In-depth analysis of accidents with heavy goods vehicles

Effects of measures promoting safe heavy goods traffic
Titel: In-depth analysis of accidents with heavy goods vehicles – Effects of measures promoting safe heavy goods traffic

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Foreword

This study has been carried out on behalf of the Swedish Road Administration (SRA) and aims to provide answers to which measures should be carried out in order to reduce the number of fatal accidents involving heavy goods vehicles, and to some extent the effect and potential of different measures.

The study has been carried out by road safety analysts Johan Strandroth and Matteo Rizzi of SRA Consulting Service. Special thanks to Claes Tingvall, Anders Lie, Thomas Lekander, Magnus Lindholm, Carina Teneberg, Björn Winstrand and Fredrik Lemon at SRA and Anders Kullgren, Anders Ydenius and Sigrun Malm at Folksam for valuable input.

Norrköping, November 2008

Johan Strandroth, Matteo Rizzi
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Summary

Every year, around one hundred persons are killed in accidents involving heavy goods vehicles, which represents around 20 per cent of all persons killed in road accidents. Of these, the greater part die in passenger cars, but a number of motorcyclists, cyclists, pedestrians and bus passengers are also killed in collisions with heavy goods vehicles. About ten of the persons killed are drivers of heavy goods vehicles. Both the degree of injury and degree of disability point to collisions with heavy goods vehicles producing more serious consequences than other accidents. This illuminates the importance of preventing these accidents, as they both represent a high risk of people being killed and a high risk of permanent medical impairment for those involved.

Foreign heavy goods vehicles have often been blamed for causing problems from an accessibility and road safety perspective in Sweden. However, this study has not found that foreign heavy goods vehicles are more prone to accidents than Swedish ones. Nor is there any reason to suspect that drivers of heavy goods vehicles of any particular age group should be at greater risk of accidents than others. On the other hand, the age of the heavy goods vehicle appears to be of importance. When it comes to the age of the passenger cars, this in turn appears to play an even greater role in relation to the risk of people being killed in collisions with heavy goods vehicles. New cars offer greater safety, both in terms of avoiding accidents and in lessening the consequences of an accident. It can now be confirmed that the safety standard of cars is of importance also in very serious collisions, typical for accidents involving heavy goods vehicles.

In order to reduce the number killed in accidents in which heavy goods vehicles are involved, it is important to look at the potential and effect of different measures. In order to classify the measures, this study has used the categories safe roads, safe use and safe vehicles. This links with the conditions mentioned in the interim goal efforts for road safety in which many actors are involved. It also highlights the fact that the responsibility for Vision Zero option for heavy goods vehicles cannot rest on one actor, but must be divided across all who work towards safe roads, safe use and safe vehicles.

It can also be stated that there are even now many fatal accidents that could be avoided using measures that are today known and available. However, in order to achieve the goal, new solutions are needed, aimed at roads, users and vehicles. In summary:

- The potential of measures related to safe roads would reduce the number of fatalities by around 75 per cent, or 70 fatalities per year.
- The potential of measures related to safe use would reduce the number of fatalities by just over 20 per cent, or 20 fatalities per year.
- The potential of measures related to safe vehicles would reduce the number of fatalities by 65 per cent, or 65 fatalities per year.
- The greatest individual effects are produced by median barriers (54 %), rumble strips (20 %), sober passenger car drivers (13 %), lane departure warning (15 %) and emergency brakes + deformation zone (27 %).
- A combination of emergency brakes and deformation zone on heavy goods vehicles would reduce the number of fatalities in head-on collisions by just over 50 per cent.
- A great challenge is posed by side collisions with oncoming traffic and intersections on main roads.
Introduction

BACKGROUND

Every year, around one hundred persons are killed in accidents in which heavy goods vehicles are involved, which represents around 20 per cent of all persons killed in road accidents. Of these, the greater part die in passenger cars, but a number of motorcyclists, cyclists, pedestrians and bus passengers are also killed in collisions with heavy goods vehicles. Around ten of the persons killed are drivers of heavy goods vehicles.

Development of the number of fatalities

Most of the people who die in collisions with heavy goods vehicles travel in passenger cars and collide with oncoming traffic. 70 per cent of all fatalities are drivers and passengers in passenger cars. The remaining fatalities are almost exclusively unprotected road users.

Collisions with oncoming traffic and overtaking accidents represent 56 per cent of all fatalities. Since 2000, the distribution has not changed significantly. However, the number of fatalities in collisions with oncoming traffic fell considerably up to 2005, and then increased again until 2007.
The reduction in the number of accidents with oncoming traffic appears to correlate with the reduction in the number of fatalities on national roads up to and including 2005. While the number of fatalities on the municipal road network has stayed around ten per year, those on the national road network have changed from around 85 in 2003 to 60 in 2005 and back to 85 in 2007.

![Diagram 3: Development of the number of fatalities in accidents with heavy goods vehicles per road manager. N=440. Source: SRA.](image)

It is a bit more difficult to see any trend in the development of the number of fatalities per speed limit. Possibly the number of fatalities on roads with a speed limit of 70 and 90 km/h fell up to 2005 and then increased. For roads with the speed limits 30 and 50 km/h, the number has varied from 10 to 25 fatalities per year.

![Diagram 4: Development of the number of fatalities in accidents with heavy goods vehicles per speed limit. N=787. Source: SRA.](image)
PURPOSE
There are many measures, relating to both the road environment and vehicle and driver aspects, that can be expected to reduce the number of fatalities in accidents with heavy goods vehicles. But in order to prioritize correctly among these measures, it is necessary to know the potential of the various measures. This study is intended to provide background material to make the work to increase the road safety of heavy vehicles as effective as possible. Part 1 is intended to create a picture of the problem, while Part 2 contains an analysis of the effect and potential of different measures. The measures whose potential have been investigated are linked to some of the conditions of use described in System for målstyrning av trafiksäkerhetsarbetet (“A System for Target Management of Road Safety Work”) and to concepts such as safe roads, safe vehicles and safe use.

METHOD
Part 1 deals with the distribution of fatal accidents per nationality and age of the heavy goods vehicle and passenger car and the age of the driver of the heavy goods vehicle and passenger car. A comparison is also made of the degree of injury and of disability of drivers of passenger cars depending on whether the collision was with another passenger car or with a heavy goods vehicle. The background material for the development of accidents is information from the period 2000-2007, gathered and arranged by road safety analysts at the SRA. The distribution of accidents across different parameters is taken from the accident database Strada from the period 2003-2007, in which the police register road accidents and which also provides background material for official statistics.

Healthcare services also register accidents in Strada, but at personal injury level, which forms the basis for the calculation of degree of injury and of disability. By studying the long-term effects of injuries from actual accidents, Folksam has created a model for forecasting the risk of disabling injuries of varying degrees of seriousness. The model has been used in this study to estimate the risk of a degree of disability of at least 10 per cent for injuries to car occupants involved in accidents with heavy goods vehicles (appendix 1).

Part 2, which is the main section of the study, uses in-depth studies of accidents involving heavy goods vehicles to provide an objective picture of the issue, showing the potential in terms of numbers of lives saved. A number of hypotheses and issues relating to the indicators and conditions of the stage target are developed and compared to the material gathered from the Swedish Road Authority’s in-depth studies of fatalities involving heavy goods vehicles from 2006-2007. In this way, it is possible to see which problems create which conditions, and which measures actually are relevant for this type of accident. In some cases, the problem and the effect of measures are quantified and in some cases only an assessment is made of whether the problem actually is relevant (figure 1).

1 Swedish Traffic Accident Data Acquisition
The basis for calculating the effect of each measure is the already known or assumed connection between implementation and reduction of the number of fatalities. The percentage reduction of fatalities is multiplied with the fatalities relevant to the problem area found in the in-depth studies. The percentage reduction in the number of fatalities is then used to calculate the number of lives saved per year, based on an average of 95 fatalities per year in accidents involving heavy goods vehicles during the period 2000-2007.

The result is not a forecast of lives saved however, but an estimate of the number of fatalities that could have been avoided during the period 2006-2007 in ideal circumstances, dependent upon 100 per cent implementation of a certain measure. It is also obvious that the effectiveness of the measures is not statistically significant, but only aims to provide knowledge about the size and relevance of the effectiveness.
Results

PART 1 – DISTRIBUTION OF FATALITIES ACROSS IMPORTANT PARAMETERS

Heavy goods vehicles and drivers of heavy goods vehicles

The absolute majority (84%) of heavy goods vehicles involved in fatal accidents are registered in Sweden. The proportion of heavy goods vehicles from the rest of the Nordic countries and Europe involved in the accidents is 8 per cent each. Together, foreign heavy goods vehicles are involved in 16 per cent of fatalities, while representing 18 per cent of the total transport mileage carried out by heavy goods vehicles on Swedish roads. The proportion of accidents involving foreign heavy goods vehicles is thus representative, based on the transport mileage they carry out.

The number of fatalities is distributed in a relatively representative way based on the age of the heavy goods vehicle and the transport mileage. However, there appears to be a certain under-representation of the 2000 model and later, and a certain over-representation of heavy goods vehicles of 1995-1999 models.


Almost 90 per cent of the heavy goods vehicles involved in fatalities are driven by drivers aged 20-59 years. Drivers of the age 60-69 years represent 10 per cent and drivers of the age 18-19 years 2 per cent.

Passenger cars and drivers of passenger cars

Fatalities in passenger cars per age of passenger car display a similar, but much clearer pattern than for heavy goods vehicles. Based on transport mileage, older passenger cars are heavily over-represented, while newer models are heavily under-represented in fatal collisions with heavy goods vehicles.
A comparison with the age of other fatalities in passenger cars shows no particular discrepancies for those who die in collisions with heavy goods vehicles. The pattern of the number of fatalities falling with increasing age apart from 70+ is however slightly clearer for other fatalities in passenger cars.

Diagram 9: Fatalities in passenger cars in accidents involving heavy goods vehicles, distributed by age, compared to age of other fatalities in passenger cars. N=1218. Source: Strada police.

Degree of injury
It is clear that the degree of injury is higher for people in passenger cars colliding with heavy goods vehicles than for collisions with other passenger cars. The proportion ISS² > 15 is more than five times as large for collisions with heavy goods vehicles.

Diagram 10: Degree of injury to people in passenger cars colliding with heavy goods vehicles compared to degree of injury for people in passenger cars colliding with other passenger cars. N=14 151. Source: Strada healthcare.

² Injury Severity Score
In the same way that the degree of injury is greater, the proportion of injuries leading to disability is higher for collisions with heavy goods vehicles compared to collisions with passenger cars. The greatest risk of injuries causing disability and the greatest difference compared to passenger cars is for head injuries: 30 per cent of head injuries in collisions with heavy goods vehicles produce a degree of disability in excess of 10 per cent (Appendix 1).

![Diagram 11: Proportion of injuries leading to a degree of disability of at least 10 per cent for people in passenger cars colliding with heavy goods vehicles compared to people in passenger cars colliding with passenger cars. N=61 604. Source: Strada healthcare.](image-url)
PART 2 – EFFECTS OF MEASURES

Tabell 1 lists the hypotheses about measures whose effects have been calculated. For each measure, the question is posed “How many lives would be saved if...?”

<table>
<thead>
<tr>
<th>Measure Description</th>
<th>Estimated Lives Saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>All roads carrying heavy goods vehicles had median barrier</td>
<td>...</td>
</tr>
<tr>
<td>All roads carrying heavy goods vehicles had central and side rumle strips</td>
<td>...</td>
</tr>
<tr>
<td>All intersections in urban areas with heavy goods traffic were roundabouts</td>
<td>...</td>
</tr>
<tr>
<td>All intersections on main roads were safe</td>
<td>...</td>
</tr>
<tr>
<td>All pedestrian and bicycle crossings in urban areas with heavy traffic were speed controlled</td>
<td>...</td>
</tr>
<tr>
<td>All reversing by heavy goods vehicles in urban areas was safe or prohibited</td>
<td>...</td>
</tr>
<tr>
<td>All drivers of passenger cars were sober (estimation of maximum benefit)</td>
<td>...</td>
</tr>
<tr>
<td>All drivers of passenger cars wore a seatbelt</td>
<td>...</td>
</tr>
<tr>
<td>All drivers of passenger cars maintained the speed limit</td>
<td>...</td>
</tr>
<tr>
<td>All drivers of heavy goods vehicles were sober (estimation of maximum benefit)</td>
<td>...</td>
</tr>
<tr>
<td>All drivers of heavy goods vehicles wore a seatbelt</td>
<td>...</td>
</tr>
<tr>
<td>All drivers of heavy goods vehicles maintained the speed limit</td>
<td>...</td>
</tr>
<tr>
<td>All heavy goods vehicles had no technical shortcomings</td>
<td>...</td>
</tr>
<tr>
<td>All heavy goods vehicles had well secured loads</td>
<td>...</td>
</tr>
<tr>
<td>All passenger cars had the same crashworthiness as new vehicles</td>
<td>...</td>
</tr>
<tr>
<td>All passenger cars were equipped with Electronic Stability Control (ESC)</td>
<td>...</td>
</tr>
<tr>
<td>All passenger cars were equipped with lane departure warning (LDW)</td>
<td>...</td>
</tr>
<tr>
<td>All passenger cars were equipped with forward collision warning in rear-end collisions</td>
<td>...</td>
</tr>
<tr>
<td>All heavy goods vehicles had systems for detecting unprotected road users at low speed</td>
<td>...</td>
</tr>
<tr>
<td>All heavy goods vehicles were equipped with Electronic Stability Control (ESC)</td>
<td>...</td>
</tr>
<tr>
<td>All heavy goods vehicles were equipped with lane departure warning (LDW)</td>
<td>...</td>
</tr>
<tr>
<td>All heavy goods vehicles were equipped with forward collision warning in rear-end collisions</td>
<td>...</td>
</tr>
<tr>
<td>All heavy goods vehicles were equipped with automatic emergency brakes with</td>
<td>...</td>
</tr>
<tr>
<td>1. Speed limits of 90 km/h and 70 km/h remain as today</td>
<td>...</td>
</tr>
<tr>
<td>2. Speed limit of 90 km/h becomes 80 km/h and of 70 km/h remains as today</td>
<td>...</td>
</tr>
<tr>
<td>3. Speed limit of 90 km/h becomes 80 km/h and of 70 km/h remains as today, with safe cars</td>
<td>...</td>
</tr>
<tr>
<td>All heavy goods vehicles were equipped with emergency brakes + deformation zone + safe cars</td>
<td>...</td>
</tr>
<tr>
<td>1. Speed limits of 90 km/h and 70 km/h remain as today</td>
<td>...</td>
</tr>
<tr>
<td>2. Speed limit of 90 km/h becomes 80 km/h and of 70 km/h remains as today</td>
<td>...</td>
</tr>
</tbody>
</table>

The effects of the measures are shown separately in the following tables as the number of lives saved based on ideal conditions, which means that the measure is 100 per cent implemented. The measures are categorized depending on whether they relate to safe roads, safe use or safe vehicles. Although some measures of course have the effect of reducing other types of accidents, in this study only the reduction in fatalities in accidents involving heavy goods vehicles is included. The causal connection and basis
for calculation is shown in Appendix 2. Table 2 shows the effects of measures for safe roads. The greatest effect is for median barriers, where the starting point is that all accidents involving oncoming traffic and overtaking would be eliminated. Rumble strips in the central and side strips are expected to halve the number of fatalities that start with the car leaving its lane, which would result in around 19 lives saved each year. Safe intersections in urban areas would in principle mean replacing the current intersections with roundabouts, which would save 4 lives.

Safe main road intersections in turn has no particular measure linked to it, but 13 lives saved is rather the potential of the condition 100 per cent safe main road intersections. The relatively low potential of speed controlled pedestrian and bicycle crossings is the result of most fatalities in urban areas occur through unprotected road users being run over rather than hit, which means that the speed in itself is not as crucial for the outcome of the accident.

Table 3 shows the effects of measures for safe use. The greatest potential for safe use is from sober drivers of passenger cars. The fatalities that are assumed to be reduced are those where a driver of a passenger car who is under the influence of alcohol has caused the accident. As it cannot be assumed that the accident would have been avoided with a sober driver, the result is an estimation of the maximum benefit. There are few cases of drivers of heavy goods vehicles under the influence of alcohol causing accidents, and the potential of the condition of sober drivers of heavy goods vehicles would only be one or so lives saved per year. The same applies to well secured loads, as the cases where a poorly secured load causes a fatality are relatively few each year. It has not been possible to show that the potential of speed compliance is particularly great, only a few lives saved per year. The starting point is that seatbelted people in cars driven at high speed (more than 10 km/h above the speed limit) on roads with speed limits of 50 or 70 km/h would have had a chance of surviving if they had kept to the speed limit displayed. Using the same logic, seatbelted car occupants maintaining the speed limit might have survived if heavy goods vehicles driving too fast on roads with speed limits of 50 or 70 km/h had kept within the speed limit. However, the potential is in all probability an underestimate, as the collision speed in many cases is unknown, in particular for the heavy goods vehicle. There is little potential from seatbelted

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Table 2: Effects of measures for safe roads

<table>
<thead>
<tr>
<th>Lives saved</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Median barriers</td>
<td>51</td>
</tr>
<tr>
<td>Central and side rumble strips</td>
<td>19</td>
</tr>
<tr>
<td>Safe intersections in urban areas</td>
<td>4</td>
</tr>
<tr>
<td>Safe intersections on main roads</td>
<td>13</td>
</tr>
<tr>
<td>Speed controlled pedestrian and bicycle crossings</td>
<td>2</td>
</tr>
</tbody>
</table>

3 In order to make a safe assessment of the collision speed of the heavy goods vehicle, an analysis of the tachometer reading or excerpt from a digital tachometer would be required. This is lacking in at least half of all accidents.
drivers of passenger cars. Sometimes there is no medical assessment of whether the deceased would have survived if a seatbelt had been used, but in general the conclusion is that the great crash severity the person in the passenger car is exposed to cannot be survived, despite a seatbelt. Among drivers of heavy goods vehicles, five lives would be saved each year with a seatbelt, which corresponds to around half of all drivers of heavy goods vehicles killed each year.

<table>
<thead>
<tr>
<th>Lives saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sober drivers of passenger cars</td>
</tr>
<tr>
<td>Sober drivers of heavy goods vehicles</td>
</tr>
<tr>
<td>Seatbelted drivers of passenger cars</td>
</tr>
<tr>
<td>Seatbelted drivers of heavy goods vehicles</td>
</tr>
<tr>
<td>Well secured loads</td>
</tr>
<tr>
<td>Speed limit compliance by drivers of passenger cars</td>
</tr>
<tr>
<td>Speed limit compliance by drivers of heavy goods vehicles</td>
</tr>
</tbody>
</table>

Table 4 shows the effects of measures to achieve the condition safe vehicles. The measures can roughly be categorized by systems that act to prevent accidents (Electronic Stability Control (ESC), automatic braking, lane departure warning (LDW) noticing unprotected road users, automatic emergency brake, safe reversing) and/or crashworthiness, although these systems to some extent work together. LDW is calculated to have the greatest potential, and for heavy goods vehicles and passenger cars together it is expected to save just over 20 lives per year; the system would thus be able to halve the number of fatalities caused by drifting out of lane. ESC systems are expected to save around 10 lives per year. The difference compared to LDW is mainly due to the number of relevant accidents being lower, which means that there are fewer accidents caused by losing control than by drifting out of lane. Automatic brakes that help drivers to avoid rear-end accidents are expected to save around three lives per year if they were installed in all passenger cars, and around two lives per year if installed in all heavy goods vehicles.

A system that gives drivers of heavy goods vehicles the opportunity to detect unprotected road users and thus prevents them from being run over should reduce the number of fatalities by a maximum of ten per year. A version of this is also safe reversing, which would prevent a further one or two fatalities per year. For unprotected road users, there is thus greater potential in preventing being run over at low speed than preventing being hit at high speed.

As concerns increased crashworthiness in new vehicles, the calculated potential is around ten lives per year, and is based on the risk of dying in a passenger car having fallen by 1.5 per cent on average each year due to increased collision safety.
Automatic emergency brakes for heavy goods vehicles are not available today, but have been included as the system is of interest for the future and, purely theoretically, could have great potential, as a large part of the accidents are collisions with oncoming traffic between heavy goods vehicles and passenger cars. As the heavy goods vehicle often is the passive part, which retains control during the course of the accident up until the collision, it should be theoretically possible to detect oncoming traffic on its way over to the wrong side of the road, activate an emergency brake when the collision is unavoidable and thus reduce the collision speed considerably. The uncertainty is for which accidents such a system would have an effect, and if so, how great this effect would be. Another question is how long before the collision an automatic emergency braking system would have to be activated and how this corresponds to the amount of time that passes from the moment the oncoming party crosses the centre line until the collision.

The target group used is head-on collisions in accidents relating to oncoming traffic and overtaking between passenger cars and heavy goods vehicles. The longest possible time between detection and collision has been assumed to be 2.5 seconds. The accidents studied in depth have then been categorized according to the length of time for detection that was possible in the individual case, as 0.5–0.9 seconds, 1–1.4 seconds, 1.5–1.9 seconds and 2.0–2.5 seconds. The magnitude of the effect is expressed as reduced risk of fatality due to reduced rate of change\(^4\) (\(\delta v\)) for the passenger car. The rate of change is of course dependent upon the approaching speed of the passenger car itself, but in particular the speed of the heavy goods

\(^4\) The rate of change is the change of speed a vehicle experiences during a collision.

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<table>
<thead>
<tr>
<th>Measures</th>
<th>Lives saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crashworthiness in new vehicles</td>
<td>8</td>
</tr>
<tr>
<td>Safe reversing by heavy goods vehicles</td>
<td>1</td>
</tr>
<tr>
<td>Heavy goods vehicles without technical faults</td>
<td>3</td>
</tr>
<tr>
<td>Electronic Stability Control systems for passenger cars</td>
<td>9</td>
</tr>
<tr>
<td>Electronic Stability Control systems for heavy goods vehicles</td>
<td>3</td>
</tr>
<tr>
<td>Lane departure warning for passenger cars</td>
<td>14</td>
</tr>
<tr>
<td>Lane departure warning for heavy goods vehicles</td>
<td>8</td>
</tr>
<tr>
<td>Automatic braking for passenger cars in rear-end collisions</td>
<td>3</td>
</tr>
<tr>
<td>Automatic braking for heavy goods vehicles in rear-end collisions</td>
<td>2</td>
</tr>
<tr>
<td>Detecting unprotected road users</td>
<td>9</td>
</tr>
<tr>
<td>Automatic emergency brake for heavy goods vehicles:</td>
<td></td>
</tr>
<tr>
<td>1. 90 km/h and 70 km/h as today</td>
<td>6</td>
</tr>
<tr>
<td>2. 90 km/h becomes 80 km/h and 70 km/h remains as today</td>
<td>9</td>
</tr>
<tr>
<td>3. 90 km/h becomes 80 km/h and 70 km/h remains as today, with safe cars</td>
<td>14</td>
</tr>
<tr>
<td>Automatic emergency brake + deformation zone + safe cars:</td>
<td></td>
</tr>
<tr>
<td>1. 90 km/h and 70 km/h as today</td>
<td>25</td>
</tr>
<tr>
<td>2. 90 km/h becomes 80 km/h and 70 km/h remains as today</td>
<td>26</td>
</tr>
</tbody>
</table>

Table 4: Effects of measures for safe vehicles.
vehicle, as the weight relationship is so unequal. For instance, a weight relationship of 1:20 (passenger car 1.5 tons and heavy goods vehicle 30 tons) and collision speed for both the passenger car and heavy goods vehicle of 80 km/h results in a delta v for the passenger car of just over 150 km/h, which produces a crash severity which in most cases cannot be survived. If, in the same example, the heavy goods vehicle instead applied an emergency brake two seconds before impact, and could reduce its speed during braking by barely 30 km/h per second\(^5\), the delta v of the passenger car would amount to around 95 km/h, which halves the risk of dying in a car that is safe according to the standard of today. The link between a change in speed and the risk of death depending on the car’s safety level is in turn taken from the power model previously used in many circumstances with this aim, and is described in Appendix 3. The result of the calculations with the system of automatic emergency brakes is accounted for in Table 4 because of slightly different starting points:

1. If the system were used on roads with the speed limit system that was used during the period 2006-2007 when the accidents studied occurred, this is calculated as saving around six lives per year.
2. If roads with the then speed limit of 90 km/h were reduced to 80 km/h, the number of lives saved would increase to nine per year.
3. The same starting point as in Item 2 above, but with a higher level of safety for the passenger car, is expected to save around 14 lives per year.

Something that would further reduce the risk of people in passenger cars dying in collisions with heavy goods vehicles, both by reduced intrusion and reduced crash severity, is a deformation zone of some type on the heavy goods vehicle. The reduced risk of dying is based on a deformation zone producing a lower average acceleration during the collision process (Appendix 3). It can be discussed how long such a deformation zone should be and exactly what function it would have, but in this study it has been assumed to be 75 cm at the front of the heavy goods vehicle. The result for this system is also accounted for with different speed limit systems, but now the starting point is the highest safety level for the passenger car:

1. If the system were used on roads with the speed limit system that was used during the period 2006-2007 when the accidents studied occurred, the system is calculated to save around 25 lives per year.
2. If roads with the then speed limit of 90 km/h were reduced to 80 km/h, the number of lives saved would increase to 26 per year.

Together, an emergency brake and deformation zone on heavy goods vehicles in combination with a high level of safety for passenger cars could theoretically save around 25 lives per year, which would more than halve the number of people killed in head-on collisions between passenger cars and heavy goods vehicles.

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\(^5\) Barely 30 km/h per second = 0.8 m/s\(^2\). This is a substantial retardation for a heavy goods vehicle, but perfectly possible according to the vehicle industry. Naturally, wet or wintry driving conditions would produce a lower retardation.
Discussion

The fact that most of those who die in oncoming road accidents with heavy goods vehicles car occupants is not surprising. The great majority of traffic on the roads consists of passenger cars, the accidents of which mainly consist of single vehicle and oncoming road accidents. However, the development of the number of fatalities in the 21st century is interesting. Although transport mileage for both passenger cars and heavy goods vehicles has increased during the period, the number of fatalities in total and in passenger cars was at a lower level in 2007 than in 2000. From 2000 up until 2005, a clear reduction occurred, but then this turned into an increase until 2007. The reduction was probably due to the large amount of roads with median barriers built starting in 2000. The fact that the number of fatalities then increases may be explained that the number of fatalities on roads without median barriers with speed limits of 90 and 70 km/h have increased at the same rate as the increase in transport mileage. Continued work on introducing median barriers would produce a continued fall in the number of fatalities on the national road network.

In the municipal road network, fatalities have not fallen over the last five years. Most of the people who are killed in urban areas are unprotected road users, and apparently the speed-reducing measures introduced for the benefit of this group in other circumstances have not had any effect on accidents involving heavy goods vehicles. This can be understood as speed is not the crucial factor for the degree of injury, but the fact that pedestrians and cyclists are run over. In order to reduce accidents in urban areas, measures are needed to prevent unprotected road users from being run over.

Foreign heavy goods vehicles have often been blamed for causing problems from an accessibility and road safety perspective in Sweden. However, this study has not found that foreign heavy goods vehicles are more prone to accidents than Swedish ones. Nor is there any reason to suspect that drivers of heavy goods vehicles of any particular age group should be at greater risk of accidents than others. On the other hand, the age of the heavy goods vehicle appears to be of importance. As the heavy goods vehicle in this study usually was passive during the course of the accident, this should have to do with a reduced degree of injury once the accident is a fact, rather than a reduced risk of accidents. The reduced degree of injury from new heavy goods vehicles may be due to rear underrun protection, which reduces the risk of the counterpart being crushed under the heavy goods vehicle, became mandatory for heavy goods vehicles coming into use as from 10th August 2003.

For passenger cars, age appears to play an even greater part for the risk of being killed in collisions with heavy goods vehicles. New cars offer greater safety, both in terms of avoiding accidents and in lessening the consequences of an accident. It can now be confirmed that the safety standard of cars is of importance also in very serious collisions with great crash severity, typical for accidents involving heavy goods vehicles.

Both the degree of injury and degree of disability suggest that collisions with heavy goods vehicles producing more serious consequences than other accidents. This is not particularly surprising, but illuminates the importance of preventing these accidents, as they both entail a high risk of people being killed and a high risk of permanent medical impairment for those involved.

In order to reduce the fatalities in accidents in which heavy goods vehicles are involved, it is therefore important to look at the potential and effect of different measures. In order to classify the measures, this study has used the categories safe roads, safe use and safe vehicles. This links with the conditions mentioned in the interim goal efforts for road safety in which many actors are involved. It also highlights the fact that the responsibility for Vision Zero for heavy goods vehicles cannot rest on one actor, but must be divided across all who work towards safe roads, safe use and safe vehicles. It can also be stated that there are even now many fatal accidents that could be avoided using measures that are today known and available. However, in order to achieve the goal, new solutions are needed, aimed at roads, users and vehicles.

The measures developed for safer roads together have the potential of saving around 70 lives per year. The biggest effect comes from median barriers as an almost 100 per cent solution for preventing accidents involving oncoming traffic and overtaking. As median barriers will not become reality on all roads carrying heavy traffic, installing rumble strips appears to be an effective measure. Safe main road intersections also have great potential. Unfortunately, no measure was found that would individually achieve such a condition with a known effect, so this is an important issue to consider in the design of new roads. It can be determined that the new 2+1 roads being built have great potential for preventing accidents involving oncoming traffic, but the intersection design and the crash severity that crossing road users are subjected to in intersections-related accidents is in principle unchanged compared to earlier road designs. Here, new creative solutions are needed. In urban areas, roundabouts have made it safer for passenger cars in collision with heavy goods vehicles, but the situation for unprotected road users is unchanged. It is not enough to introduce speed controlled pedestrian crossings, but solutions are needed to prevent cyclists and pedestrians from being run over by heavy goods vehicles, whose drivers have difficulty seeing those who are close to the heavy goods vehicle.

Safe use has previously been difficult to define, but has lately been emphasized as a component of increased road safety, just as have safe roads and safe vehicles. Of the three elements proposed for inclusion in the concept safe use – road user behaviour, consumer behaviour and citizen behaviour – it is road user behaviour that has been taken into consideration in this study. In purely hypothetical terms, it could of course be possible also to have included consumer and citizen behaviour (which has been done to a certain extent by measuring, for instance, the benefit of everybody buying and travelling in new, safe passenger cars), but this has not been the focus or any expressed aim. The conditions of use measures in the accidents are about speed, sobriety and seatbelt use, as well as well secured loads.
The greatest potential for reducing fatalities is sober drivers of passenger cars, with 13 lives per year. Of course, the starting point that sober drivers would have avoided the accident is uncertain, but still totally reasonable. Sober drivers of heavy goods vehicles does not have such a great potential, but is still of great important, as each case of an inebriated driver of a heavy goods vehicle can have serious consequences. This is something that has become clear in several highly publicized accidents, where inebriated drivers of heavy goods vehicles have caused accidents with a number of fatalities. The utmost importance is also given to the issue, as professional drivers also are role models, both privately and in their professional capacity, and with their citizen behaviour have an effect and influence on the behaviour of other road users.

Well secured loads is often cited as being important for road safety, and quite rightly so, as the consequences of dropped or unsecured goods can be disastrous. However, the number of fatal accidents is not that great, which makes the potential of increasing work on well secured loads relatively small. The issue has also been worked on consciously for a long period, and relatively high safety awareness and safe use in this area should therefore already exist.

In general, compliance with speed limits is the condition that has the greatest potential for saving lives in traffic. Earlier calculations using the power model shows that if everybody maintained the speed limits, around 150 lives would be saved each year. However, in collisions with heavy goods vehicles, the potential does not appear to be as great. The hypothesis that speed and safety class of the passenger car do not play any role in collisions with heavy goods vehicles has in itself been refuted, as it proved that safe cars in general also increase the chances of surviving these collisions. However, in this case it has been proved that only a few lives would be saved each year if passenger cars and heavy goods vehicles kept within the speed limits. However, in order for this figure to be certain, the collision speed must be known to be able to assess the chance of survival if the collision speed had been the same as the speed limit. As the collision speed is unknown in around half the accidents, there is consequently a number of unknown cases and the assessed effect is an underestimate. The potential for compliance with speed limits in collisions with heavy goods vehicles should therefore be greater than can be shown in this study.

As mentioned in the results, the potential of seatbelt use is also uncertain. The uncertainty lies in the fact that some cases lack a medical assessment of whether the deceased would have survived if a seatbelt had been used. In general, a seatbelt is the most effective protection system, as half of those who die not wearing a seatbelt in passenger cars would have survived with a correctly used seatbelt. When it comes to passenger cars in collision with heavy goods vehicles, it might be thought that the great crash severity that the person in the passenger car is subjected to could not be survived despite a seatbelt being worn. It is another matter if both parties had maintained the speed limit. In this case, the chances of survival would probably be much greater and thus also the potential of wearing a seatbelt. In heavy goods vehicles though, the potential is greater, in particular in relation to the number of fatalities in heavy goods vehicles. Of the total around ten persons who die each year in a heavy goods vehicle, half would have survived if all had used a seatbelt.
The division into passive (crashworthiness) and active (accident prevention) vehicle safety systems is imperfect when it comes to understanding the course of an accident as a whole. But in this analysis, the division is of benefit, as the effect of each individual system becomes easy to understand.

The effect of passive systems has been calculated as eight lives per year. The calculation is based on the assumption that new vehicles are much safer in a collision compared to older ones, and the condition of 100 per cent new passenger cars. An uncertainty in the calculation is the assumption that the generally improved crashworthiness can be implemented also in collisions with heavy goods vehicles. However, it stands to reason that a car with better crashworthiness in general would also be safer in a collision with a heavy goods vehicle.

Of the active safety systems, lane departure warning is calculated to have the greatest potential of reducing fatal accidents between passenger cars and heavy goods vehicles: fourteen and eight lives respectively for passenger cars and heavy goods vehicles. The potential is greater than electronic stability control, for instance, as this is assessed as being about half as great, saving around ten lives per year. As the effects of both the systems are of the same magnitude, it is the number of relevant accidents that makes the difference. Quite simply, more accidents happen through drifting out of lane, which is when passenger cars and heavy goods vehicles drive off course into an oncoming lane of traffic, than through loss of control. There is no determined effect relation for lane departure warning systems, which is an uncertainty factor. One could, for instance, speculate that the system may encounter problems in difficult winter driving conditions or with unclearly painted or worn road markings. How great the problems would be is difficult to say. But as most of the accidents in this analysis occur on the larger road network, where the standard of road surfaces and winter maintenance is good, it is perhaps a marginal problem.

Forward collision warning in rear-end collisions is available on the market today and is an example of systems that work both to prevent accidents but also to reduce damage if the collision is unavoidable, so called mitigation. In order to simplify the calculation, it has been assumed that the system prevents fatal rear-end accidents, either by completely avoiding the accidents or by mitigating the consequences – so that it is not a fatal accident. The potential of such a system is calculated at five lives saved per year, of which three in passenger cars and two in heavy goods vehicles. Rear-end accidents do not only occur between cars, but also by cars driving into unprotected road users. There is thus the opportunity to increase the potential of these systems by developing them to detect also unprotected persons, such as motorcyclists and moped drivers. These can also be extra difficult for a driver to detect in queues formed on major roads, where fatal rear-end collision accidents occur most often.

However, the great potential in detecting unprotected road users lies not in preventing rear-end accidents at high speed, but in preventing running somebody over in a urban area. Around ten persons per year die by being run over or reversed over in urban areas at low speed. The running over occurs from all directions of the heavy goods vehicle, but mainly from the
In-depth analysis of accidents with heavy goods vehicles

in the front and from the side. Being run over from the front occurs when the heavy goods vehicle starts from stationary and “overlooks” the unprotected person, and from the side when the heavy goods vehicle is turning and the unprotected person ends up between the axles and then under one of the back wheel pairs. A number of accidents where cyclists and pedestrians have ended up under the heavy goods vehicle with entry from the side have occurred, despite the heavy goods vehicle having side underrun protection designed to prevent this particular occurrence. This indicates that these side underrun protection systems are not sufficient. Better side underrun protection systems, mirrors that increase the heavy goods vehicle driver’s field of vision and active systems that alert the driver to unprotected road users are necessary to reduce fatal accidents in urban areas.

In some cases, technical shortcomings in the heavy goods vehicle, such as poor brakes, tyres, etc, have been of crucial importance for the accident arising. If these faults had not existed, around three lives per year could have been saved. Such crucial faults of heavy goods vehicles could possibly be traced to safe use, as they mainly relate to handling in the form of maintenance than the characteristics of the vehicle itself. But for the sake of simplicity, vehicles without technical shortcomings have been placed in the category safe vehicles.

As great efforts are made to check the condition of heavy goods vehicles through annual inspections, flying inspections, service and maintenance, etc, one could believe that the safety problem of vehicle faults and thus the potential should be greater. But perhaps the same logic as for well secured loads can be used. This is that efforts in this area over the years have made technical faults in vehicles that cause accidents more and more rare. The great investments in vehicle maintenance is probably also motivated by financial reasons and not just by road safety reasons.

As mentioned before, the collision speed of a heavy goods vehicle is by far the most important parameter for reducing the risk of car occupants cars being killed in collisions with heavy goods vehicles. Automatic braking systems on heavy goods vehicles thus appear to be a system with great potential. This is partly because it works to reduce speed, and partly because most of the fatal accidents with heavy goods vehicles involved are head-on collisions with passenger cars, and partly because the heavy goods vehicle often retains control over the course of the accident up to the collision.

The calculated effect of automatic emergency braking varied a lot, depending on the preconditions assumed, which is not particularly remarkable. With cars and speed limits from the period during which the accidents in the study occurred, namely 2006-2007, the potential is relatively small based on the number of relevant accidents. Out of all car occupants who were killed in oncoming traffic accidents, only 7 per cent could have been saved if all heavy goods vehicles had been equipped with automatic emergency brakes. However, the effect increases quickly if the speed limit were to be lowered to, for instance, 80 km/h where it is now 90 km/h and the impact safety of passenger cars were improved. A difficult crucial parameter is the time for applying the emergency brakes a heavy goods vehicle has. Of course, this time period depends on the design of the road environment (road width, road markings, etc) but also on the way in which the passenger car is driven over into the lane of the heavy goods vehicle (drifting...
out of lane or loss of control). The earlier the system can detect that the counterpart is on its way over into the lane of oncoming traffic, the earlier the emergency brakes can be engaged and the lower the collision speed of the heavy goods vehicle. As mentioned, this factor is crucial, as each second or even tenth of a second earlier the heavy goods vehicle can brake, the better the chances of surviving in accordance with the power model.

Something that would really create an effect is a combination of automatic braking system, safe passenger cars and also a deformation zone on the heavy goods vehicle. There are two prime reasons why a deformation zone would increase the chances of survival in a collision with a heavy goods vehicle. The first reason is that the time of collision is extended, which produces a lower average acceleration for the same rate of change as without the deformation zone. The second reason is that the deformation of the passenger car would reduce and be replaced by deformation of the heavy goods vehicle. After all, in many cases it is not the crash severity that kills people in passenger cars, but the great intrusion into the coupé of the car, in particular in head-on collisions with little overlap. The model for calculating the further effect of the deformation zone is based on having a greater chance of survival at the same rate of change. There is today no empirically developed relation that describes this reduction in risk, which makes the assumption uncertain. However, the potential should, like all other potentials in this study, be regarded as a pointer rather than as an absolute truth.

The combination of deformation zone, safe cars, lower speed limits and automatic emergency brakes should, in theory, reduce the number of fatalities by around 25 per year. This is a halving of the number of fatalities in head-on collisions. Of course, a deformation zone would reduce the degree of injury in other types of accidents, such as intersection accidents or rear-end accidents, but not sufficiently in order to provide any great effect in itself. For these types of accidents too, crashworthiness needs to be complemented with other “mitigating” and accident-preventing systems in order to reduce crash severity to a survivable level.

A few large challenges remain, where crash severity during accidents with heavy goods vehicles is so large that it is difficult to see today how it would be possible to manage such accidents in future. This applies in particular to side collisions in oncoming road accidents and intersection-related accidents on main roads. It is clear that collision speed on these occasions must be reduced until the heavy goods vehicle is almost stationary, and thus that accident-preventing intelligent systems are required to save lives in this type of accident.

This study shows clearly that there are many effective measures with great potential for reducing the number of fatalities in accidents with heavy goods vehicles. The most effective measures are concerned mainly with rebuilding the road environment and thus making oncoming traffic with heavy goods vehicles impossible. Whilst rebuilding is in progress, this is a solution that will take effect in the very long run. What applies particularly to the minor road network is that one should not expect median barrier to be in place within the foreseeable future. For this reason, a combination of safe roads, safe use and safe vehicles is needed in order to reduce fatal accidents. If we achieve road safety conditions within these areas, we can
save a great number of lives. It is also important to keep up with technical developments and to adapt the road transport systems according to these new conditions. Perhaps intelligent vehicle systems in the future will be so effective at preventing accidents in certain environments that expensive road measures, that would normally prevent these accidents, can be concentrated to road environments where the vehicle systems have difficulty working in a satisfactory manner.
Conclusion

This study shows that there are many effective measures with great potential for reducing the number of fatalities in accidents with heavy goods vehicles.

- The potential of measures related to safe roads would reduce the number of fatalities by around 75 per cent, or 70 fatalities per year.
- The potential of measures related to safe use would reduce the number of fatalities by just over 20 per cent, or 20 fatalities per year.
- The potential of measures related to safe vehicles would reduce the number of fatalities by 65 per cent, or 65 fatalities per year.
- The greatest individual effects are produced by median barriers (54 %), rumble strips (20 %), sober passenger car drivers (13 %), lane departure warning systems (15 %) and emergency brakes + deformation zone (27 %).
- A combination of emergency brakes and deformation zone on heavy goods vehicles would reduce the number of fatalities in frontal collisions by just over 50 per cent.
- A great challenge is posed by side collisions with oncoming traffic and intersections on main roads.
References


Appendix 1: Degree of injury and degree of disability

DEGREE OF INJURY

ISS shows the mortality risk for a person based on the three most seriously injured body regions on a person assessed by healthcare (the sum of the squares of the injury with the highest AIS for the three body regions) ISS 1-8 shall be interpreted as mild injury, ISS 9-15 as severe injury and ISS >15 as very serious injury.

DEGREE OF DISABILITY

The basis for Folksam’s model of the injuries that cause disability are studied of the extent to which injuries with different AIS levels result in permanent disability (table 5).

<table>
<thead>
<tr>
<th>AIS 1 (per cent)</th>
<th>AIS 2 (per cent)</th>
<th>AIS 3 (per cent)</th>
<th>AIS 4 (per cent)</th>
<th>AIS 5 (per cent)</th>
</tr>
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<tbody>
<tr>
<td>Face</td>
<td>0.4</td>
<td>6.0</td>
<td>60.0</td>
<td>60.0</td>
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<td>3.0</td>
<td>8.0</td>
<td>35.0</td>
<td>75.0</td>
</tr>
<tr>
<td>Neck/throat</td>
<td>2.5</td>
<td>10.0</td>
<td>30.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Upper back</td>
<td>0.0</td>
<td>7.0</td>
<td>20.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Lower back</td>
<td>0.1</td>
<td>6.0</td>
<td>6.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Abdomen</td>
<td>0.0</td>
<td>0.0</td>
<td>4.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Arm</td>
<td>0.3</td>
<td>3.0</td>
<td>15.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Leg</td>
<td>0.0</td>
<td>3.0</td>
<td>10.0</td>
<td>40.0</td>
</tr>
</tbody>
</table>

The comparison of a collision between a heavy goods vehicle and a passenger car in this study is done at injury level. The result should therefore be interpreted as the difference in risk for a person in a passenger car of an injury leading to at least 10 per cent disability (table 6).

<table>
<thead>
<tr>
<th></th>
<th>pc vs pc</th>
<th>pc vs pc</th>
<th>pc vs pc</th>
<th>pc vs hgv</th>
<th>pb vs hgv</th>
<th>pb vs hgv</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>number</td>
<td>percentage</td>
<td>Total</td>
<td>number</td>
<td>percentage</td>
</tr>
<tr>
<td></td>
<td>injured</td>
<td>injured</td>
<td></td>
<td>injured</td>
<td>injured</td>
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</tr>
<tr>
<td>Face</td>
<td>3 078</td>
<td>42</td>
<td>1.3</td>
<td>598</td>
<td>37</td>
<td>6.2</td>
</tr>
<tr>
<td>Head exkl. face</td>
<td>3 272</td>
<td>464</td>
<td>14.2</td>
<td>694</td>
<td>219</td>
<td>31.6</td>
</tr>
<tr>
<td>Neck/throat</td>
<td>24 370</td>
<td>710</td>
<td>2.9</td>
<td>1 697</td>
<td>60</td>
<td>3.5</td>
</tr>
<tr>
<td>Upper back</td>
<td>1 881</td>
<td>41</td>
<td>2.2</td>
<td>220</td>
<td>17</td>
<td>7.8</td>
</tr>
<tr>
<td>Thorax</td>
<td>6 972</td>
<td>83</td>
<td>1.2</td>
<td>1 243</td>
<td>50</td>
<td>4.0</td>
</tr>
<tr>
<td>Lower back</td>
<td>1 736</td>
<td>23</td>
<td>1.3</td>
<td>186</td>
<td>4</td>
<td>2.3</td>
</tr>
<tr>
<td>Abdomen</td>
<td>1 703</td>
<td>10</td>
<td>0.6</td>
<td>404</td>
<td>7</td>
<td>1.7</td>
</tr>
<tr>
<td>Arm</td>
<td>5 780</td>
<td>66</td>
<td>1.1</td>
<td>894</td>
<td>22</td>
<td>2.4</td>
</tr>
<tr>
<td>Leg</td>
<td>5 853</td>
<td>100</td>
<td>1.7</td>
<td>1 023</td>
<td>38</td>
<td>3.7</td>
</tr>
<tr>
<td>All body regions</td>
<td>54 645</td>
<td>1 539</td>
<td>2.8</td>
<td>6 959</td>
<td>454</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Table 5: The risk that an injury causes at least 10 per cent disability. Source: Folksam

Table 6: Comparison between the proportion of disability-producing injuries for persons in passenger cars in collision with a passenger car and a heavy goods vehicle. N=61 604. Source: Strada healthcare.
There is a difference in the classification of injuries between Strada and Folksam, which means that there may be differences in the results. The difference lies mainly in that many diagnoses of less severe injuries have been grouped together into one group by Folksam, while in Strada they are included in the injury type other, divided up over different body regions. Thus, with Strada’s current classification, the calculation of how many will receive a disability-producing injury to a certain body region differs somewhat from what would have been the case if the injuries had been sorted in the same way as in the Folksam risk table.

As far as the results in this study are concerned, there should thus be some reservation against the absolute levels in diagram 11 and tabell 6. It should however be possible to use the comparison in diagram 11 between a collision with a passenger car and a heavy goods vehicle respectively, as the same data and model form the basis for both calculations.
Appendix 2: Questions and basis for calculation of effect

**MEDIAN BARRIER**

*Question:* How many lives could be saved if all roads carrying heavy goods vehicles had median barrier?

*Basis for calculation of effect:* 100 per cent reduction in accidents involving oncoming traffic and overtaking.

*Number of lives saved each year:* 51

**RUMBLE STRIPS**

*Question:* How many lives could be saved if all roads carrying heavy goods vehicles were equipped with central and side rumble strips?

*Basis for calculation of effect:* 50 per cent reduction in accidents where the course of events started with drifting out of line.

*Number of lives saved each year:* 19

**SAFE INTERSECTIONS IN URBAN AREAS**

*Question:* How many lives could be saved if all intersections in urban areas with heavy traffic were roundabouts?

*Basis for calculation of effect:* 100 per cent reduction in intersection-related accidents in urban areas.

*Number of lives saved each year:* 4

**SAFE INTERSECTIONS ON MAIN ROADS**

*Question:* How many lives could be saved if all intersections on main roads were safe?

*Basis for calculation of effect:* 100 per cent reduction in intersections-related accidents on main roads.

*Number of lives saved each year:* 13
SPEED CONTROLLED PEDESTRIAN AND BICYCLE CROSSINGS

*Question:* How many lives could be saved if all pedestrian and bicycle crossings in urban areas with heavy traffic were speed controlled?

*Basis for calculation of effect:* 100 per cent reduction in cyclists and pedestrians hit by a heavy goods vehicle on pedestrian and bicycle crossings.

*Number of lives saved each year:* 2

SAFE REVERSING BY HEAVY GOODS VEHICLES

*Question:* How many lives would be saved if all reversing of heavy goods vehicles in urban areas was safe or prohibited?

*Basis for calculation of effect:* 100 per cent reduction in cyclists and hit by a reversing heavy goods vehicle in urban areas.

*Number of lives saved each year:* 1

SOBER DRIVERS OF PASSENGER CARS

*Question:* How many lives could be saved if all drivers of passenger cars were sober (estimation of maximum benefit)?

*Basis for calculation of effect:* 100 per cent reduction in fatalities where a driver of passenger car under the influence of alcohol caused the accident.

*Number of lives saved each year:* 13

SOBER DRIVERS OF HEAVY GOODS VEHICLES

*Question:* How many lives could be saved if all drivers of heavy goods vehicles were sober (estimation of maximum benefit)?

*Basis for calculation of effect:* 100 per cent reduction in fatalities where a driver of a heavy goods vehicle under the influence of alcohol caused the accident.

*Number of lives saved each year:* 1

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7 As it cannot be assumed that the accident would have been avoided with a sober driver, meaning that the alcohol was the crucial cause of the accident, the result is an estimation of maximum benefit.
SEATBELTED DRIVERS OF PASSENGER CARS

Question:
How many lives could be saved if all drivers of passenger cars wore seatbelts?

Basis for calculation of effect:
Deduction of all unbelted drivers of passenger cars who according to a doctor would have survived with a belt.

Number of lives saved each year: 1

SEATBELTED DRIVERS OF HEAVY GOODS VEHICLES

Question:
How many lives could be saved if all drivers of heavy goods vehicles wore seatbelts?

Basis for calculation of effect:
Deduction of all unbelted drivers of heavy goods vehicles who according to a doctor would have survived with a belt.

Number of lives saved each year: 5

HEAVY GOODS VEHICLES WITHOUT FAULTS

Question:
How many lives could be saved if all heavy goods vehicles were without technical faults?

Basis for calculation of effect:
100 per cent reduction in fatalities where technical faults in a heavy goods vehicle caused the accident.

Number of lives saved each year: 3

WELL SECURED LOADS

Question:
How many lives could be saved if all loads were well secured?

Basis for calculation of effect:
100 per cent reduction in fatalities where the load of a heavy goods vehicle caused the accident.

Number of lives saved each year: 1
ELECTRONIC STABILITY CONTROL SYSTEMS ON PASSENGER CARS

Question:
How many lives could be saved if all passenger cars were equipped with ESC systems?

Basis for calculation of effect:
80 per cent reduction in fatal accidents where the initial event of the course of the accident was loss of control of a passenger car.

Number of lives saved each year: 9

ELECTRONIC STABILITY CONTROL SYSTEMS ON HEAVY GOODS VEHICLES

Question:
How many lives could be saved if all heavy goods vehicles were equipped with ESC systems?

Basis for calculation of effect:
100 per cent reduction in fatal accidents where the initial event of the course of the accident was loss of control of a heavy goods vehicle.

Number of lives saved each year: 3

LANE DEPARTURE WARNING FOR PASSENGER CARS

Question:
How many lives could be saved if all passenger cars were equipped with LDW systems?

Basis for calculation of effect:
50 per cent reduction in fatal accidents where the initial event of the course of the accident was a passenger car drifting off course.

Number of lives saved each year: 14

LANE DEPARTURE WARNING FOR HEAVY GOODS VEHICLES

Question:
How many lives could be saved if all heavy goods vehicles were equipped with LDW systems?

Basis for calculation of effect:
50 per cent reduction in fatal accidents where the initial event of the course of the accident was a heavy goods vehicle drifting off course.

Number of lives saved each year: 4

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8 The effect relationship is an assumption after in-depth study of the relevant accidents.
9 Systems that warn the driver when the car is in the process of leaving the traffic lane.
DETECTION OF UNPROTECTED ROAD USERS

Question:
How many lives could be saved if all heavy goods vehicles were equipped with a system that detected unprotected road users at low speed?

Basis for calculation of effect:
100 per cent reduction in pedestrians and cyclists hit and run over on roads with speed limits of 30 and 50 km/h.

Number of lives saved each year: 9

CRASHWORTHINESS OF NEW VEHICLES

Question:
How many lives could be saved if all passenger cars had today’s level of crashworthiness?

Basis for calculation of effect:
1.5 per cent reduction of risk per model year for fatal accidents. 2006 is counted as “today” as the first accidents in the analysis occurred then.

Number of lives saved each year: 8

AUTOMATIC BRAKING FOR PASSENGER CARS IN REAR-END COLLISIONS

Question:
How many lives could be saved if all passenger cars were equipped with forward collision warning in rear-end collisions?

Basis for calculation of effect:
100 per cent reduction in rear-end accidents where a passenger car drives into a heavy goods vehicle in front of it.

Number of lives saved each year: 3

AUTOMATIC BRAKING FOR HEAVY GOODS VEHICLES IN REAR-END COLLISIONS

Question:
How many lives could be saved if all heavy goods vehicles were equipped with automatic braking to avoid rear-end collisions?

Basis for calculation of effect:
100 per cent reduction in rear-end accidents where a heavy goods vehicle drives into a vehicle in front of it.

Number of lives saved each year: 2
Appendix 3: 
Link between speed and risk of fatality

AUTOMATIC EMERGENCY BRAKE

The link between speed and the risk of a fatality in a road accident can be described using what is called the power model:

\[ Y^1 = \left( \frac{v_1}{v_0} \right)^{3.5} \cdot Y^0, \]

Where \( Y_0 \) is the number of fatalities before any change in speed, \( Y_1 \) is the number of fatalities after the change, \( v_0 \) is the original speed and \( v_1 \) the new speed.

In this study, the speed in the power model is the rate of change or delta \( v \). As the starting point for calculating risk curves, it is assumed there is a 10 per cent risk of being killed in a passenger car with delta \( v \) of 65 km/h and 75 km/h respectively depending on the safety standard. The risk curves are thus not empirically produced, but calculated with the aid of the power model and with different starting points. The curves can be seen in diagram 12.

Diagram 12: Link between the risk of a fatality and rate of change, delta \( v \).
In a head-on collision between a heavy goods vehicle and a passenger car, delta v can as previously mentioned amount to over 150 km/h, which few people would survive, as can be seen from the risk curves in diagram 12. If an automatic emergency brake is instead applied with different time intervals, delta v reduces for the passenger car and thus also the risk of a fatality in accordance with diagram 13. With two seconds of emergency braking on a road with the speed limit 90 km/h, the risk of a fatality thus falls to, on estimate, between 25 and 40 per cent.

**Diagram 13: Increased survival potential with automatic emergency brake.**

The relationship between speed and risk of a fatality

AUTOMATIC EMERGENCY BRAKE AND DEFORMATION ZONE

In two collisions with the same rate of change, people in passenger cars in collision with heavy goods vehicles with and without deformation zone would have a greater chance of survival in the former, as having the deformation zone would cut the average acceleration during the course of the collision. This can be illustrated by moving the risk curves to the right in accordance with Diagram 15. The risk of being killed in a head-on collision is then, with automatic emergency braking after two seconds and a deformation zone of 75 cm, between 10 and 20 per cent.
Diagram 14: Increased survival potential with automatic emergency brake and deformation zone.