Predicting the Impact of Vehicle Safety Developments in Emerging Markets following the Industrialised Countries’ Experience
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ABSTRACT

Vehicles in emerging markets are not typically regulated to the same extent as seen 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. With rapid growth in passenger cars expected, the number of road deaths and casualties in emerging markets is likely to rise, unless targeted and efficient interventions are planned and initiated urgently.

The objective of this work was to quantify the casualty benefit that could be realised in an emerging market, if the experiences and lessons learned in the Europe Union (EU), including minimum car safety standards and consumer testing, were efficiently applied. Malaysia was selected as the emerging market for study in this paper, because it is a Contracting Party to the UN 1958 Agreement and has recently applied the major UN vehicle safety regulations.

Clear differences in vehicle safety developments in Britain compared with Malaysia were identified through analysis of NCAP results and accident data. Frontal impact performance varied, with some cars tested in ASEAN NCAP performing to levels similar to those seen in Euro NCAP today, whilst others were significantly worse. Based on this evidence, in broad terms, this study assumes that new car models sold in Malaysia are approximately 10 years behind today’s (2014/15) equivalent European cars, in terms of vehicle safety developments. However, the fleet in Malaysia is older than that seen in Britain, so it is possible that the entire fleet (with many older cars) could reflect a level of safety more like Britain before 2004. Therefore, the Malaysian casualty benefits predicted by this study represent a conservative estimate.

By taking the vehicle safety development experience witnessed in the EU and applying it to the situation in an emerging market, this work quantifies the casualty reduction potential could be a saving of between 1,200 and 4,300 Malaysian fatalities by 2030.

INTRODUCTION

Road vehicles in some of the world’s emerging markets are not currently regulated to the same extent as industrialised regions. 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 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 Europe, the US, Japan 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.

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 five car regulations, which are defined as a minimum for today’s world markets:

- Approved seat belts and anchorages for all seating positions (UN Reg. 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)

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.

This paper aims to highlight the combined safety benefits that are realised through the establishment of minimum mandatory car standards enforced through regulation, in conjunction with consumer (NCAP) programmes, which seek to set more challenging vehicle safety design safety targets. Global NCAP has established testing programmes in a number of emerging markets.

Malaysia was selected as the emerging market for this study because it is a Contracting Party to the UN 1958 Agreement and has a vehicle safety improvement strategy, which recently included applying most of the major UN Regulations. Malaysia hosts ASEAN NCAP tests and so it was possible to evaluate the safety performance of some of the vehicles currently sold and to bench-mark performance against similar European vehicles.

Specifically, this paper aims to quantify how many car user fatalities are likely to be prevented in Malaysia between 2014 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 ASEAN NCAP will provide on further real world vehicle improvements.

METHOD

Information from Great Britain and Malaysia forms the basis of the study, including accident data, exposure data, and historic and expected developments in fleets. From these data and NCAP test results, the relative safety status of cars in the emerging market compared to the history of European vehicle safety developments is identified. A series of statistical models on British data measure the effect of developments in secondary vehicle safety and apply these effects to the potential impact on casualties in Malaysia if similar developments were seen.

Secondary safety modelling

Car safety has improved in Britain over the past two decades, but how much of this improvement is due to secondary safety features and how much is due to changes in the conditions in which vehicles are driven, for example due to improvements to the road system or changes in the weather, or the way in which they are driven is difficult to define. Statistical modelling is required to disaggregate these effects. The models (Broughton, 2003) use data from the British STATS19 database to model the proportion of casualties killed in road accidents (the severity proportion). The details of the model are shown in the Technical Annex. From these results it is possible to predict the number of casualties which would have occurred if secondary safety had not improved over time.

Prediction modelling

In order to predict the possible future effect of secondary safety improvements in cars in Malaysia we use a scenario based modelling method derived initially in Broughton et al (2000).

The models derived start with a set of possible baseline models, which predict the number of casualties over the next few years if the number of registered vehicles (a proxy for traffic) follows a series of possible scenarios and basic vehicle safety developments continue in the way that has been observed up until the current time. The impacts of further vehicle safety interventions can then be added to the baseline model to predict the impact of these additional measures.

The baseline model is defined as:

\[ C'(2030) = C(2012) \left( \frac{T(2030)}{T(2012)} \right) (1-\alpha)^{19} \]

where:

- \( C'(2030) \) is the predicted adjusted number of car occupant fatalities in 2030 given current progress in vehicle safety
- \( C(2012) \) is the number of car occupant fatalities in 2012 (the latest known year)
- \( T(2030) \) is the expected number of registered cars in 2030 based on a series of scenarios
• $T(2012)$ is the number of registered cars in 2012
• $\alpha$ is the average annual fatality rate of reduction (adjusted rate) predicted over the 19 year period 2012-2030

For the baseline model, the expected number of registered cars is predicted based on the following broad scenarios:
  a) Similar growth or decline to that observed in recent trends.
  b) No change in current level.
  c) Increased or decreased growth or decline relative to current trend.

Some possible scenarios for changes to vehicle safety progress are added to the baseline model. These new measures have been defined as:
  1) Introduction of similar regulations and adaptations to the NCAP testing regime, similar to those seen in Europe over the same time period.
  2) Introduction of regulations and NCAP adaptations as above, but over a shorter period.

Application of the scenarios is based on a number of assumptions:
  i. Accident types for cars are similar in Britain and Malaysia.
  ii. The uptake rate of these regulations and the relative timing is the same in Malaysia as in Britain.
  iii. The impact of NCAP in Malaysia is insignificant, but grows as we have seen in Britain in terms of individuals’ buying habits. Since the introduction of ASEAN NCAP in Malaysia, we have seen very little evidence of a change in the buying habits in the new sales data as the poorer safety performing cars remain popular.

The results of the secondary safety modelling are used to provide the predicted casualty saving due to secondary saving improvements. In order to apply these to the Malaysian data it is necessary to understand the current state of the Malaysian fleet in terms of fleet renewal and safety standards, relative to a specific point in time in the British fleet. The fleet renewal has been determined from data on the sales of new cars from 2005 to 2010 from Motor Trader (2014). NCAP tests were the most accessible and robust method for comparing safety levels of different cars, however it was not possible to compare star ratings or scores across different NCAPs as the methods vary. Therefore, simple subjective safety levels have been identified by experienced vehicle engineers comparing the visible structural stability of the most popular cars in the most recent NCAP tests in the Malaysian region compared to those in Britain over the last 20 years. These structural scores take into account the visible deformation of the A-pillar and the sill, along with any movement in the steering column and the airbag positioning/interaction with the dummy’s head.

There were some limitations in the method partly due to the video formats. Firstly, these results are based on expert, but subjective opinions. In many cases it was difficult to code exactly into one category and the most appropriate category has been chosen according to the judgment of the experts. Secondly, 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. From some of the camera views it was easier to see steering column and wheel movement compared to others, which may mean that movement was more easily picked up in some types of videos. The NCAP tests are based on the newest car model derivative at the time of the test.

DATA

This section compares vehicle fleet and road fatality figures for Malaysia in the latest available year and for Britain in 1999, 2004, 2009 and 2013. The years covered by the British data reflect the investigation to determine where the current car safety standard in Malaysia is in relation to the British developments.

Casualty data

MIROS provided the total number of road fatalities in Malaysia from 1995 to 2013. This can be combined with information from WHO (2009, 2013) which provide the distributions of these fatalities by road user type for 2007 and 2010. Interpolating from these figures enables us to derive estimates of the number of car occupant fatalities from 2007 to 2012 as shown in Table 1.
Table 1. Estimated number of car occupants from 2007 to 2012 in Malaysia (red numbers are extrapolated)

<table>
<thead>
<tr>
<th>Year</th>
<th>Deaths</th>
<th>Proportion of car occupants in deaths</th>
<th>Car occupant deaths (estimated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>6,282</td>
<td>23%</td>
<td>1,445</td>
</tr>
<tr>
<td>2008</td>
<td>6,527</td>
<td>24%</td>
<td>1,566</td>
</tr>
<tr>
<td>2009</td>
<td>6,745</td>
<td>25%</td>
<td>1,686</td>
</tr>
<tr>
<td>2010</td>
<td>6,872</td>
<td>26%</td>
<td>1,787</td>
</tr>
<tr>
<td>2011</td>
<td>6,877</td>
<td>27%</td>
<td>1,857</td>
</tr>
<tr>
<td>2012</td>
<td>6,917</td>
<td>28%</td>
<td>1,937</td>
</tr>
</tbody>
</table>

In 2012, relative to the population the car death rate in Malaysia was 66.1 per million population. In comparison, the highest equivalent rate in Britain was in 1972 (60 per million population) with rates between 31 and 13 from 1999 to 2012.

NCAP comparisons

As of December 2011 new cars in the Asean region could be tested by the New Car Assessment Programme (ASEAN NCAP). A total of nine cars in the top 20 most popular cars in Malaysia were tested by ASEAN NCAP. For the purposes of comparing vehicle safety across Malaysia and Britain, these nine cars and a further 31 cars in the top 10 new sales in 1999, 2004, 2009 and 2013 across Euro NCAP from 1997 to 2014 were observed and scored based on structural deformation in the frontal test which is broadly comparable across the two NCAPs. Structural deformation was classified into one of nine categories:

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

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.

Table 2. Count of cars tested by NCAP by structural deformation score

<table>
<thead>
<tr>
<th>Structural deformation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>9</th>
<th>Proportion of new sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asean</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>45%</td>
<td></td>
</tr>
<tr>
<td>Euro 1999</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td></td>
<td>35%</td>
<td></td>
</tr>
<tr>
<td>Euro 2004</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>26%</td>
<td></td>
</tr>
<tr>
<td>Euro 2009</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16%</td>
<td></td>
</tr>
<tr>
<td>Euro 2013</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24%</td>
<td></td>
</tr>
</tbody>
</table>

Broadly, the Asean cars appear to be performing somewhere around the Euro 2004 level.

Fleet data

Table 3 compares car fleet facts in Malaysia in 2012 and Britain in 2004. In Malaysia, 10.5m cars were registered which included 0.6m new cars (OICA (2013) for registrations and Malaysian Automotive Association (MAA, 2014) for sales data). The number of registered cars is growing substantially each year.

Table 3. Comparison of registered car facts in Malaysia and Britain

<table>
<thead>
<tr>
<th></th>
<th>Britain: 2004</th>
<th>Malaysia: 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. reg cars (DfT, 2013a)</td>
<td>25.8m</td>
<td>10.5m</td>
</tr>
<tr>
<td>Growth in reg cars from previous year</td>
<td>3.1%</td>
<td>6.5%</td>
</tr>
<tr>
<td>Proportion of reg cars new (DfT, 2013b)</td>
<td>9.7%</td>
<td>5.3%</td>
</tr>
<tr>
<td>Proportion of cars aged 6 years or less (DfT, 2014)</td>
<td>53%</td>
<td>28% (2010)</td>
</tr>
<tr>
<td>Motorisation rate (DfT, 2013b)</td>
<td>0.44</td>
<td>0.36</td>
</tr>
</tbody>
</table>
Detailed registered car data were not available to the research team for Malaysia during the research. However, based on sales data from 2005-2010 (Best Selling Cars Blog, 2014) we estimated that 28% of the Malaysian car fleet is at most six years old. In comparison, the number of cars and the proportion of these cars that are 6 years or younger is twice as high in Britain in 2004. Given the information in Table 3, there is some suggestion that the current fleet in Malaysia contains older cars relative to Britain in 2004, therefore any expected casualty savings are likely to be underestimates.

RESULTS

Secondary safety in Britain
The secondary safety modelling is shown in detail in the Technical Annex. This shows that there have been considerable reductions in fatalities in Britain since 1990 due to developments in secondary safety. It is estimated based on these models that 302 lives have been saved between 2004 and 2013 in Britain due to secondary safety which is a reduction in car driver fatalities of 4.2%.

Predictive modelling in Malaysia
Based on the number of registered cars and the car occupant fatality estimates shown in Table 1, the fatality rate for car occupants can be estimated. These are shown in Figure 1 with two possible trends. Both trends are based on a linear function. A longer term analysis (1995 – 2013) was carried out on all fatalities and all registered vehicles and this suggested that a linear trend was more appropriate than a log linear trend. There is a longer trend which takes into account data from 2007 to 2012 and a shorter trend (based on 2009-2012), which encompasses what appears to be a possible change in trend in 2009, when the car occupant fatality rate started to decrease. It was decided that, given these trends are based on relatively few data points, the longer trend should be used as this is less likely to contain as much random fluctuation as the shorter trend.

The possible baseline scenarios for car registration growth in Malaysia from 2012 to 2030 have been devised as:
A. The trend in car registrations continues to grow linearly at the current rate: an average annual rate of 5.4% relative to 2012
B. The trend in car registrations continues to grow linearly at an average annual rate of 0.7% relative to 2012. 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 2012. 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.

Relative to the population (and assuming a constant linear growth), the associated motorisation rates by 2030 are 0.52 (A), 0.29 (B), 0.96 (C) and 0.59 (D). The current motorisation rate in Malaysia is 0.36 and in Britain is 0.45.
as shown in Table 3. This shows that scenario C is highly unlikely, and further calculations do not consider this scenario.

Assuming that the relationship between car occupant fatalities and registered cars remains the same as in the current trend, the derived number of car occupant fatalities that could be expected under the three feasible scenarios A, B and D are shown in Figure 2. The associated increase in car occupant fatalities in 2030 compared to 2012 for the three remaining baseline scenarios 68% (A), -5% (B) and 92% (D).

![Figure 2. Predicted number of car occupant fatalities in Malaysia 2007-2030 based on three scenarios](image)

These baseline scenarios assume that vehicle safety developments continue at the current rate. However, if the impact of regulations on vehicle manufacturers and NCAP on buying habits that were seen in Europe could be replicated in Malaysia, then we would expect a reduced number of fatalities over the same period. Based on the comparisons shown in vehicle safety between Malaysia and Britain on new cars tested in NCAP programmes, the suggestion is that the current vehicle safety standard in Malaysia could be equivalent to the 2004 standards in Europe. We know that Malaysia is not exactly as Europe was in 2004. In particular, as shown in Table 3, the proportion of the cars in the fleet that were reasonably new (6 years or under) is approximately half that in Britain in 2004. This suggests that the fleet renewal rate in Malaysia is currently slower than observed in Britain in 2004, and therefore any regulations or new safety technologies or features would likely infiltrate the fleet at a much slower pace than observed in Britain. As discussed above, in Britain, 4.2% fewer car drivers died between 2005 and 2013 due to the progression in secondary safety.

We have predicted the impact on fatalities of two future scenarios:
1. A proportional reduction in the baseline scenarios fatalities equivalent to half the proportional reduction observed in Britain to take into account the difference in fleet turnover rate observed in Britain.
2. The same proportional reduction in the baseline scenarios as observed in the Britain which might reflect a quicker fleet turnover or a quicker uptake of regulations than observed in Britain.

Table 4 shows the estimated potential car occupant fatality savings over 17 years between 2014 and 2030 based on the potential baseline trends in car occupant fatalities in Malaysia shown in Figure 2, and the two named future scenarios 1 and 2 above.

<table>
<thead>
<tr>
<th>Table 4. Estimated potential car occupant fatality savings between 2014 and 2030 given future scenarios 1 and 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline scenario</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>D</td>
</tr>
</tbody>
</table>
CONCLUSIONS

In 2012, the car user death rate was 66.1 per million Malaysian population compared to 13 per million British population. This represents a significantly higher casualty rate, and this is only partially associated with differences in vehicle safety standards.

Comparing the performance of cars in Asean and Euro NCAP frontal impact tests, we concluded that broadly, today’s Asean cars could be performing somewhere around the Euro 2004 level. This was based on an engineering visual assessment of the cars’ structural behaviours during the impact tests. However, it is not known how well the Asean 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.

The casualty modelling assumes that recent car safety regulations that have come into force in Malaysia, have improved the secondary safety protection afforded to new car model users, to a level similar to that seen in Europe in 2004. Based on information on the age of the car fleet in Malaysia, it is possible that the entire fleet (with many older cars) could reflect a level of safety more like Britain before 2004. Therefore, the casualty benefits predicted for Malaysia by this study represent a conservative estimate.

In Britain from 2005-2013, the estimated effectiveness of improvements in car secondary safety, since 2004-05 registered vehicles, was 4.2% for car driver fatalities. That is, 4.2% fewer car drivers died between 2005 and 2013 due to improvements in secondary safety in cars.

The current motorisation rate in Malaysia is 0.36 and in Britain is 0.45. Depending upon the change in motorisation rates and the uptake of new cars, we estimate that between 1,200 (scenario B, 0.29 motorisation rate) and 4,300 (scenario D, 0.59 motorisation rate) car user fatalities could be prevented on Malaysia’s roads between 2014 and 2030. This assumes that the car secondary safety improvements seen in Britain since 2004 are transferred to the Malaysian vehicle fleet.

This paper has provided estimates for fatality reductions associated with secondary safety measures for car users that are likely to be seen in Malaysia because of the adoption of UN Regulations. Establishing minimum mandatory regulations within the marketplace has been a significant step and provides a real world example of what can be achieved.

Further work will summarise the potential benefits for pedestrian protection and ESC advances in Malaysia and other emerging markets.

Acknowledgements
This research was funded by Global NCAP.

References


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


TECHNICAL ANNEX – Secondary safety modelling

Method

The following variables are included in logistic regression models:

- **Registration year of the vehicle**: used to estimate the reduction in the severity of drivers’ injuries linked to changes in succeeding ‘cohorts’ in the car fleet
- **Accident year**: accounts for the fact that other road safety measures and conditions will have affected the road system
- **Age and sex of the casualty**: to allow for the differences in injury severity and car choice for different demographics of drivers
- **Vehicle type of striking car**: controls for the differences in protection offered to occupants of different sizes of cars.
- **Road type**: is a proxy for speed of accident and controls for the influence of speed on injury severity.

The modelling is used to predict the number of casualties which would have occurred if secondary safety had not improved. This calculation assumes 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.

Results

In total, 2,802,648 car driver casualties were injured in accidents recorded in STATS19 between 1989 and 2013. Of these 83% (2,329,292) had a valid age, vehicle registration year, vehicle type and speed limit and these data have been used for this analysis. It has been assumed that excluding those vehicles where the data is unknown does not bias the results of the model, and the casualty estimates presented are weighted to take into account those that are unknown.

**Modelling results** Figure 3 shows the proportion of 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 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 3 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. It is suggested that this is due to the impact of manufacturers starting to consider the impact of possible regulations on the car industry.

One other possible explanation for this trend 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. In June 2006, the Department for Transport commissioned some work to match STAT19 data to hospital data in an attempt to determine levels of underreporting (Broughton and Keigan, 2010); however the conclusions are hard to draw out and the trend over time was not investigated. Even if this trend is true, the changes in reporting rate do not bias the crucial results relating to registration year as we are interested in the trend from 2004 onwards when applying the data to Malaysia.

**Estimated casualty benefits** Following the methodology outlined in Broughton (2003), 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 2004-05 registered cars how many additional fatalities would have occurred up to 2013.

These calculations assume that the total number of collisions remains unchanged, but that more drivers would have been killed because of the lower secondary safety. The model is used to adjust the severity proportions of the modern cars to match with those registered in 2004-05. Casualties in cars registered before 2004-05 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. The total figure shown in Table 5 is based on modelled data to smooth out variability in the trend due to random variation.

<table>
<thead>
<tr>
<th>Accident year</th>
<th>Actual fatality numbers</th>
<th>Estimated fatality numbers if secondary safety had not improved</th>
<th>Reduction in fatalities due to secondary safety improvements</th>
<th>Proportional reduction due to secondary safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>934</td>
<td>990</td>
<td>56</td>
<td>5.7%</td>
</tr>
<tr>
<td>2010</td>
<td>568</td>
<td>583</td>
<td>15</td>
<td>2.5%</td>
</tr>
<tr>
<td>2013</td>
<td>543</td>
<td>602</td>
<td>59</td>
<td>9.8%</td>
</tr>
<tr>
<td>Total (modelled) 2005-2013</td>
<td>6,874</td>
<td>7,176</td>
<td>302</td>
<td>4.2%</td>
</tr>
</tbody>
</table>

Hence, between 2005 and 2013 the estimated effectiveness of improvements in secondary safety since 2004-05 registered vehicles was 4.2% for car driver fatalities. That is, 4.2% fewer car drivers died between 2005 and 2013 due to improvements in secondary safety in cars.