



**6th International Symposium on
Heavy Vehicle Weights and Dimensions**
Saskatoon, Saskatchewan, Canada June 18 - 22, 2000

Countermeasures for Safer Commercial Vehicles

**By Iain Knight and Ian Simmons
The Transport Research Laboratory
UK**

Abstract

Commercial vehicles account for 7% of all traffic (by distance travelled) in the UK but they are involved in nearly 17% of all UK road traffic accident fatalities. This results in an annual toll of approximately 600 fatalities with an associated cost to society of an estimated £570 million per year. This paper discusses the merits of a number of vehicle design countermeasures that have the potential to substantially reduce the number and severity of commercial vehicle accidents.

The countermeasures discussed include underrun protection to the front rear and side of trucks, rollover warning and reduction devices, and advanced electronic control systems for impact prediction, occupant and pedestrian protection. All of these systems are evaluated against real world accident data and are ranked in order of the number of lives per year that they are estimated to be capable of saving.

1.0 INTRODUCTION

The Transport Research Laboratory (TRL) has been involved in Heavy Goods Vehicle (HGV) safety research for many years. The programme of research has involved identifying problem areas from studies of accident statistics, developing and testing vehicle design countermeasures and evaluating them in accident studies to prioritise future research and legislative action.

In the UK many people instinctively feel that, because of their size and weight, there is little that can be done to protect people when they become involved in accidents involving HGVs. However, research has shown that this is not the case. This report will begin by defining the number of commercial vehicle accidents in the UK and will then describe work on various safety devices, or countermeasures, identified by TRL and others as having the potential to substantially reduce accident and injury levels. Wherever an assessment is available the potential of the countermeasure will be evaluated in terms of the number of UK lives that could be saved annually by fitting it to all relevant vehicles.

2.0 HGV ACCIDENTS IN THE UK

There are approximately 420,000 HGVs registered in the UK out of a total of nearly 27 million vehicles and they constitute just 7% of all vehicle traffic (by distance travelled). However, an HGV is involved in 17% of all road traffic accident fatalities in the UK. Less than 2% of all people injured on UK roads receive injuries that prove fatal. For accidents involving HGVs, just over 3% of people injured are killed. These statistics demonstrate that HGVs are much more likely to cause a fatality when they become involved in an accident than other vehicle types.

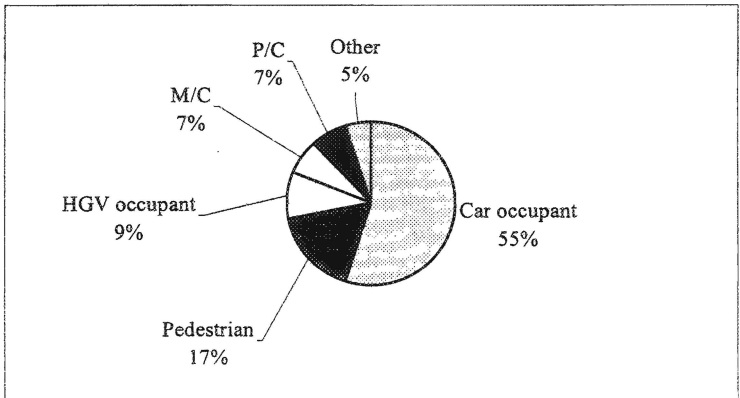


Figure 1. Breakdown of road users killed in UK HGV accidents

As might be expected given the size of HGVs, their occupants are less frequently killed than other road users that become involved in accidents with them. Figure 1 shows that car occupants are by far the most common road users to be killed in accidents involving HGVs. This demonstrates that it is important for manufacturers and operators to consider the safety of other road users as well as the occupants of their vehicles. Injuries to third parties can substantially increase accident costs through personal injury claims and can have a very detrimental effect on a company's public image.

3.0 COUNTERMEASURES

Previous accident studies (Knight, 1998) have suggested that vehicle design features can significantly influence accident and injury rates. For example it can be shown that the incidence rate of pedal cyclists killed after a collision with the side of an articulated vehicle has fallen by more than 65% since the introduction of a law requiring sideguards to be fitted to all semi-trailers.

This section will describe a range of commercial vehicle-based countermeasures, from basic mechanical designs to advanced 'intelligent' electronic systems, that are currently being considered by TRL.

3.1 Front underrun protection

The single most common HGV accident type in the UK is a head-on frontal collision between a car and an HGV. Approximately 150 car occupants lose their life every year in this type of collision in the UK alone. In the majority of these accidents the car runs underneath the front of the HGV in such a manner that the energy-absorbing frontal structure of the car is deformed by only a minimal amount and the front of the HGV comes into contact with the 'A' pillar region of the car. The result of this is considerable intrusion into the passenger compartment of the car and usually severe head and chest injuries to front seat occupants often resulting from direct contact between occupant and HGV.

In this type of collision the intrusion into the cars' passenger compartment, and hence the chances of an occupant surviving, could be dramatically improved by equipping the HGV with a rigid front underrun guard. Essentially this involves placing a strong rigid structure across the whole front of an HGV at car bumper height (typically 300-400mm). This allows the energy-absorbing front structure of the car to be effective and prevents direct contact between HGV and occupant. Tests conducted at TRL in the 1980's demonstrated the effectiveness of this concept and further work by EEVC working group 14 estimated that a 56 kph, 75% offset, car to truck collision would be survivable for restrained car occupants. TRL have estimated that fitting a rigid front underrun guard to all HGVs in excess of 3500 kg gross would reduce the number of UK fatalities by 34 per year. A European directive requiring these devices has been published and is under consultation in the UK. It is expected that it will become law in the near future.

Further safety improvements could be made if the underrun guard was designed such that it not only allowed the energy-absorbing characteristics of the car to be used, but also absorbed part of the collision energy itself. Effectively the underrun guard would have an energy-absorbing phase to improve the 'ride down' characteristics for the car occupants, followed by a rigid phase to prevent underrun occurring. Research suggests (EEVC WG14, 1996) that energy-absorbing front underrun guards will allow a 75 kph, 75% offset, car-to-truck collision to be survivable. It is predicted (Knight, 2000) that this could prevent the deaths of up to 50 car occupants in the UK every year.

A further development of the underrun protection concept is currently being considered at TRL. For an underrun guard to absorb energy part of it has to deform or move. However, there is very limited space underneath the front of a vehicle to accommodate this crush/movement. This means that the stiffness of the energy-absorbing phase has to be high to enable significant amounts of energy to be absorbed. Systems that have been developed to-date are therefore tuned to absorb an appropriate amount of energy for a particular size of vehicle at a particular speed. Sensors are now being developed that have the potential to detect an imminent impact and to identify the size and speed of the impacting object. TRL are engaged in research to refine these sensors such that their output can be used to set up an adaptive underrun device so that it is in the correct position and absorbs the appropriate amount of energy for the particular collision that they are about to become involved in. Since this concept is in its early stages the potential of such a device has not yet been evaluated in terms of real world injury reduction yet, so it is not possible to estimate how many lives that it might be capable of saving.

3.2 Rear underrun protection

When a car collides with the rear of an HGV it tends to run underneath it in the same fashion as described for frontal impacts and rear-underrun protection has therefore been a legal requirement in the UK since 1983. However, around 22 car occupants are still killed in this type of collision each year despite the fact that the relative collision speeds in this type of impact are typically much lower than for head-on collisions. One criticism of current rear underrun protection is that it is often found to fail in higher speed or low overlap collisions. Accident statistics (Knight 2000) suggest that strengthening rear guards such that this does not occur and ending the legal exemptions for certain vehicle types (mainly tipping vehicles) could prevent the deaths of 8 people per year. It is also estimated that fitting energy-absorbing rear guards with the same capabilities of energy-absorbing front guards could prevent 12 deaths per year, if fitted to all HGVs. Again impact detection sensors could be used to create an adaptive rear underrun device that could provide still greater benefits.

3.3 Rollover prevention

Rollover of heavy commercial vehicles has been an acknowledged problem for many years now. There are approximately 500 instances of HGV rollover every year in the UK and 40% of all fatally injured HGV occupants were travelling in a vehicle that rolled. Other

road users are also at risk with approximately twenty-three car occupants killed in collisions where a HGV rolled over at some point during the accident.

Good mechanical design of an HGV and its load has the potential to reduce the number of rollover incidents by increasing the stability of the vehicle. However, it is unlikely that the stability can be increased sufficiently to make the rollover threshold of a vehicle loaded with medium density goods higher than the coefficient of friction between the tyres and road. This means that rollover is likely to remain the most common outcome when a vehicle is driven too fast around a bend.

Appropriate driver training and awareness programmes might also reduce the frequency of rollover accidents. However, drivers of articulated vehicles are very much isolated from the behaviour of their trailer. Since the trailer is usually the dominant element in a rollover it can be very difficult for a driver to detect imminent rollover until it is too late.

At TRL we are leading a collaborative project to develop a device capable of monitoring the likelihood of rollover in service. The technology is derived from a sensor used for on-board axle weighing systems and monitors dynamic wheel loads across the rearmost axle of a vehicle. As the vehicle leans to one side during a corner, more and more of its weight is supported on one side of the axle. Once the load on a wheel reaches zero that wheel has lifted away from the ground and the likelihood of rollover can be considered to be 100%. The sensing technology has now been proved by full-scale track tests to correlate well with lateral acceleration. However, at present the signal obtained can only be used for monitoring likelihood of rollover. This can provide extremely useful fleet management data but the device will be of considerably more use when the second phase of the project is complete. This is intended to transform the device into a closed loop system capable of early detection of an imminent rollover. The system will then physically intervene to prevent the rollover from occurring. Modelling of HGV suspension in rollover has suggested that the most effective way to achieve this will be by direct intervention to reduce vehicle speed.

This type of closed loop device will not eliminate rollover accidents because it can do nothing about rollovers after collisions or rollovers as a result of leaving the carriageway and rolling into a ditch. However, accident studies (Knight, 2000) estimate that it could prevent the deaths of up to 12 road users per year.

3.4 "Pedestrian Friendly" front ends

In general, vehicle manufacturers tend to concentrate on providing protection for the occupants of their vehicles. There has been relatively little progress in developing techniques to provide protection for pedestrians or pedal cyclists.

There have been some minor measures implemented on cars; for example, removing sharp edges such as door handles, wing mirrors and mascots. However, these measures are modest and there is considerable potential to improve pedestrian protection measures on the

vehicle. The heavy goods vehicle industry has successfully improved the protection of pedal cyclists and pedestrians with the use of sideguards, although accident studies show that there is still scope for the improvement of these devices. However, little has been done to improve the front end of the vehicle.

Examination of the injuries most frequently found in collisions between HGVs and pedestrians suggests that it is unlikely that the pedestrian will benefit significantly if the impact speed is greater than 30 miles/hr. Ideally, a "pedestrian friendly" front end would be flat and lined with a "soft" face to cushion the initial impact. This could be combined with a device that prevents the pedestrian from being run over by the impacting vehicle. The benefits of the system will also apply to collisions with pedal cyclists.

One way to achieve this could be the use of so-called "soft" body structures. A deliberately soft crush zone at the front of the vehicle would reduce the magnitude of initial impact between a vehicle and a pedestrian. This could be achieved using honeycomb structures, deformable plastics, or advanced viscous fluids.

A more comprehensive solution could be provided by the use of a predictive pedestrian sensing system. These systems sense the presence of a pedestrian before an impact actually occurs and they offer the only way of providing sufficient time to set up protection measures such as airbags on the frontal exterior of a vehicle.

A predictive pedestrian protection system requires three elements. Firstly, the sensor must provide sufficient information to permit a foolproof detection of a pedestrian, as opposed to a tree, car, road furniture, etc. Secondly, the electronics must interpret this data to give range and relative velocity of the pedestrian, both of which are required to activate the safety system correctly. Thirdly, the system must deploy its device(s) at the correct time. A system that reacts only on contact with a pedestrian cannot work on a commercial vehicle with a flat front that contacts all body regions virtually simultaneously. Thus it makes sense to consider a pre-impact system, triggered by the presence of a pedestrian in a position highly likely to be impacted by the car. The sensor swept area will need to be up to 5m in front, and up to 1m to the side to cater for a person running out in front of the vehicle, or one who the driver has not seen.

It is important that the predictive system will reliably determine the collision conditions as errors could prove fatal. However, the technology is developing rapidly and it is anticipated that it will reach a level that can provide the necessary levels of reliability. In addition, it may be possible for short-range (less than 2 metres) sensors to be used that could reduce the likelihood of errors and simplify the algorithms needed for the data processing.

Details of the injury reduction potential of inflatable devices on the front of vehicles have not been fully evaluated as yet. However, if it is assumed that a passive "soft front" system would be capable of protecting fit mature adults, that were not run over, at speeds of up to 25 miles/hr then accident analysis (Knight, 2000) suggests that the deaths of 6 pedestrians a year could be prevented. This was evaluated using very cautious criteria because devices

have not yet been tested and the advanced predictive systems could offer significantly improved benefits.

3.5 All-round detection

An investigation of the available accident data has shown that a number of accidents occur when pedestrians or cyclists come into contact with HGVs during cornering or manoeuvring. The lorry driver may be taking all sensible precautions and driving perfectly normally, but if a pedestrian or cyclist is in a blind spot, or the lorry is already turning, the pedestrian or cyclist will not be seen. Once contact has taken place the driver may not be aware that anything untoward has occurred and completes the manoeuvre. The typical accident mechanisms are either that the pedestrian or cyclist is drawn under the rear wheels, or is caught in the side structure of the lorry. In many cases these incidents occur at relatively low speeds.

Whilst the truck industry has introduced sideguards in an attempt to reduce injuries to pedestrians and pedal cyclists, the design of many types of sideguard, using an open frame structure, can cause significant injuries when a pedestrian or pedal cyclist is trapped within it. There is no reason why a lightweight solid panel could not be used, although it would need to be hinged to allow access for servicing. Such a device would also reduce the aerodynamic drag of the vehicle leading to improved fuel economy. TRL have estimated (Knight, 2000) that fitting improved sideguards of this design to all HGVs (i.e. no exemptions) could save 8 lives per year in the UK.

Injuries resulting from impacts with the front end of the vehicle could be significantly reduced by using a "soft" fronted vehicle as described above. Similar technology could be employed at the rear and sides of the vehicle but this is likely to involve significant cost and the number of people involved in these types of impact are much fewer than for frontal collisions. In addition, the benefits of side mounted inflatable devices could be negated under some circumstances; for example, if the inflating device actually knocked a pedal cyclist off as it inflated.

Significant reductions in these incidents could be made if the driver of the vehicle was alerted to the presence of a pedestrian or cyclist using a buzzer or warning light. Hence, the use of an all-round vehicle detection system would have benefit.

Sensing systems such as radar, infrared, capacitive, and video could be used to provide a passive monitor of the presence of pedestrians or cyclists around the vehicle. Complex algorithms would be needed to ensure that any object positioned close to the vehicle was correctly identified but initial results suggest that reliable systems are feasible. Although false alarms are not likely to be serious they could lead to the driver taking the warning less seriously, which would detract from the value of the system.

A relatively common accident mechanism in the UK is where a pedestrian crosses the road directly in front of an HGV that is stationary in traffic or at crossing signals. Unless the

pedestrian is very tall they are usually in a blind spot at the front of the vehicle and cannot be seen by the driver. Therefore, if traffic signals change or vehicles in front move forward, the driver of the HGV sees no reason not to pull forward as well. This will result in the pedestrian being knocked down and run over by the HGV without the driver ever being aware of their presence. It is estimated that using advanced sensors to detect the pedestrian presence and warn the driver could prevent the deaths of 10 pedestrians per year.

Problems at the side of vehicles are often caused when an HGV (particularly if articulated) turns left into a side road. The HGV might be stationary at traffic lights when a pedal cyclist rides up the nearside and stops in a position close to the passenger side front wheel. Typically, this area is a blind spot for HGVs. As the signals change the HGV and cyclist both move forward and the HGV begins to turn left. The cyclist typically collides with the nearside front area of the truck and falls to the floor. The driver is not likely to be aware of such a small collision and will continue to turn left such that the rear wheels of the vehicle pass over the prone cyclist. Traditional sideguards are ineffective in this situation because the victim is already on the floor when they pass into the sideguard area and they simply pass over the top of them. Alerting the driver to the initial presence of the cyclist using sensor systems will be likely to stop the driver turning left until it is possible to see the cyclist and know that it is safe to proceed. It is estimated that this type of system could prevent 9 deaths per year in the UK.

An alternative approach would be to use a simple transponder that could be detected by a vehicle system. This is well-known technology, small in size and available at low cost. When a receiver has detected a cyclist, the receiver illuminates an icon, or sounds a warning buzzer in the vehicle cab alerting the driver of the presence of a pedestrian or cyclist in a vulnerable position. This approach lends itself well to pedal cyclists where the device could be fitted to the saddle or reflector as standard equipment on new bicycles. However, asking pedestrians to carry this type of device on their person at all times is likely to create issues in relation to privacy and social freedom.

In the future, if people begin to carry smart cards, it should be possible to provide a means of detecting these so that both pedestrians and cyclists can be protected at low cost and without intrusion.

3.6 Collision avoidance

Collision avoidance systems are a further development of the type of electronic sensing and control systems already discussed. They can take a wide variety of forms from relatively simple straight-line braking systems to systems that will adjust vehicle speed appropriate to conditions and take full vehicle control if a collision is detected. Collision avoidance systems are already on the drawing board with a number of manufacturers and offer significant potential for future technology to reduce the number of road accidents and the associated levels of injury.

These systems are likely to be introduced in stages and already several top-end production cars have an intelligent cruise control system that is capable of maintaining a predetermined gap between vehicles to reduce the potential accidents resulting from vehicles being driven too close together. In this example the sensor technology is generally a radar device as this currently offers the most cost-effective solution. The radar determines the relative distance between the vehicles and operates the accelerator/ brake to control the following vehicle.

The key factor in the introduction of these systems is the reliable detection of the impacting object. This can be achieved in many ways using arrays of sensors such as radar and infrared detectors. Other systems such as video cameras and capacitive sensors also offer potential for sensing objects. However, these systems need further development to provide the level of reliability required for such a safety critical system. Alternative solutions include the use of inter-vehicle communications to provide the on-board computers with data about the type and state of each vehicle.

Clearly there are safety implications for these systems as a potential false detection or actuation could result in an accident. International working groups are currently examining these issues.

In the future, collision avoidance systems are likely to involve taking over the full control of the vehicle from the driver including steering. The technology exists now to perform these tasks but it is not yet ready as the sensors and algorithms needed to ensure correct and reliable detection of collisions require further development. However, these systems are likely to achieve the necessary levels of performance within the next 10 years.

The wide variety of potential systems made it difficult to evaluate the accident reduction potential of a generic system in our accident study since the precise characteristics of collision avoidance systems that may be available in the future are not yet known. However, for the purpose of our assessment of real world accident data, TRL have evaluated an assumed basic system that is not far from readiness today. The characteristics of the system are that it would be capable of detecting a vehicle or solid object directly ahead in a straight line and assessing the distance and relative velocity between the two. Algorithms would calculate when action must be taken to avoid a collision and the brakes would be applied in time to bring the vehicle to a stop before impact. The system would not be capable of taking steering action of any kind, would not detect pedestrians or cyclists, and would not be capable of avoiding very low overlap impacts. This theoretical system would be primarily aimed at avoiding lack of attention/fatigue accidents where a goods vehicle collides with stationary or slow-moving vehicles ahead with little or no pre-impact braking. It is estimated that a collision avoidance system as described will be capable of preventing 44 fatalities per year in the UK. Assuming that a more sophisticated system can be made reliable then the casualty reduction potential will be still higher.

4.0 CONCLUSIONS

Table 1 summarises the estimates of UK benefits for the various countermeasures discussed, in order of fatality reduction potential. The individual items listed are not necessarily independent of each other, so the combined potential benefits of combinations of measures cannot be found by summing the individual savings for each measure.

Table 1. Estimate of UK lives saved annually by various countermeasures

Countermeasure	Estimate of UK lives saved
Fit energy-absorbing underrun guards to all HGVs>3500kg	50
Fit basic collision avoidance system	44
Fit rigid underrun guards to all HGVs>3500kg	34
Fit an all round detection system	19
Prevent pre-impact rollover	12
Fit improved sideguards to all HGVs>3500kg	8
Passive pedestrian friendly front end	6

Table 1 shows that energy absorbing front underrun protection currently has the largest fatality reduction potential in the UK and it is worth noting that, in general, mechanical systems remain high on the priority list despite the proliferation of new electronic technology. Whilst advanced electronic adaptable systems are seen to have considerable potential benefits and will no doubt play a large part in the future safety of commercial vehicles, there is still much that can be done to the basic mechanical design to reduce injuries.

For example, this report has concentrated mainly on the protection of other road users. However, there are significant benefits to be obtained from protecting the truck occupant by means such as three point seat belts and improved structural crashworthiness. Improved braking systems incorporating antilock systems and higher grip tyres also have the potential to reduce the number of accidents.

5.0 REFERENCES

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