenger cars forecast in Brazil, the number of road deaths and casualties is expected to rise, unless targeted and efficient interventions, including improvements to the vehicle safety standards for new cars, are urgently initiated.

Brazil has started to introduce vehicle safety legislation and the Latin New Car Assessment Programme (Latin NCAP) is raising awareness about the importance of car safety and creating consumer based competition to motivate improvements. However, to ensure the democratisation of international vehicle safety standards to help create an automotive market in Brazil that provides adequate levels of safety, **further development of the minimum regulatory standards is required**. The priorities for Brazil include the need to introduce a **side impact crashworthiness test and to mandate for Electronic Stability Control (ESC)** to be fitted to every new passenger car. These are internationally proven to be cost effective countermeasures that save lives and there are established and harmonised UN Regulations available to apply now.

A series of statistical models have been used to predict how many car user deaths and injuries would be prevented in Brazil, if the experiences and lessons learned over the past 20 years in the Europe Union (EU), specifically establishing minimum car secondary safety regulations and consumer testing, were efficiently applied. In effect, the UN Regulations No. 14, 16 (seat belts and anchorages), 94 (occupant protection in frontal collision) and 95 (occupant protection in side or lateral collisions) have been modelled. Based on conservative assumptions, the study concludes that **over 34,000 fatalities and up to 350,000 seriously injured casualties could be prevented between 2015 and 2030**.

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1 Introduction

1.1 Global road safety

Road traffic injuries are a leading cause of preventable death and injury. Road casualties represent a significant development issue, because they disproportionally affect low- and middle- income countries, which according to the World Health Organisation (WHO, 2015) are estimated to cause economic losses of up to 5% of GDP.

In 2013, over 1.25 million people died on the world's roads, with up to 50 million more people sustaining serious injuries and living with long-term adverse health consequences. Globally, road traffic injuries are estimated to be the ninth leading cause of death across all age groups in 2015, and are predicted to become the seventh leading cause of death by 2030 (WHO, 2015). The rise in casualties is predicted because of rapid economic growth, with associated increased urbanization and motorization, particularly in emerging economies. Road crashes are a leading cause of death among young people, and **the main cause of death among those aged 15–29 years**.

In 2010, as a response to the growing road injury epidemic, the UN General Assembly adopted Resolution 64/255 to establish the Decade of Action for Road Safety (2011–2020). The stated aim is to "***stabilize and reduce predicted levels of road traffic fatalities around the world***". The Global Plan of Action provides the roadmap towards this goal, promoting proven, cost-effective solutions for making roads safer, including those pertaining to the following categories or "pillars":

1) road safety management;
2) safer roads and mobility;
3) safer vehicles;
4) making road users safer; and
5) improved post-crash response and hospital care.

The Global Plan of Action also provides a framework for coordinating action at an international level.

Adding urgency to the need to implement the Decade's Global Plan is the recent adoption by UN Member States of the Global Goals for Sustainable Development. **These include a target to halve road traffic deaths and injuries by 2020** (UN, 2015). This is the UN's strongest ever commitment to road injury prevention.

1.2 Global vehicle safety

Road vehicles in most of the world's emerging markets are not currently regulated to the same extent as industrialised regions. The WHO 2015 Status report reveals that only 40 countries worldwide apply the most important vehicle safety standards. The combination of growing fleet sizes, made-up of vehicles that do not have to meet basic safety standards, contributes to today's casualty rates, which are considerably higher in emerging markets compared to Europe and other industrialised regions. The lack of effective vehicle safety regulation is responsible for at least some of the difference. With rapid growth in passenger cars expected to continue, the number of road deaths and casualties in emerging markets is likely to rise, unless targeted and efficient interventions are planned and initiated urgently.

In the automotive sector, minimum safety regulations and standards have evolved in the European Union (EU), Japan, the US, and other world regions over the last 50 years. There are differences with regard to the nature of tests and criteria which must be met, but the current regulations that apply in the industrialised regions share the objective to provide the highest level of cost-effective safety performance. It is recognised that there are specific differences between the EU and US Regulations, if compared line by line, but it is the outcome mandated by these regulations in real-world car accidents that is important.

In 1996, European Union Directives 96/79/EC and 96/27/EC, which set the minimum statutory standards for the frontal and side impact safety performance of cars, were adopted. These Directives meant that, from 1998 onwards all new car models, and from October 2003 all new cars sold in the European Single Market had to meet these standards. These EU requirements were also then adopted by the World Forum for Harmonisation of Vehicle Regulations, UNECE Working Party 29, as Regulations 94 and 95; and thus became available for adoption internationally by countries that applied the Forum's 1958 Agreement.

Therefore, for practical reasons and to align with the UN Decade for Action for Road Safety, UN Regulations and Global Technical Regulations (GTRs) are referenced as our assumed baseline for minimum mandatory Standards. The UN Decade of Action for Road Safety encourages all countries to apply and promulgate motor vehicle safety regulations as developed by the UN's World Forum for the Harmonization of Vehicle Regulations (WP29). This paper identifies six car regulations, which are defined as a minimum for today's world markets:

- Approved seat belts and anchorages for all seating positions (UN Regulations 14 and 16).
- Occupant protection in frontal collision (UN Regulation 94)
- Occupant protection in side or lateral collisions (UN Regulation 95)
- Pedestrian protection (GTR 9)
- Electronic Stability Control (ESC) (GTR 8)

Vehicle engineering safety standards in the world's emerged markets have progressed considerably over the past few decades, primarily due to the introduction of mandatory front and side impact tests and Electronic Stability Control (ESC) regulations. However, the overall level of car safety cannot be solely attributed to the stringent regulatory provisions. Cars are typically designed and manufactured to exceed the minimum regulatory thresholds, partly driven by the more demanding Euro NCAP consumer testing criteria.

The UN Decade of Action also has a stated activity to: 'Encourage implementation of new car assessment programmes in all regions of the world in order to increase the availability of consumer information about the safety performance of motor vehicles'. The European New Car Assessment Programme (Euro NCAP) was launched at TRL in 1997 to provide an independent assessment of the safety performance of popular cars sold in Europe; the aim was to encourage, on the one hand, consumer awareness of the safety performance of the cars they buy and on the other, to motivate manufacturers to exceed the minimum requirements set out by legislation.

Over time Euro NCAP has become more sophisticated, and as well as maintaining its original methodology, which provides a star rating (between one and five stars) based on the car's performance in a number of secondary safety crash tests, including adult and child occupant and pedestrian protection assessments, it also assesses the primary safety or crash avoidance and mitigation credentials of the vehicle.

There is much more that must be done to improve car safety in the world's industrialised regions for all road users, especially pedestrians and cyclists, and this should be harmonised through evolving relevant and cost effective regulations based on robust evidence. The rapid development of Advanced Driver Assistance Systems (ADAS) and vehicle autonomous technologies offer realistic opportunities to prevent many future collisions. Equally, the importance of public vehicle safety awareness campaigns and the competitive pressures and incentives created by consumer testing programmes is a vital part of the continual development.

The challenge is to ensure that the progress made in industrialised regions is quickly and cost effectively applied in emerging markets, so that vehicle safety is a right for all, regardless of wealth.

1.3 Vehicle safety standards in Brazil

1.3.1 Overview

In 2014, new regulations came into force that require manufacturers selling cars in Brazil to fit airbags and anti-lock brakes (ABS), and which include requirements for manufacturers to meet a frontal impact crashworthiness test (either based on UN R94 or FMVSS 208).

1.3.2 Frontal impact test

The Brazilian National Traffic Council (CONTRAN) released Resolution 221, which defines the maximum permit-able biomechanical criteria for driver and passenger dummies (Hybrid III) in the event of a vehicle frontal impact. These maximum allowable biomechanical injury criteria apply for new vehicles in production from January 2014.

CONTRAN's Resolution 221 defines that the tests have to be done according to ABNT NBR 15300-1 standard, followed by:

- ABNT NBR 15300-2 standard; or
- ABNT NBR 15300-3 standard.

The vehicle manufacturers have the freedom to choose whether to use ABNT NBR 15300-2 or ABNT NBR 15300-3 standards:

- The ABNT NBR 15300-1 and 15300-2 test is similar to the US FMVSS 208 standard. It is a frontal impact test at 56 kph, with a perpendicular full width rigid barrier; the 'male' Hybrid III driver and passenger dummies are seat belted.
- The ABNT NBR 15300-1 + 15300-3 follows the UN R94 and 96/79/EC standards. It is a frontal impact test at 56 kph, with a perpendicular 40% Offset Deformable

Barrier (ODB); the 'male' Hybrid III driver and front passenger dummies are seat belted.

Although the tests are at the same severity (56 kph), the barriers impacted are different. In the ABNT NBR 15300-2 test, the full width of the car's front structure is loaded by a rigid barrier, which is a more stringent test with respect to occupant protection, because of the higher vehicle deceleration compared to ABNT NBR 15300-3. In the ABNT NBR 15300-3 test, 40% of the width of the car's front structure is loaded and the ODB absorbs some of the impact energy. The OBD test configuration is designed to prevent deformation and intrusion into the occupant space and provides a 'softer' deceleration pulse for the restraint systems (seat belts and airbags) compared to ABNT NBR 15300-2.

The ABNT NBR 15300-2 and the ABNT NBR 15300-3 standards and their differences concerning occupant protection are outlined by da Cunha, V *et al*. (2011). It is not known which test (ABNT NBR 15300-2 or ABNT NBR 15300-3) is the most representative and applicable for the population of car crashes in Brazil. Specifically, the question is, are real world frontal car collisions in Brazil that result in serious and/or fatal occupant injury, more likely to involve full or partial overlap of the vehicle? There are also concerns about how manufacturers will demonstrate how they have met the required standards.

1.3.3 Recommended next steps: Side impact and ESC

In summary, Brazil has successfully started the legislative process and is now applying some standards that are similar to the EU or the US, but there is still a significant gap between the regulated vehicle safety standards in the industrialised regions and Brazil. The most significant shortfalls concern the lack of a side impact test requirement, ESC is not mandated and there are no requirements for pedestrian protection.

Side impacts are one of the most common collision types which result in car user fatalities and serious injuries. UN Regulation No. 95 on lateral collision protection defines a test procedure and performance requirements for a simulated impact of another car into the side of the tested vehicle at 50 km/h. The test procedure is well understood by the automotive industry and the engineering knowledge and technology is very mature and cost effective to apply. We strongly recommend that Brazil urgently adopts and applies UN Regulation 95. Further, the UN Regulations for full-width frontal impacts and pole side impact tests are currently being drafted and these should also be adopted by Brazil as soon as practicable.

Electronic Stability Control (ESC) helps keep the vehicle on course in critical situations such as swerving to avoid an obstacle. It detects understeer or over-steer and counters it by applying the brakes to individual wheels. ESC reduces loss-of-control accidents, such as run-off-road collisions and rollovers, and is known as one of the most effective primary safety systems (Hoye, The Effects of Electronic Stability Control (ESC) on Crashes – An Update 2011). It was first introduced on the market in 1995 and became mandatory in the EU in 2011 for new models and in 2014 for all cars. Many lives could be saved in Brazil through mandating the fitment of ESC and this should be prioritised.

Another noteworthy example of crash prevention technology is Autonomous Emergency Braking Systems (AEBS), which use camera systems to detect imminent collisions and brake the vehicle without driver input. These are believed to have a high potential to avoid or mitigate read-end collisions with other vehicles and collisions with vulnerable road users (McCarthy et al. (2012). Fitment of AEBS is not currently mandatory for cars in the EU, but is incentivised by NCAPs in some regions which can be expected to accelerate uptake in the market and contribute to reducing road casualties.

Pedestrian protection is outside the scope of this study, which is focussed on car user safety. However, vulnerable road user (VRU) impact-friendly vehicle design is a very important subject and an established UN GTR (9) is in place. Future work should look to prioritise countermeasures for all road users in Brazil.

Brazil[1] has not yet become a contracting party to either the 1958 or 1998 Agreements of the UN World Forum for Harmonisation of Vehicle Regulations. In practical legislative terms it would be more efficient for Brazil if they become a contracting party and equally importantly it would give Brazil a voice to help shape the future of vehicle safety legislation.

1.4 Aim and research questions

1.4.1 Overall research aim:

This paper highlights the combined safety benefits that are realised through the establishment of minimum mandatory car standards enforced through regulation, in conjunction with consumer programmes, which seek to set more challenging vehicle safety design safety targets. The Global New Car Assessment Programme (Global NCAP) was established in 2011 as an international platform for cooperation among NCAPs and to support new programmes in a number of emerging markets. Latin NCAP began testing in 2010 and this paper focusses on Brazil which is the region's largest market and producer of motor vehicles.

Specifically, **the aim of this paper is to quantify how many car user fatalities are likely to be prevented in Brazil between 2015 and 2030, as a combined result of adopting the basic secondary safety measures**, namely seat belt standards and UN Regulations 94 and 95 and the impact that Latin NCAP will provide on further real world vehicle improvements.

Individual research questions:

1. What have the effects of vehicle safety improvements been in Britain since 1990?
2. What are the likely effects of similar safety improvements in cars in Brazil?

1.5 Method overview

Given the overall trends observed in Great Britain over the past three decades, it is possible to make an estimate of the likely impact that a similar general suite of vehicle safety improvements might have in emerging markets.

Three stages of analysis are used to achieve this:

- Quantification of the historical impact of secondary vehicle safety on fatality numbers in Britain

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[1] DENATRAN (http://www.denatran.gov.br/) have recently attended the UN's Working Party 29 as an observer and it is hoped they will become a contracting party to either the 1958 or 1998 agreement.

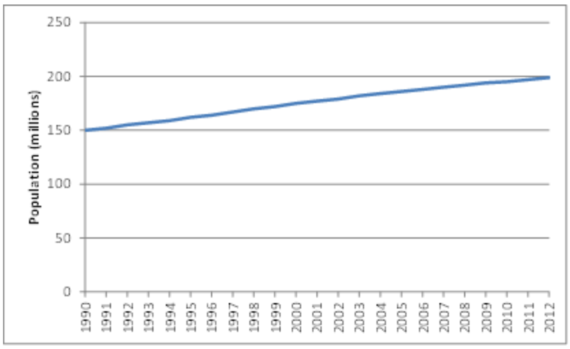
- Comparison of vehicle fleet age and size, vehicle safety standards and casualty numbers in Brazil and Britain
- Transfer of the safety impact observed in Britain to Brazil based on the current characteristics of the fleet.

More details of these methods are shown in Appendix A.

2 Road safety facts in Brazil

Section 2.1 presents a brief overview of some of the key facts from Brazil based on information from WHO (2013, 2009, 2004)[2] to provide some context. Section 2.2, 2.3 and 2.4 present more detailed data on casualties and the fleet, as well as a comparison between NCAP test results from Brazil and Britain.

2.1 Country facts

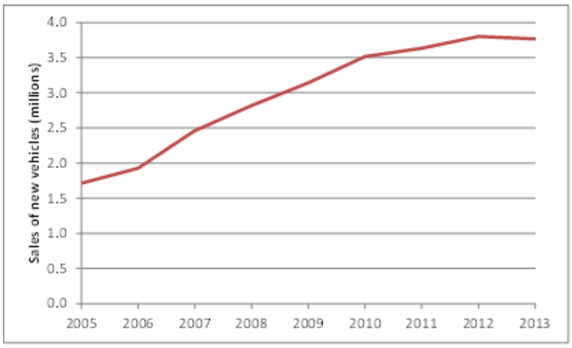


Population

Population (2010): *194,946,488*

Median age (2012): *29.9 years*

Annual GNI per person (2010): *9540 USD*



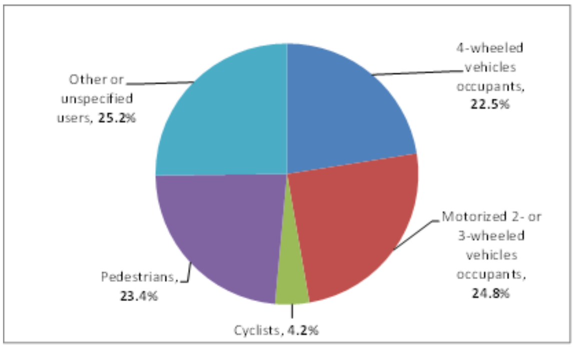
Vehicles[3]

Registered vehicles (2012): *76,137,191*

Registered cars (2012): *42,682,111*

Motorisation rate (2012): *187 cars per 1000 population*

Growth in registered vehicles since 2007 (2010): *31%*



Road deaths

Estimated number of road traffic deaths (2010): *43,869*

Proportion of deaths that were male (2009): *82%*

Estimated death rate per 100,000 population (2010): *22.5 (18.3 in 2007)*

Percentage of road deaths under the age of 15 (2002)[2]: *22%*

Road safety

There is a national seat belt law which applies to both front and rear occupants. Usage rates were 88% front seat and 11% rear seat in 2007. As of 2010, new cars have been assessed by Latin NCAP.

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[2] WHO (2004, 2009, 2013). Global status report on road safety. http://www.who.int/violence_injury_prevention/road_safety_status/report/en/

[3] OICA. Sales of new vehicles. http://www.oica.net/

2.2 Casualty data

In Brazil, the casualty data is sparse; however the number of fatalities per year, as shown in **Figure 1**, is known to be high and increasing. The numbers have risen from around 33,000 in 1995 to around 44,000 in 2010; an increase of 33%. In addition, the fatality rate per population has also increased since 2000, although this is likely to be due to increasing motorisation amongst the population.

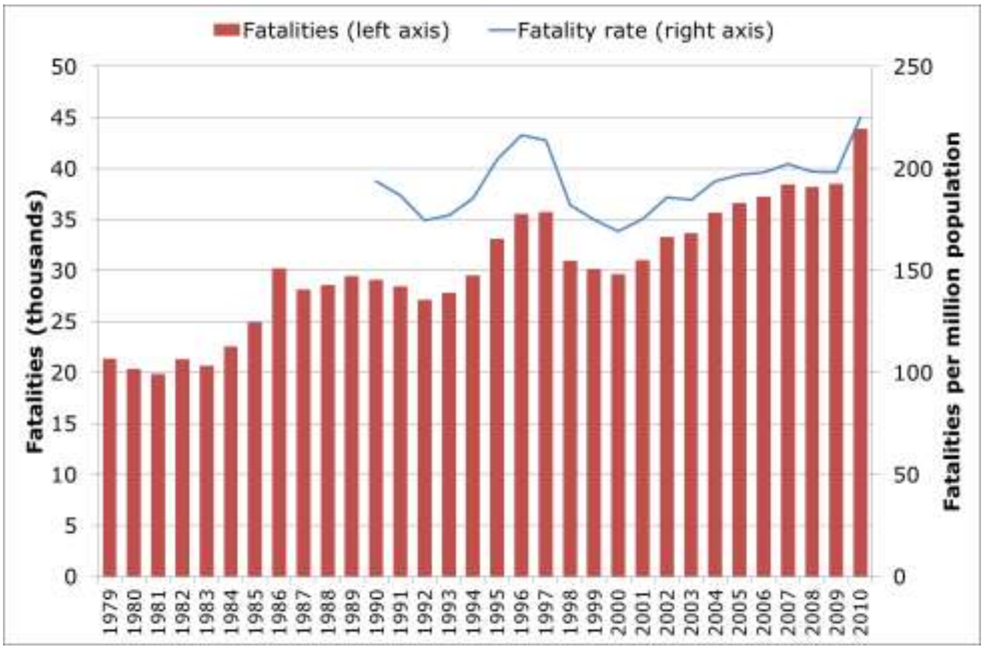

Figure 1: Number of fatalities and fatality rate per population from 1979 to 2010[4]

This growth in motorisation, particularly in cars is hinted at in **Figure 2** which shows a large increase in the proportion of the fatalities that were car and light van occupants from 10% in 2006 to 22% in 2009.

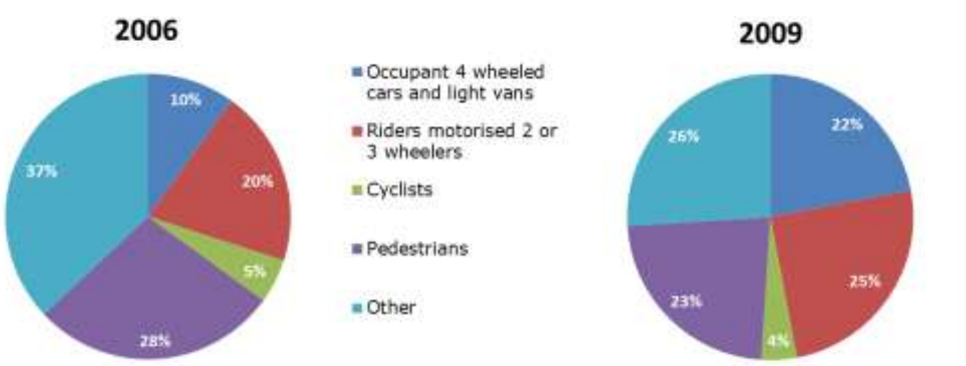

Figure 2: Road accident fatalities by road user group (2006 & 2009)[2]

[4] WHO (2014). Number of road traffic deaths. http://apps.who.int/healthinfo/statistics/mortality/whodpms/tables/tblB.php

2.3 Car fleet

The number of vehicles and the number of cars registered has grown substantially since 1998, and now makes up about 55% of the vehicle fleet. However, the proportion of the fleet that is made up of cars has reduced over time, with **Figure 3** showing that motorcycle growth is contributing to this reduction.

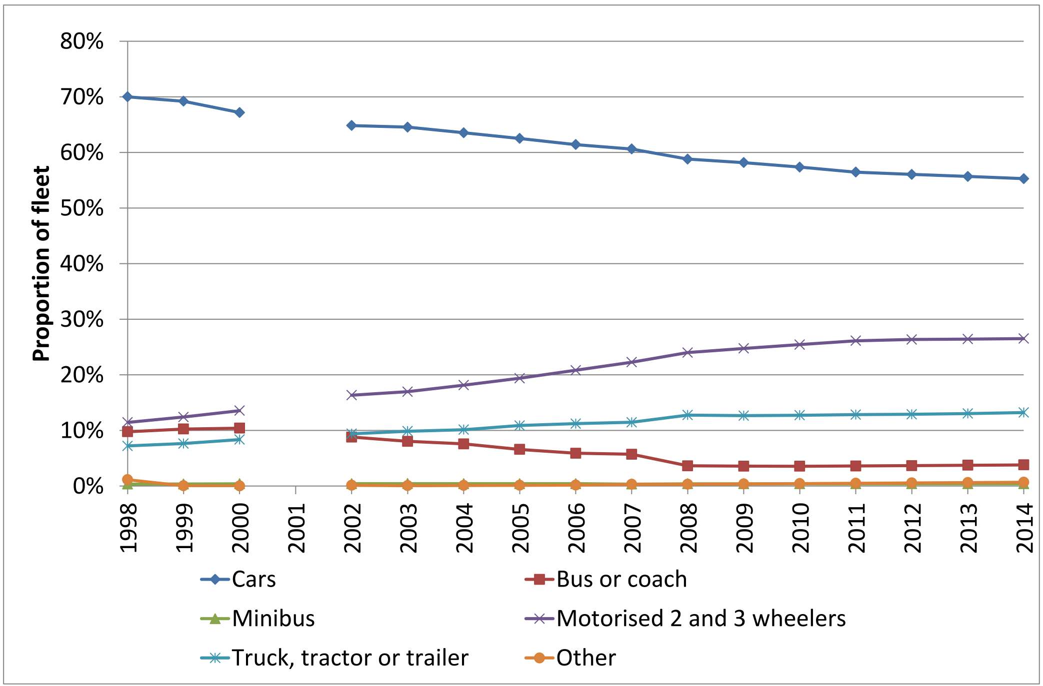

Figure 3: Distribution of registered vehicles by vehicle type (1998-2014) [5]

Age of the fleet is also reported by Brazilian government's Departamento Nacional de Trânsito (DENATRAN[5]) and the distribution very clearly shows that the majority of the vehicle fleet is aged 10 or more years. The trends are not sufficiently consistent to report any obvious general trends in ages. However, from this data source, it was possible to estimate that 34% of the car fleet is 6 years or younger in 2014.

[5] DENATRAN website (http://www.denatran.gov.br/). Data for 2001 were not available

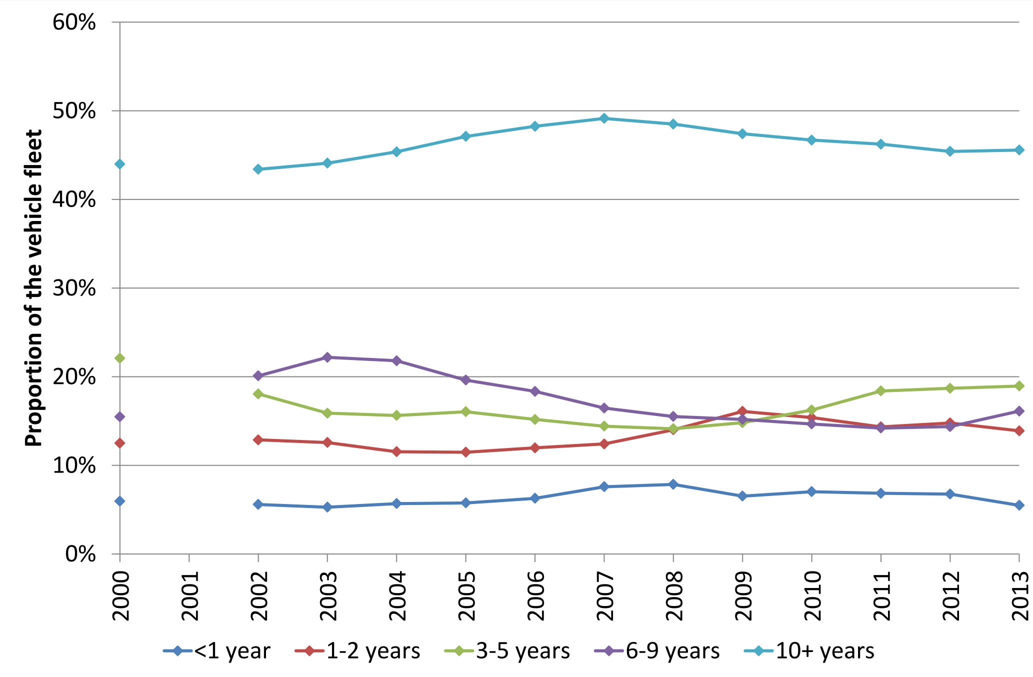

Figure 4: Distribution of registered vehicles by vehicle age (2000-2013)[5]

The top 20 registered cars in Brazil are shown in **Table 1** and incorporate 65% of the car fleet. Clearly the VW Gol is a very popular car and this has been a top selling car for many years. Fiats, Fords and GM models also contribute significantly to the top 20 registered car fleet.

Table 1: Top 20 cars registered in 2014

Car	Proportion of the car fleet	Car	Proportion of the car fleet
VW Gol	12.4%	GM Chevette	2.0%
Fiat Uno	8.0%	GM Monza	1.8%
Fiat Palio	7.2%	VW Saveiro	1.7%
GM Corsa	4.3%	Ford I	1.6%
VW Fusca	4.0%	Ford Escort	1.6%
Ford Fiesta	3.5%	VW Voyage	1.6%
GM Celta	2.6%	Fiat Siena	1.6%
VW Fox	2.2%	VW Parati	1.6%
Fiat Strada	2.2%	Ford KA	1.4%
VW Kombi	2.0%	Toyota Corolla	1.2%

2.4 Vehicle safety in the fleet

Using the methodology described in Appendix A.2, a total of 30 NCAP car tests were observed and scored using nine structural deformation categories. The distribution of the structural deformation score is shown in **Table 2**. This shows a mixture of scores across the different NCAP regions and years. However, broadly, the Latin cars appear to be performing somewhere between the Euro 1999 and Euro 2004 cars.

Table 2: Structural deformation by NCAP test group

Structural deformation	1	2	3	4	6	7	9
Latin				1	3	1	2
Euro 1999			1			2	2
Euro 2004	3	2	2		1	1	
Euro 2013	8	1					

Good performing cars in Latin NCAP (scoring 1, 2, 4 or 6 in the structural deformation) are similar to the better cars tested in Euro NCAP from 2003-2005.

Medium performing cars in Latin NCAP (scoring 3 or 7) appear to have the right safety features and structures, but when the test videos were observed, the vehicles and their restraint systems did not perform in an optimum way to ensure occupant protection.

Due to the limited data available, it is not possible to measure the representativeness of the Latin NCAP tested cars with regard to all new car sales in Brazil. Therefore, in Section 4.4 an assumption is made to correlate the safety performance of new cars sold in Brazil today, with new cars sold in Europe between 1999 and 2004.

3 Estimating the impact of secondary safety in Britain

3.1 Introduction

The following section examines how car secondary safety for drivers has improved in Great Britain in recent decades. Statistical modelling, as described in Section A.1, has been used to predict the number of casualties which would have occurred if secondary safety had not improved.

The proportion of car driver casualties killed in Britain decreased from 1989 to 2013. Newer cars have secondary safety features which improve the protection offered to occupants of the vehicle in a collision and this is likely to have contributed to the reduction in fatalities. The improvements due to secondary safety features as opposed to changes in the conditions in which vehicles are driven are quantified in this section. For example, improvements to the road system or changes in the weather, or the way in which vehicles are driven are all likely to have influenced the casualty trend. Statistical modelling is required to disaggregate these effects.

3.2 Results

In total, 2,802,648 car driver casualties were injured in accidents recorded in STATS19 between 1989 and 2013; around 1% of these were fatally injured. Excluding driver casualties on the basis of missing information for the key variables leaves 83% of the total number of driver casualties for use in the modelling. It will be assumed that excluding those vehicles where the data is unknown does not bias the results of the model; however the casualty estimates presented will be an underestimate of the actual number of lives saved.

For car driver casualties, two models are used: one for built-up roads (≤40mph) and one for non-built-up roads (>40mph). The number of car drivers killed split by road type is shown in **Table 3**.

Table 3: Car driver casualties killed by road type (1989-2013)

Road Type	Killed car drivers
BU road (≤40mph)	3,296
NBU road (>40mph)	18,140
Total	**21,436**

Figure 5 shows the model results for a specific subset: male 25-59 year old small family car driver casualties killed by registration year in 2013 on built up and non-built up roads. The trends for other subsets are similar. The blue dots show the result of the model when year of registration is included as a factor, and the red line shows the model results when a linear trend is assumed for the improvements to secondary safety. A break-point in the linear trend occurred in 1990-91 registered vehicles on both built-up and non-built-up roads.

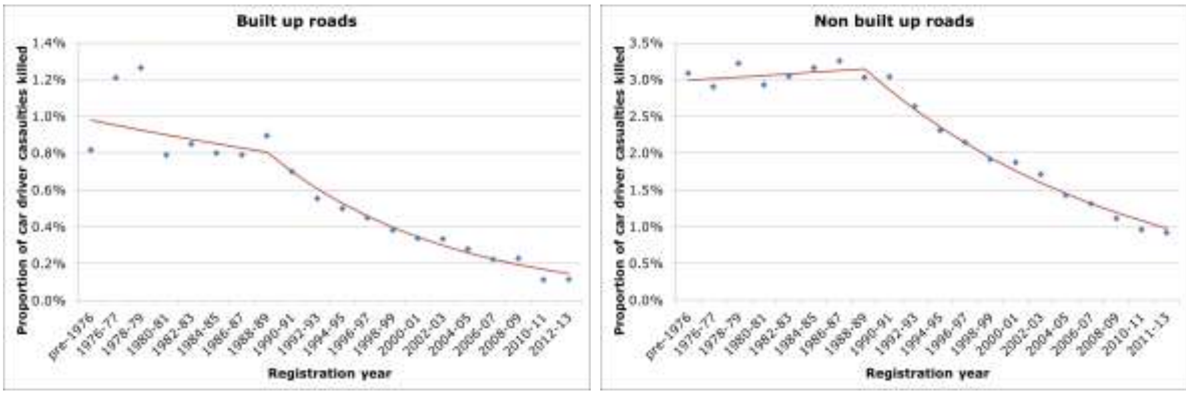

Figure 5: Modelled fatality proportion by registration year for car drivers (males 25-59, small family cars, 2013)

Figure 5 indicates that, for accidents on built-up and non-built-up roads, since 1990-91 improvements to secondary safety for car occupants have improved more rapidly than pre-1990. We propose that this is due to the impact of vehicle regulations due to be implemented that the manufacturers were already preparing for.

The models can also be used to examine how the secondary safety of vehicles registered in a given year change as accident year increases (**Table 4**).

Table 4: Modelled fatality proportion for car drivers in 1990-91 registered vehicles by accident year (BU roads, males 25-59, small family cars)

Accident Year	% of drivers killed
1990	0.28%
2000	0.33%
2010	0.47%

In 1990, the model indicates that 0.28% of casualties were killed in newly registered vehicles (i.e. those registered in 1990-91). By 2000 it is likely that some of the vehicles registered in 1990-91 will have been scrapped, but some still remain and the model indicates that the proportion of casualties killed had increased to 0.33% in these vehicles. By 2010, this proportion had increased again to 0.47%.

The structural design of vehicles registered in 1990-91 did not change during the period 1990 to 2010, however the increase in car drivers killed could have been due to changes to the vehicles in which the 1990-91 registered vehicles collide with; the car fleet is diverging in size with more larger and smaller vehicles. It is also likely that as vehicles get older it is possible that other secondary safety features such as airbags may have degraded, thus reducing the occupant protection offered by these vehicles.

One other possible explanation for this increase is a change to the level of underreporting in STATS19. If slight and/or serious casualties were being reported less over time, but the level of fatality reporting remained the same then the proportion of casualties killed would appear to increase. Assuming there is no bias in the underreporting by age of vehicle, changes to reporting rate over time should not influence the key results relating to registration year.

3.3 Estimated casualty benefits

The models described above can be used to estimate the number of lives that have been saved by improvements to the secondary safety of cars. 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 fatalities would have occurred in 2010.

These calculations assume that the total number of collisions remains unchanged, but that more drivers would have been killed because of the lower levels of secondary safety. The model is used to adjust the severity proportions of the modern cars to match with those registered in 2000-01. Casualties in 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. As a result, the casualty estimates presented in **Table 5** are an underestimate for the actual casualty benefit.

Table 5: Actual and estimated car driver fatality numbers between 2002 and 2020 if secondary safety had remained at level of 2000-01 registered vehicles

Actual (estimated) casualty numbers	Estimated casualty numbers if secondary safety had not improved	Reduction in casualties due to secondary safety improvements	Proportional saving
12,905	14,537	1,632	11.2%

Between 2002 and 2020, the estimated effectiveness of improvements in secondary safety since 2001 registered vehicles is 11% for car driver fatalities and the predicted cumulative saving is 1,632 fatalities.

4 Estimating the potential impact of vehicle safety developments in Brazil

Given the savings observed in Britain and the trends identified in Brazilian data, it is possible to estimate the potential casualty savings that could be achieved by introducing similar regulations to those seen in Britain, in the Brazilian market. The following section summarises the results of this prediction. The main method includes:

- Understanding the current fatality rate in Brazil
- Predicting the growth in passenger cars forward into the future
- Applying the fatality rate to the growth in passenger cars to estimate a baseline number of fatalities if developments in road safety do not change
- Applying the quantified changes in fatalities observed in Britain due to secondary safety to these baseline scenarios, taking into account the current vehicle safety standards in the fleet and the current turnover of vehicles.

A more detailed method is included in Appendix A.3.

4.1 The current fatality rate

Figure 1 identifies the number of road fatalities in Brazil from 1979 to 2010. This could be combined with information from **Figure 2** which provides the distribution of these fatalities by road user type for 2006 and 2009. However, these figures are uncertain as they contain a large proportion of unknown road users and the proportion for car occupants changes dramatically from 2006 to 2009. If these numbers were interpolated forward it would predict a large and unsustainable increase in the proportion of deaths that were car occupants. Instead, the proportion of car occupants within deaths in 2009 was used and the gradient of change in another emerging market (Malaysia) was used to predict this trend forward.

Interpolating from these figures enables us to derive estimates of the number of car occupant fatalities from 2006 to 2010 as shown in **Table 6**.

Table 6: Calculation establishing the number of car occupants from 2006 to 2010 in Brazil (red figures indicate extrapolation from the Malaysian trend)

Year	Deaths	Proportion of car occupants in deaths	Car occupant deaths (estimated)
2006	37,238	20.6%	7,684
2007	38,404	21.2%	8,136
2008	38,127	21.8%	8,313
2009	38,452	22.5%	8,652
2010	43,894	23.2%	10,200

Figure 3 identifies the number of registered cars over the same period. From this the fatality rate for car occupants can be derived, as shown in **Table 7**, and interpolated backwards to include a longer trend-line.

Table 7: Car occupant death rate per 1,000 registered cars in Brazil (2006-2010)

Year	Reg cars (1,000s)	Car occupant deaths	Fatality rate per 1,000 vehicles
2006	27,869	7,684	0.276
2007	29,852	8,136	0.273
2008	32,055	8,313	0.259
2009	34,537	8,652	0.251
2010	37,188	10,200	0.274

Based on this fatality rate calculation, a linear trend is shown in **Figure 6**. This trend is used to predict the baseline casualty trend after 2010.

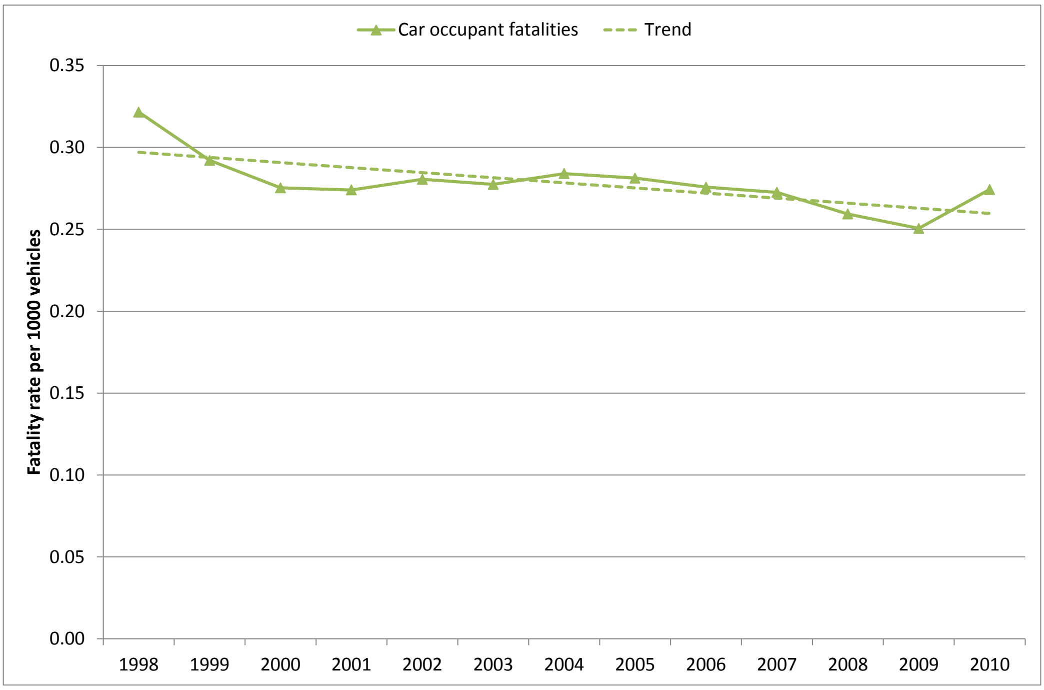

Figure 6: Car occupant fatality rate per 1,000 registered cars in Brazil (1998-2010)

4.2 Predicted growth in passenger cars

In order to predict casualty trends forwards, the growth in passenger cars is required. The possible baseline scenarios for car registration growth in Brazil from 2010 to 2030 have been devised as:

a) The trend in car registrations continues to grow linearly at the constant rate of an average annual rate of 5.4% relative to 2014

b) The trend in car registrations continues to grow linearly at an average annual rate of 0.7% relative to 2014. This is equivalent to the growth rate in Britain between 2004 and 2013.

c) The trend in car registrations continues to grow linearly at an average annual rate of 14.8% relative to 2014. This is equivalent to the highest annual average increase in car registrations in Britain, in the 1950s.

d) The trend in car registrations continues to grow linearly at an average annual rate of 5.4% as in scenario a) but also encompasses a gradual move from motorcycles to cars resulting in half of the number of motorcycles in the fleet in 2030. This is equivalent to an annual average increase of 7.0% per year.

Figure 7 shows the predicted number of registered cars under each of these scenarios.

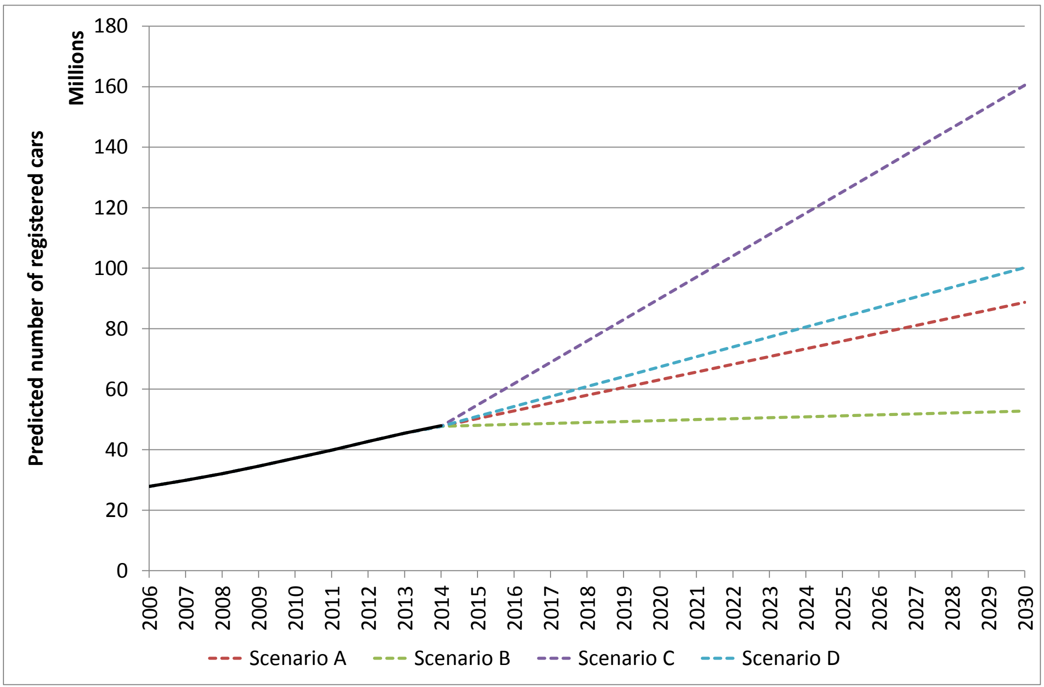

Figure 7: Predicted number of registered cars from 2013-2030 by scenario

Relative to the population (and assuming a constant linear growth), the associated motorisation rates by 2030 are shown in **Table 8**. The current motorisation rate in Brazil is 19% and in Britain is 45%. This shows that scenario C is highly unlikely and this scenario is not followed through in the following steps.

Table 8: Predicted motorisation rates in 2030 relative to predicted population

Scenario	Motorisation rate
A	36%
B	21%
C	64%
D	40%

4.3 Changes in casualties for each traffic growth scenario

Assuming that the relationship between car occupant fatalities and registered cars remains the same as shown in **Figure 7**, the derived numbers of car occupant fatalities that could be expected under the remaining three scenarios are shown in **Figure 8**. The associated annualised rates of change for the scenarios are shown in **Table 9**.

Table 9: Change in number of car occupant fatalities

Scenario	Average annual change	Predicted number 2030	Increase in 2030 compared to 2014
A	3.7%	17,527	48%
B	-0.3%	10,427	-12%
D	5.0%	19,800	68%

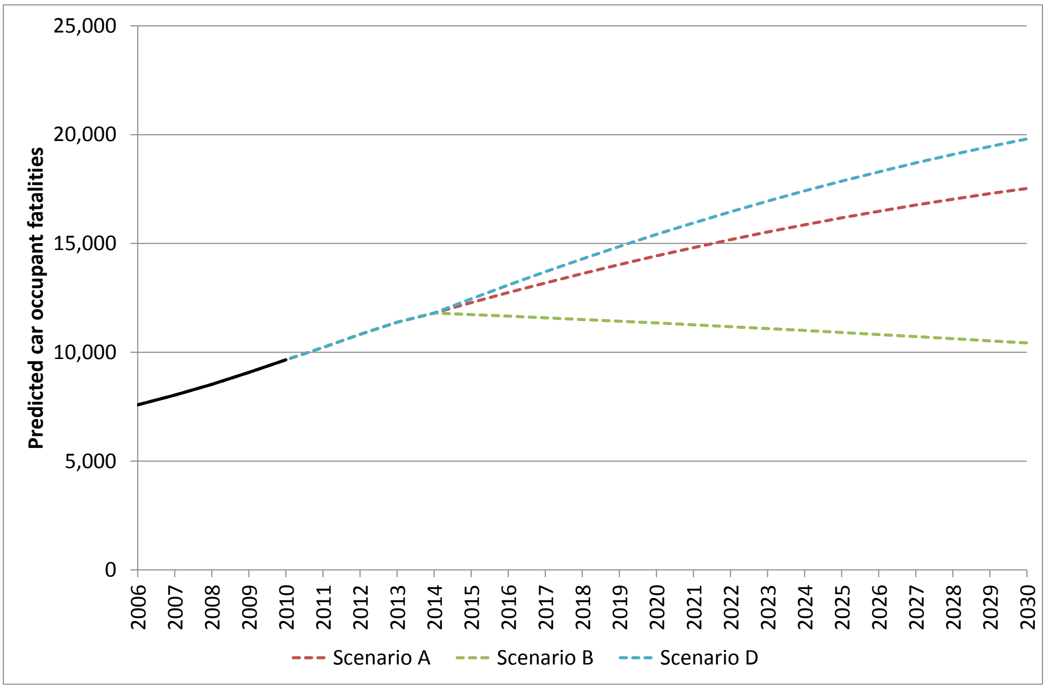

Figure 8: Predicted number of baseline car occupant fatalities in Brazil 2006-2030 based on three scenarios

4.4 Assessment of current Brazilian car fleet safety

Seven of the top 20 registered vehicles have been NCAP tested and their star rating and TRL structural crashworthiness has been included in **Table 10**.

Table 10: Estimated top 20 cars registered in 2014

Make model	Proportion of all cars	NCAP star	NCAP year	Structural crashworthiness
VW Gol	12.4%	3	2010	6
Fiat Uno	8.0%	1	2011	7
Fiat Palio	7.2%	0	2014	6
GM Corsa	4.3%	1	2011	9
Ford Fiesta	3.5%	4	2012	4
GM Celta	2.6%	1	2011	9
Toyota Corolla	1.2%	4	2010	6

When compared with British data, as discussed in Section 2.4, the cars in Latin NCAP appear to be distributed similarly across the crashworthiness scales for around the standards of vehicle safety observed in 2001 in Great Britain.

However, it should be borne in mind that although the Latin NCAP cars look similar to the Euro NCAP cars on the crashworthiness scale:

- Many of them are not subject to side impact test requirements.
- The safety feature and technology fitment may be different – especially side impact airbags and seat belt pretensioners and load limiters.

In addition, only seven of the top 20 cars registered in Brazil in 2014 have been tested by Latin NCAP. Therefore, it is not known what bias may be caused by the large proportion of vehicles whose frontal impact secondary safety performance is not known, for example have the better performing cars been more frequently selected for testing?

However, the only objective, albeit limited data available, is the Latin and Euro NCAP test results. Therefore, based on comparing the Latin and Euro NCAP car frontal impact crashworthiness performance, a **conservative assumption** is made that new car sales in Brazil in 2015, are approximately equivalent with respect to secondary safety, to new car that were sold in Europe in 2001. If the population of new vehicles sold in Brazil are not as safe as seen in Europe in 2001, this study will **underestimate the potential casualty savings.**

4.5 Fleet renewal

Figure 4 shows the distribution of the age of the car fleet in Brazil up to 2013. A large proportion of the fleet is 10 or more years old which implies that in this part of the fleet, the vehicles safety standards are (relatively) extremely low. One comparable measure with Brazil and Britain in 2001 is the proportion of the fleet that is 6 years or younger. In Brazil in 2013, this was 34% of the fleet and in Britain in 2001, 51% of the fleet was six years or younger. Based on these proportions, it is expected that the impact of introducing new safety measures into the car fleet will take longer in Brazil than observed in Britain due to the old cohort of cars. The estimates of the impact of secondary safety in Britain in 2001 (shown in **Table 5**) were a reduction of 11% over 19 years. It is proposed that this proportional saving is reduced by 60% to take account of the differences in turnover of the Brazilian and British fleets.

4.6 Predicted reductions in fatalities in Brazil

Based on the information gathered in the previous stages and two assumed scenarios for the uptake of regulations and vehicle safety developments in Brazil, the following estimates are made of the number of fatalities that could be saved in Brazil if similar regulations were introduced to those in Britain:

a) Over a similar timescale

b) Over a quicker timescale

Table 11: Potential savings in fatalities achieved between 2015 and 2030 due to secondary vehicle safety developments

Scenario	Number of fatalities predicted without vehicle safety developments	Similar timescale		Quicker timescale	
		Saving in fatalities	Proportion saving	Saving in fatalities	Proportion saving
A	254,716	18,573	7.3%	30,955	12.2%
B	189,626	12,502	6.6%	20,836	11.0%
D	275,577	20,519	7.4%	34,198	12.4%

5 Summary and Conclusions

5.1 The global vehicle safety challenge

Vehicle engineering safety standards in the EU (and other industrialised regions) have progressed considerably over the past few decades, primarily due to the introduction of mandatory crashworthiness impact tests and Electronic Stability Control (ESC) regulations. However, the overall level of car safety in the EU cannot be solely attributed to the stringent regulatory provisions. This is because cars are typically designed and manufactured to exceed the minimum regulatory thresholds, partly driven by the more demanding Euro NCAP consumer testing criteria.

There is much more that must be done to improve vehicle safety in the EU (and other industrialised regions) to reduce the number of road casualties. There is growing experience and knowledge with regard to developing cost effective and technically feasible solutions to address the real world casualty problems experienced on the EU's roads today, and more importantly the problems that will be faced in the future, especially as our population demographics (e.g. aging society) and mobility trends will change.

The vehicle engineering and associated technical legislative knowhow that has been developed to deliver the safety improvements observed in the industrialised regions in the past 20 years, must be applied to the emerging markets to ensure road safety is democratic. This is especially relevant, because unlike the casualty trends in the industrialised countries, the casualty trends in emerging markets such as Brazil continue to rise. This is due to increasing motorisation and consequently exposure to risk, and less developed vehicle safety standards.

5.2 Minimum car secondary safety requirements for Brazil

In 2010, it is estimated that **10,200 car occupants died** as a result of road accidents in Brazil, which is a higher death rate per population than has ever been observed in Great Britain. With the number of cars predicted to increase over the next 15 years by an annual average rate of between 0.7% and 7.0%, **this death toll is expected to rise considerably, unless road safety strategies and regulations can be effectively and urgently introduced**.

In this research, a series of statistical models have been used to estimate **the potential to reduce car user road deaths and serious injuries in Brazil**. The models are based on the assumptions that Brazil adopts car secondary safety regulations similar to those introduced in Europe in the late 1990s, and an effective consumer testing programme (Latin NCAP) continues to raise public awareness.

Specifically, the statistical models assume the following future **minimum car secondary safety regulation standards**:

- Approved seat belts and anchorages for all seating positions (UN Regulations 14 and 16).
- Occupant protection in frontal collision (UN Regulation 94)
- Occupant protection in side or lateral collisions (UN Regulation 95)

Comparing the performance of cars in Latin and Euro NCAP frontal impact tests, we concluded that broadly, today's Brazilian cars could be performing somewhere around the Euro 2001 level. This was based on an engineering visual assessment of the cars' structural behaviours during the impact tests and an evaluation of the dummy kinematics and predicted injury risks. However, it is not known how well Brazil's cars would perform in equivalent Euro NCAP side impact conditions, or the level of secondary safety offered by cars in the current fleet, which have not undergone NCAP testing.

Therefore, concluding that new cars sold in Brazil in 2015 are like those sold in the EU in 2001 is a **conservative assumption**. This assumption may overestimate the current crashworthiness performance of new cars sold in Brazil, which will mean that this report underestimates the potential benefits from introducing minimum regulations in conjunction with Latin NCAP testing.

In addition, the turnover of the fleet is much slower in Brazil, with the majority of cars being more than nine years old. **This further highlights the need to accelerate progress with regard to introducing new vehicle regulations in Brazil as soon as practicable**.

5.3 The benefits of vehicle safety standards in Brazil

The estimated quantifiable impact of car secondary safety developments in Great Britain from 2002 to 2020 is a saving of 11% car user fatalities, compared to if vehicle safety standards had remained as they were in 2001. This estimate has been applied to the Brazilian fleet, taking into account the slower turnover. Assuming that similar regulations were introduced, namely seat belt standards and UN Regulations No. 94 and 95, and a similar impact of consumer testing was observed in Brazil between 2015 and 2030 as was seen in Britain between 2002 and 2020, it is predicted that **between 12,500 and 34,200 car user fatalities could be saved**.

This analysis focussed on the number of car user fatalities that could be saved by improvements to secondary safety, but in addition there are likely to be reductions across all injury severities including serious and slight casualties. Information on the number of non-fatal casualties was not available for Brazil, but if we assume that the ratio of fatalities to serious injuries is similar in Brazil to that of Great Britain (widely considered to be approximately 1 fatality to every 10 serious injuries), then the number of **killed or seriously injured car user casualties prevented by improvements to secondary safety could be in the region of 140,000 to 380,000**.

5.4 Summary and Recommendations

In summary, Brazil has successfully started the legislative process and is now applying some standards that are similar to the EU (and other similar industrialised regions), but there is still a significant gap between the regulated vehicle safety standards in the industrialised regions and Brazil.

This paper has provided estimates for fatality and serious injury reductions associated with secondary safety measures for car users that could be seen in Brazil, if the minimum standards are urgently adopted. To achieve these reductions **Brazil must mandate UN Regulation No. 95 on lateral collision protection**. If minimum vehicle standards are not rapidly established in Brazil, the road casualty public health, economic and development issues will continue to be significant.

Electronic Stability Control (ESC) and Pedestrian protection measures have not been assessed by this study. However, there is established international evidence that many car user lives could be saved and injuries prevented in Brazil, if ESC is incorporated in vehicle regulation requirements. Similarly, vulnerable road user (VRU) impact-friendly vehicle design is an important countermeasure, especially for Brazil given the road casualty characteristics. Therefore, it is strongly recommended that ESC (GTR 8) and pedestrian protection (GTR 9) are adopted into Brazilian car safety regulations.

This study has considered vehicle safety, which is one of the five UN pillars of action. It is important to emphasise that a "**Safe System**" approach requires action with respect to safer roads, vehicles and road users; including road engineering, education, enforcement and improved post-crash response and hospital care. Only by managing the whole system will the casualty reductions be maximised. For example, the vehicle safety engineering improvements discussed and quantified in this paper will be effective, providing car users wear seat belts. Therefore, **ensuring seat belt use programmes are in place and effectively enforced is a key part of the "Safe System" for car users**.

Finally, there is a **global requirement for better and more harmonised data on road traffic fatalities and injuries**. Without real world data there is a lack of knowledge with respect to understanding the problems and this limits the development and implementation of cost effective countermeasures. Brazil, like many countries, would benefit from improved monitoring of country-level road casualty trends. Gathering accurate and representative road collision and casualty data enables evaluation methodologies to assess progress and tailored prevention measures to be prioritised. Importantly, data should be collected to detail registered vehicles and journeys, because these exposure parameters are very important to compare the scale of road user deaths and injuries and the relative risk of collisions and/or injuries over time; as motorisation rates, urbanisation and other demographic, behavioural and technology trends unfold.

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References

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

Broughton J, Allsop RE, Lynam DA and McMahon CM (2000). The numerical context for setting national casualty reduction targets. TRL Report 382, Transport Research Laboratory, Crowthorne.

Broughton J and Keigan M (2010). Linking STATS19 and Scottish Hospital In-Patient data for the SafetyNet project. TRL Report PPR207, Transport Research Laboratory, Wokingham.

da Cunha, V. and Travassos, X., "Brazil's New Vehicle Front Impact Safety Standards - ABNT NBR 15300-1 & ABNT NBR 15300-2 or ABNT NBR 15300-3: A Free Choice for the Vehicle's Manufacturer," SAE Technical Paper 2011-36-0195, 2011, doi:10.4271/2011-36-0195.

Department for Transport (DfT) (2013a). Vehicles (TSGB09) - Statistical data sets - GOV.UK. [ONLINE] Available at: https://www.gov.uk/government/statistical-data-sets/tsgb09-vehicles#ASEAN NCAP-TSGB0901-VEH0103 [Accessed 4 Mar. 2015].

DfT (2013b). Vehicles (TSGB09) - Statistical data sets - GOV.UK. [ONLINE] Available at: https://www.gov.uk/government/statistical-data-sets/tsgb09-vehicles#ASEAN NCAP-TSGB0901-VEH0103 [Accessed 4 Mar. 2015].

DfT (2014). Number of registered cars by make, model and year of first registration. Data direct from DfT.

Gasnier, M (2014). Best Selling Cars – Matt's blog » 2014. [ONLINE] Available at: http://bestsellingcarsblog.com/2014 [Accessed 4 Mar. 2015].

Hoye, A. (2011). The Effects of Electronic Stability Control (ESC) on Crashes - An Update. Accident Analysis & Prevention, 43(3), 1148-1159.

Lloyd, L.K., Reeves, C., Broughton, J. and Scoons, J. (2012). Investigating the reduction in fatal accidents in Great Britain from 2007-2010. TRL Published Project Report PPR663.

McCarthy, M., Barrow, A., Reeves, C., & Muirhead, M. (2012). ASSESS: Assessment of Integrated Vehicle Safety Systems for improved vehicle safety. RPN2527. TRL Limited, Crowthorne, Berkshire, UK.

Motor Trader (2014). New Vehicle Sales by brand. [ONLINE] Available at: http://www.motortrader.com.my/ . [Accessed 02 March 15].

OICA (2013). PC World Vehicles In Use. [ONLINE] Available at: http://www.oica.net/wp-content/uploads/2013/09/pc-wviu.pdf . [Accessed 03 March 15].

UN (2015). United Nations General Assembly Resolution A/RES/70/1: Transforming Our World: The 2030 Agenda for Sustainable Development, adopted 25 September 2015; see also www.globalgoals.org

WHO (2009). Global status report on road safety 2009. [ONLINE] Available at: http://www.who.int/violence_injury_prevention/road_safety_status/2009/en/ [Accessed 4 Mar. 2015].

WHO (2013). Global status report on road safety 2013. [online] Available at: http://www.who.int/violence_injury_prevention/road_safety_status/2013/en/ [Accessed 4 Mar. 2015].

WHO (2015). Global status report on road safety 2015. [online] Available at: http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/ [Accessed 8 Nov. 2015].

Appendix A Technical annex - Methodology

A.1 Secondary safety in Britain

We have used the method described in Broughton (2003) to assess the effectiveness of secondary safety systems for car occupants. In this approach, the injury severity proportion has been modelled by car registration year.

The statistical modelling uses data from police reported injury accidents (from the British STATS19 accident database) occurring between 1989[6] and 2013. These data are analysed using logistic regression models fitted to the proportion of car driver casualties who were killed. The model uses four independent variables:

- Car registration year is used to estimate the reduction in the severity of drivers' injuries linked to changes in succeeding 'cohorts' in the car fleet.
- Year of accident accounts for the fact that other road safety measures and conditions will have affected the road system.
- Age/sex of driver is included as it is known that older drivers tend to be more seriously injured than younger drivers for physiological reasons and they are also more likely to drive older cars.
- Road type is used as a proxy for speed. The models are split into accidents on built-up (BU) roads (≤40mph) and accidents on non-built-up (NBU) roads (>40mph).
- Car type to examine whether secondary safety improvements have benefitted some sizes of car more than others.

The modelling will be used to predict the number of casualties which would have occurred if secondary safety had not improved. This calculation will assume that improving car secondary safety cannot prevent occupants from being injured in an accident, but can reduce the severity of the injuries suffered. As a result, this model is likely to underestimate the actual benefit as some car occupants who would previously have been slightly injured may now not be injured.

A.2 Baseline vehicle safety in Brazil

The aim for this task was to understand, in terms of vehicle structure, how similar the emerging market cars are to cars in the UK market from early Euro NCAP testing to the latest available tests.

NCAP videos were identified for the top 20 registered vehicles in Brazil in 2014 and the top 10 registered vehicles in the UK in 1999, 2004 and 2013. For Brazil these were based on the latest available tests from 2010-2014 and for the UK this included tests completed around 1997-2000, 2002-2005 and 2009-2014.

As the NCAP protocols are not exactly the same, and have changed over time we produced a basic but consistent methodology to assess the cars across the different NCAP tests.

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[6] 1989 was the first year in which the vehicle enhanced data (including the year of registration and make/model of the vehicle) were included in the STATS19 database.

A group of vehicle safety specialists classified the cars into a series of deformation categories relating to the structure of the passenger compartment after the NCAP frontal test:

1. No intrusion
2. Mild A-pillar damage
3. Severe A-pillar damage
4. Mild vehicle sill (base of door) or footwell movement/damage
5. Severe vehicle sill movement/damage
6. Mild A-pillar and sill damage
7. Severe A-pillar damage and mild sill damage
8. Mild A-pillar damage and severe sill damage
9. Severe A-pillar and sill damage

There were some limitations in the method partly due to the video formats.

- These results are based on expert but subjective opinions.
- Many of the videos from the different tests in different years and different countries had different views – some just included a side view, others included a frontal view and a view from an internal camera.
- Tests were selected based on the top registered cars in each country and therefore these will not only be new cars but will be made up of new and older cars.
- Structural movement was more difficult to see on dark coloured cars, which may mean that the results for these particular cars are not identified to be as severe as they could have been for lighter coloured cars.

A.3 Prediction modelling

Given the savings estimated in Britain due to secondary vehicle safety improvements, and assuming similar major improvements could be implemented in Brazil, a prediction model determines the estimated number of lives that could be saved in Brazil up to 2030.

The baseline model predicts the number of car occupant fatalities in Brazil if vehicle safety remains as it is and is defined as:

$$C'(2030) = C(2010)\ [\ T(2030) / T(2010)\ ]\ (1-\alpha)^{21}$$

where

- C’(2030) is the predicted adjusted number of car occupant fatalities in 2030 given no progress in road safety
- C(2010) is the number of car occupant fatalities in 2010
- T(2030) is the expected number of registered cars in 2030 based on a series of scenarios
- T(2010) is the number of registered cars in 2010
- α is the average annual fatality rate of reduction (adjusted rate) predicted over the 21 year period 2010-2030

To the baseline model are added some possible scenarios for changes to road safety progress, specifically, in this case, to vehicle safety progress. These new measures have been defined as:

I. Introduction of similar regulations and adaptations to the NCAP testing regime, similar to those seen in Europe over the same time period.

II. Introduction of regulations and NCAP adaptations as above, but over a shorter period.

Application of the scenarios is based on a number of assumptions:

a) Accident types for cars are similar in Britain to the Brazil accident types.

b) The uptake rate of these regulations and the relative timing is the same in the Brazil as the Britain.

c) The impact of NCAP in the Brazil is currently insignificant but grows as we have seen in Britain in terms of individuals' buying habits.