PASSENGER, GOODS AND AGRICULTURAL VEHICLE SAFETY - EFFECTIVENESS OF EXISTING MEASURES AND RANKING OF FUTURE PRIORITIES IN THE UK

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ABSTRACT

Larger vehicles, such as goods vehicles with a gross vehicle weight in excess of 3500kg or passenger vehicles with more than 16 seats, are involved in fewer accidents per billion vehicle kilometers travelled than passenger cars. However, these larger, heavier vehicles are involved in more fatal accidents per billion vehicle kilometers than passenger cars. The UK Department for Transport is currently reviewing its priorities for safety of large goods vehicles and large passenger vehicles. Phase 1 of the review has included an extensive literature search to identify how previous changes in regulation have affected casualty figures and to identify the predicted benefits from more recent research. Phase 2 of the review includes analysis of accident data, including STATS19 (GB national statistics), European CARE database and other UK based studies such as the Heavy Vehicle Crash Injury Study (HVCIS), Co-operative Crash Injury Study (CCIS) and the On-the-Spot (OTS) study. HVCIS is the only UK study that routinely collects nationally sampled accident data specifically relating to larger vehicles and plays a pivotal role in this review.

The project will identify the most cost effective countermeasures for larger vehicles taking predicted casualty reduction, cost of implementation, technical feasibility and likely date of introduction into account. For the first time in the UK, statistical modeling techniques, which are currently used to predict national casualty reductions, are used specifically for the analysis of casualties in accidents involving larger vehicles only.

This paper reports the findings of the analysis, to date, including analysis of the HVCIS fatal accident database which contains over 1800 fatal accident cases involving larger vehicles. Fatalities are comprised of large vehicle occupants and their opponents. The paper features pedestrian impacts as an example of one of the potential key areas of interest that has been identified by this research.

INTRODUCTION

This project has been carried out to assist the UK Department for Transport to help further improve road safety in the UK beyond 2010. The project also identifies some measures that could assist in meeting the 2010 casualty reduction targets. The project assesses the performance of existing safety measures and identifies where future road accident casualty savings can be made. The aims of the project are to determine how previous research and resulting measures have performed, to identify and prioritise current issues and to propose where best to target resources to deliver further worthwhile casualty savings.

The vehicle types covered by the research are:

- Large passenger vehicles (LPVs) – passenger vehicles with 17 or more passenger seats
- Heavy goods vehicles (HGVs) – goods vehicles with a gross vehicle weight of more then 3.5tonnes
- Light commercial vehicles (LCVs) – goods vehicles with a gross vehicle weight of up to 3.5 tones inclusive
- Agricultural vehicles
- Other motor vehicles (OMVs) – vehicles that are not classified as goods vehicles or passenger vehicles such as refuse lorries, mobile cranes, fire engines

METHOD

The project consists of three phases: review of literature, accident data analysis and consideration of countermeasures.

A review of literature relating to past research and regulatory activity was carried out to identify a list of significant changes in regulation or standard practice that might have influenced heavy vehicle safety. The review focused on estimated benefits prior to changes in regulation and evidence of actual benefits that were achieved. The areas covered by the review included, but were not limited to:

- Introduction of rear underrun protection
- Fitment of seatbelts to coaches and minibuses
- Changes to braking regulations for agricultural tractors
- Mandatory fitment of ABS to the larger categories of buses and goods vehicle

Accident data analysis used a combination of data sources. STATS19 data was used for the analysis of trends and for analysis of the effect of previous changes in regulation. Trend analyses were based on the period 1995-2005. The contribution of HGVs, LPVs and LCVs towards the UK casualty reduction targets was also analysed. Detailed analysis was carried out using STATS19 and the HVCIS fatal accident database. STATS19 data for the period 2003-2005 was used for this analysis. The HVCIS data contained accidents from 1997-2002. CCIS and OTS data were also analysed, particularly for consideration of car-derived vans. The CARE database is the disaggregate database of road accident data that is maintained by the European Commission, bringing together the national databases of the Member States. Data covering the period 2000-2004 was used to consider the UK accident situation with respect to the European context.

The data from the detailed STATS19 analysis was used to create a list of casualty groups that are injured in accidents involving large goods vehicles, large passenger vehicles or agricultural vehicles, either as occupants of those vehicle types or as opponents to those vehicle types. The casualty groups were not mutually exclusive, with some groups being sub-sets of the higher level groups, forming a hierarchical structure, an example of which is shown in Figure 1.

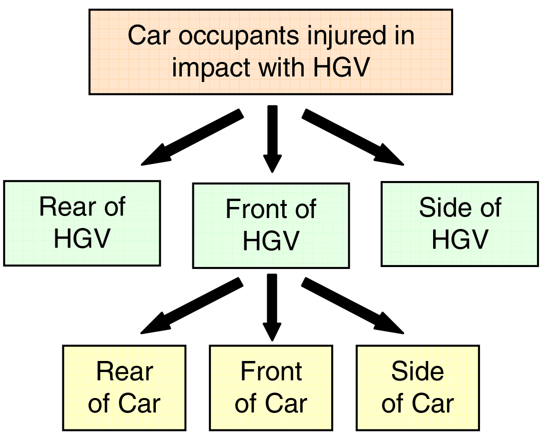

Figure 1. Hierarchy of casualty groups.

Where the casualty was the *occupant* of a commercial vehicle, for example an HGV occupant, the hierarchy was different to that for the *opponents* of the commercial vehicles, for example:

- HGV Occupant
  - HGV occupant in single vehicle accident
  - HGV occupant in rollover
  - HGV occupant in impact with other vehicle
  - HGV occupant in impact with object

The number of levels in the hierarchy was dependant on the number of casualties, in general where the number of casualties was less than ten, the group was not divided any further. The groups were not split any further than illustrated in Figure 1. Some examples of the lower level casualty groups are:

- Car occupants involved in crashes where the front of the car impacts the rear of the HGV
- Pedestrian impacts to front of LPV
- Two wheeled motor vehicle (TWMV) users in impacts between the side of the TWMV and the side of the HGV
- Pedal cyclist casualties in impacts with a minibus
- Injured HGV occupants in impacts with another HGV
- Injured LPV occupants in impact with another vehicle
- Injured agricultural vehicle occupants in rollover accidents

In order to help prioritise the action for each casualty group it was necessary to rank the importance of each group. This can be achieved in a variety of ways, for example using the total number of casualties or the number of fatalities. The UK casualty reduction targets are expressed in terms of target reductions in killed and seriously injured (KSI) casualties and it was decided that the ranking should be related to this target. However, it is possible that two casualty groups could have identical numbers of KSI casualties but within that group one could have a higher proportion of fatalities than the other. To account for this phenomenon the casualty groups were ranked in order of the societal cost of the KSI casualties in each group. The societal costs used, were those defined by the UK Government as shown in Table 1.

Table 1.
UK societal costs (TSO, 2006a)

Casualty Severity	Cost per Casualty
Fatal	£1,428,460
Serious	£160,510
Slight	£12,580

The final phase of the research considers measures that could be introduced to reduce the number or severity of road user casualties. The main focus of this paper is the accident data analysis phase of the research.

RESULTS

Literature Review

The literature review showed that most of the measures that had been implemented in the past had considerable justification, but were not necessarily expressed as specific lives saved. Changes made to agricultural vehicles were the exception to this. Although research related to safety systems such as rollover protection was reviewed, no estimated benefits were identified for the changes to weights and dimensions of agricultural vehicles or for the introduction of rollover protection systems for on road accidents in the UK. This is likely to be related to the low frequency of on road agricultural vehicle accidents and that cost benefit analyses for these vehicle types are often based on their off road use. There were however, estimated benefits for the fitment of seatbelts to agricultural vehicles for on-road accidents.

The more recent research tended to have more comprehensive predictions for potential benefits, and almost all new proposals for measures have an estimate of casualty reductions. However, the variations in the way that the benefits were predicted make direct comparisons difficult. Examples of these differences relate to the use of different samples, fatality and/or all injury reduction, predictions for different countries or for the EC and the year of prediction and associated variations in absolute casualty numbers.

There were only a few measures for which a retrospective evaluation has been carried out after implementation. A detailed retrospective evaluation can be difficult to perform because it is hard to separate the effects of multiple measures, for example improved passenger car crashworthiness and rear underrun protection. Overall, the package of measures taken appears to have been effective because accident and fatality rates have reduced substantially.

Analysis of the Effect of Previous Changes

A comparative analysis of STATS19 data before and after the introduction of safety changes was carried out to identify if there has been an effect of the changes on the accident trends. The safety changes to be assessed were selected from the list of safety measures identified during the literature review. The analysis is limited by data that is available for analysis in STATS19 and also by sufficient fleet penetration of the safety feature, for example it was not possible to assess the effectiveness of the fitment of speed limiters or more recent changes such as improved field of view from HGVs. Therefore three changes were selected for the analysis:

1. Rear underrun protection
2. Rollover crashworthiness of LPVs
3. ABS fitment on HGVs

This paper reports the investigation of rear underrun protection as an example. This analysis does not attempt to separate the influences of a number of different safety changes that occurred in the same time period, for example increased seatbelt wearing and improvements to structural crashworthiness of passenger cars as well as the rear underrun protection.

An analysis of the effects of introducing front underrun protection was carried out by comparing the vehicles fitted with front underrun protection involved in KSI accidents to those without front underrun protection in accidents from 2003 to 2005. The exact fitment of front underrun protection to vehicles involved in accidents is unknown, however an approximation was used based on date of registration of the HGVs. The data is summarised in Table 2.

Table 2.
Proportion of fatally and seriously injured car occupants in impacts with the front of HGVs by year of HGV registration

	HGV First Registered	
	Pre-2003	**2003-2005**
Number	215	72
Proportion Killed	4.2%	5.8%
Proportion KSI	15.6%	17.9%

There is no significant difference between the casualties for the two groups of HGV, however the group of HGV registered 2003-2005 is small and, hence, the analysis should be repeated when more data is available. Using the year of registration is an approximation for identifying vehicles likely to be fitted with front underrun protection. However some vehicles will have been fitted with front underrun protection prior to 2003 and some vehicles registered after 2003 may be exempt.

When considering the effectiveness of rear underrun protection two methods were used:

1. Comparison of accident injury severities before and after introduction of regulation
2. Consideration of the involvement of vehicles that are exempt from fitting underrun protection in accidents

A third method was also considered. This involved statistical modelling, comparing the proportion of casualties killed in impacts with the rear of the HGV compared with those killed in other impacts with the HGV. However, this time series analysis proved inconclusive because rear underrun protection was only fitted to new vehicles so that the during the time taken for full fleet penetration there have been numerous other changes influencing the accident pattern.

Comparison of accident data – An initial indication of the effectiveness of rear underrun protection may be gained by considering how the injury severity distribution of car occupant casualties in frontal impacts with the rear of an HGV has changed. Table 3 summarises the severity distribution of car occupant casualties for a period before the introduction of rear underrun protection (1983) and for a number of periods after the requirement to fit rear underrun protection.

Table 3.
Car occupant casualties in accidents where the front of the car collided with the rear of an HGV

Time Period	Average number (%) of casualties				Annual Total
	Fatal	Serious	Slight	KSI	
1979 to 1982	93 (3.6)	650 (25.4)	1820 (71.0)	2563 (29.0)	2563
1989 to 1992	99 (2.7)	582 (15.7)	3026 (81.6)	3707 (18.4)	3707
1999 to 2002	54 (1.3)	364 (8.5)	3790 (88.7)	4271 (11.3)	4271
2002 to 2005	47 (1.3)	263 (7.1)	3412 (91.7)	3722 (8.3)	3722

Table 3 shows that the number of car occupant fatalities initially increased after the introduction of rear underrun protection and then decreased. However, the proportion of casualties that are killed or seriously injured decreased within the initial 10 year period and has then continued to decrease. The largest reduction was in the initial period considered. This suggests that the introduction of rear underrun protection has provided some benefit, however seatbelt use and crashworthiness of passenger cars are likely to have been a substantial influence.

Consideration of exempt vehicles – The effectiveness of a measure can be assessed by comparing the involvement of vehicles fitted with the equipment compared to those without it. For rear underrun protection, this information is not available, however information about the involvement of vehicles exempt from fitting the equipment can be used as a proxy. Information about the body types of rigid HGVs is recorded in transport statistics (TSO, 2006a). Using the body type data it is possible to estimate the percentage of the vehicle fleet (for rigid vehicles only) that are exempt from fitting rear underrun protection. Based on specific vehicle exemptions outlined in the UK Construction and Use Regulations 1986 (HMSO, 1986), it has been assumed that the following vehicle categories are exempt from fitting rear underrun protection:

- Tipper
- Concrete mixer
- Car transporter
- Tractor
- Mobile plant

There are a number of vehicles where the body type is not known or classified as “other”. Some of these may be vehicles that are also exempt from fitting rear underrun protection, however it is not possible to quantify this. Therefore upper and lower boundaries for the number of exempt vehicles can be produced. The upper boundary assumes that all the “other” and not known vehicles are exempt and the lower boundary assumes that they are not exempt. The mid value applies the ratio of exempt to not exempt vehicle to those where the exemptions are not known or “other”. This data is summarised in Table 4.

Table 4.
Vehicle exemptions

	Vehicle fleet, average 2002-2004		
	Lower	Mid	Upper
Exempt Vehicles	60.5	62.6	71.2
Not Exempt	258.2	256.1	247.5
Total	318.7	318.7	318.7
Percentage Exempt	19.0%	19.5%	22.3%

Using STATS19 data that is linked to vehicle registration data, it is possible to identify, by body type, vehicles that are likely to be exempt from fitting rear underrun protection that have been involved in accidents in the UK. Table 5 summarises the number of Rigid HGVs that were impacted from the rear by the front of a car, separating those that were exempt from fitting rear underrun protection based on the assumptions described above.

Table 5.
Rigid HGVs involved in accidents where the front of a car collided with the rear of the HGV by exemptions

	Number of Rigid HGVs by maximum severity of car occupant injured				
	Fatal	Serious	Slight	KSI	Total
Exempt	7	19	216	26	242
Not Exempt	10	26	278	36	314
Total	17	45	494	62	556
% Exempt	41.2	42.2	43.7	41.9	43.3

From Table 5 it is possible to compare the proportion of vehicles that were exempt from fitting rear underrun protection and involved in accidents with the proportion of vehicles in the fleet that were estimated as being exempt from fitting rear underrun protection. Comparing Table 5 with Table 4 it is clear that a higher proportion of rigid vehicles that are involved in accidents where car occupants are injured in frontal collisions with the rear of a rigid HGV are exempt from fitting rear underrun protection, 41.9% for KSI casualties compared with the vehicle stock of between 19.0% and 22.3%.

Trend Analysis

In order to determine future safety priorities, it is important to consider the accident data in the wider context of the vehicle fleet on the road in the UK.

- Figure 2 shows a ten year trend for distance travelled by the type of vehicle used.

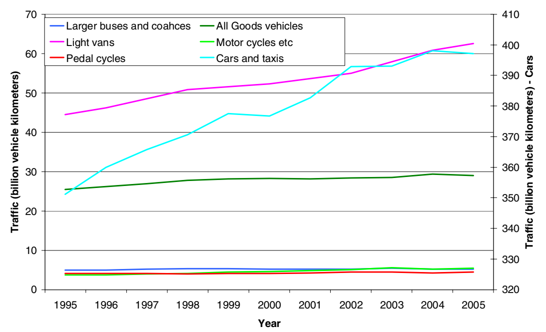

Figure 2. Trends in distance travelled by vehicle type[1].

- It is clear that there is a large growth in traffic from the use of passenger cars, with approximately a 15% increase in ten years. However, the growth of LCV traffic has increased by approximately 40% in the same period. There has also been approximately a 20% increase in goods vehicle traffic.
- Figure 3 summarises the current progress towards the 2010 casualty reduction targets.

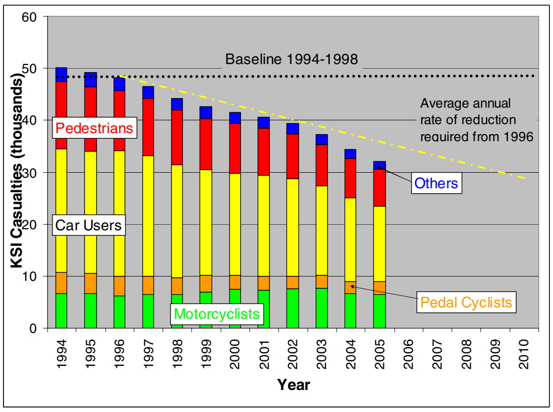

Figure 3. Progress towards casualty reduction targets (TSO 2006a and TSO 2000).

- Figure 3 shows that despite the growth in traffic, the reduction in casualties is on target.
- As well as looking at the overall trends in the use of vehicles and casualties, it is also possible to look at how large goods vehicles and large passenger vehicles have contributed towards meeting the UK's 2010 casualty reduction target. This is achieved by calculating the casualty rate in LCV (LPV or HGV) accidents relative to the overall casualty rate using equation 1.

$$\text{relative casualty rate} = \frac{\text{casulaties in HGV accidents per billion HGV kilometers}}{\text{casulaties in all accidents per billion vehicle kilometers}} \quad (1)$$

- Figure 4 shows how LCVs have contributed to the UK casualty reduction targets. A horizontal line with a value of one would indicate that accidents involving LCVs have the same casualty rate as other vehicle types and have been contributing to the casualty reduction targets in line with accidents involving other types of vehicle.

[1] Notes: 1) Decline in car use in 2000 due to fuel dispute 2001 figures affected by foot and mouth
2) Change to methodology for collecting pedal cycle data improved, affects data for 2004 and 2005
3) Light vans with GVW≤3.5tonnes
4) All goods vehicles with GVW>3.5tonnes

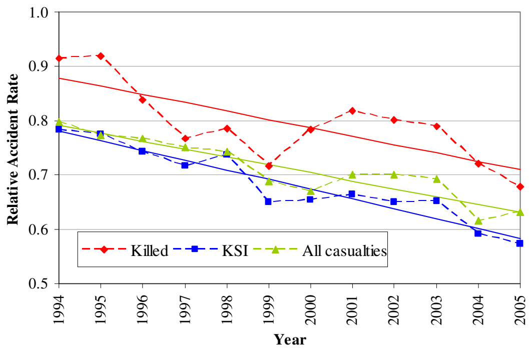

Figure 4. Contribution of LCVs to UK casualty reduction targets.

- Figure 4 shows that accidents involving LCVs have a lower casualty rate than for all accidents and that the casualty rate fell more than the casualty rate for all vehicles. This indicates that accidents involving LCVs have made a positive contribution towards the UK casualty reduction targets.
- LPVs have a casualty rate that is 3.5 – 5 times that of all of accidents. The relative KSI rate has risen slightly, so although the KSI rate fell by 44% between 1994 and 2005, the KSI rate for all accidents fell farther, by 46%. This indicates that accidents involving LPVs have slightly slowed progress toward the casualty reduction target for KSI. Conversely, the relative Killed rate tended to fall over this period. The rate of all casualties rose relatively fast throughout this period.
- HGV accidents tend to be severe, which is reflected in the high relative rate for killed, some three times that of the rate for all accidents. The killed rate fell by about 10% between 1994 and 2005 and the relative KSI rate also fell, by about 5%, contributing to the casualty reduction targets at a higher rate than other vehicle types.

Analysis of European accident data

At present, data are available for the 15 pre-Accession states, although access to German data is not permitted[2]. TRL has access to CARE, and has downloaded data for accidents involving LPVs, HGVs and LCVs. Although CARE includes full records of non-fatal accidents and casualties, in practice international comparisons only make use of data for fatal accidents and casualties because of inconsistent reporting standards and definitions among the Member States.

The aim of this analysis is to provide a European context for the British casualty data. Three groups of fatalities have been analysed: those in accidents that involve one or more LCV, one or more HGV and one or more LPV. Two types of international comparison have been made: of the proportion of the national fatality total occurring in these accidents and of the fatality risk based on accident rate. In most Member States, traffic data are not available comparable to the level of the British traffic data so comparisons of risk are based on measure of the rate per million population.

The overall fatality rate in the UK is amongst the lowest in Europe, so the UK would be expected to rank better on the rate-based comparison than the proportion-based comparison. Figure 5 illustrates the fatality rate per million population in the three groups of accident that were analysed.

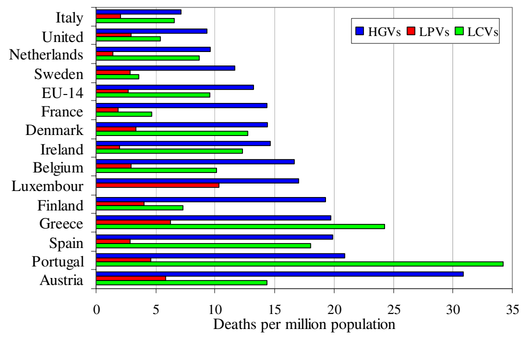

Figure 5. National fatality rates per million population in LCV, HGV and LPV accidents, 2000 – 2004[3].

The UK's LCV and HGV rates are low in comparison to other EU countries. However, UK LPV rate is around the median. When the proportion of fatalities that are caused in accidents involving LPVs, HGVs and LCVs are considered, accidents involving LPVs and HGVs are relatively a more important accident group when compared to the average for the EU-14 (15 pre-accession states but excluding Germany). Accident involving LCVs are about average.

Figure 6 summarises the distribution of fatalities for accidents involving HGVs.

[2] The UK data in CARE are the combination of STATS19 accident records from Great Britain and the T1 accident records from Northern Ireland.

[3] The low HGV rate in Italy is surprising, and may be the result of the transformation rules used to import in the Italian data into the CARE database

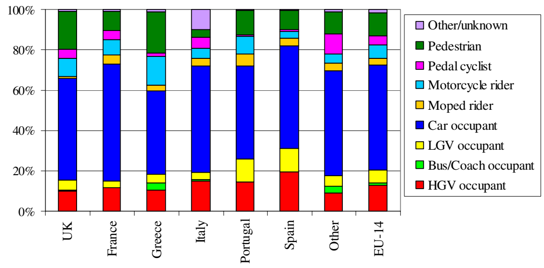

Figure 6. Distribution of fatalities in accidents involving HGVs in 2004, by road user type.

It can be seen that vulnerable road users, particularly pedestrians and motorcyclists account for a higher proportion of fatalities than in other EU countries with the exception of Greece.

Ranking of Casualty Groups

A total of 244 casualty groups were created and the number of casualties of each severity was identified for each group. The casualty groups were ranked based on the casualty count and the associated casualty costs for different casualty severities, fatal, KSI or all casualties.
Table 6 shows the ranking of casualty groups based on the count of KSI casualties and the annual cost of KSI casualties, with only the top ten shown as examples.

Table 6 shows that the ranking of casualty groups changes when both the severity and frequency of the casualties is considered. Some of the casualty groups appeared consistently in the top ten regardless of the criteria used for ranking, for example car occupants in impacts with an HGV or LCV. However these are both large groups and the impact configurations and injury mechanisms within these groups vary substantially. Pedestrians killed or seriously injured in impacts with HGVs, LPVs and LCVs all appear in the top ten when the groups were ranked by KSI cost. However, when ranked on KSI count, the pedestrians injured in impacts with HGVs are not in the top ten, whereas this group of casualties is the highest ranked of all the pedestrian casualties when based on cost. This indicates that the costs associated with the HGV-pedestrian casualties are higher even though there is a smaller number. In fact, the proportion of KSI pedestrians fatally injured in impacts with HGVs is higher than for the other two vehicle types, 33% for HGVs compared to 13% for both the LPVs and LCVs. Table 1 shows that the cost associated with a fatality is almost nine times that of the cost associated with a serious injury.

Table 6.

Examples of top ten KSI casualty groups ranked by count and annual cost

Rank	Accident Type	KSI Casualty Count	Accident Type	KSI Cost £M
1	Car Occupants in impact with HGV	2483	Car Occupants in impact with HGV	354.3
2	LCV Occupants	1983	Car Occupants in impact with LCV	195.4
3	Car Occupants in impact with LCV	1804	LCV Occupants	185.6
4	LPV Occupants	1351	Pedestrians in impact with HGV	136.1
5	HGV Occupants	1230	Pedestrians in impact with LPV	130.4
6	Pedestrians in impact with LPV	1204	HGV Occupants	127.5
7	LCV Occupants in impact with other vehicle	1173	Car Occupants in impact with HGV (Front – Front)	126.5
8	Pedestrians in impact with LCV	1121	Pedestrians in impact with LCV	121.7
9	LPV Occupants – no impact	875	LCV Occupants in impact with other vehicle	105.4
10	LPV Occupants – single vehicle	856	LPV Occupants	89.2

Detailed Accident Analysis

Detailed analysis was carried out on STATS19 data from 2003-2005. HVCIS fatal accident data covering the period 1997-2002 was also analysed. The analysis considered accidents involving HGVs, LCVs, LPVs, minibuses, OMVs and agricultural vehicles. Casualties that were the occupants of these vehicles or in opposition to these vehicles were included, which has resulted in too large an amount of data to report in this paper. Therefore, this paper presents the main findings of the detailed analysis of accidents that resulted in pedestrian impacts with the vehicles described above to provide an example of the types of analysis carried out.

STATS19 detailed analysis – The data sample consists of the numbers of pedestrian casualties as shown in Table 7 for impacts with each vehicle type.

Table 7.
Number of pedestrian casualties by impact with vehicle type in STATS 19 data sample, 2003-2005

Vehicle Type	Fatal	Serious	Slight	KSI
HGV	232	479	1314	711
LCV	146	975	3767	1121
LPV	156	1048	4583	1204
Minibus	6	86	349	92
Agricultural	4	21	57	25
OMV	19	163	821	182

Figure 7 summarises the vehicles that were in impacts with pedestrians that resulted in KSI casualties. The pedestrian casualties as a proportion of all KSI casualties for each vehicle type are also shown.

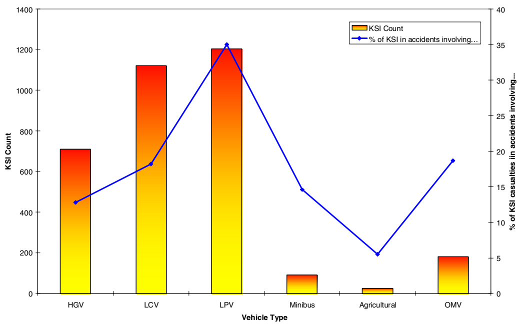

Figure 7. Number of pedestrian casualties with respect to impacting vehicle and as a percentage of all casualties from accidents involving this vehicle.

LPVs are the most frequent type of vehicle to be involved in a pedestrian impact with just over 1200 KSI casualties, an average of 401 per year. There are a similar number of pedestrian KSI casualties from impacts with LCVs. For HGVs, there is an average of 237 pedestrian KSI casualties per year. LPVs also have the highest proportion of pedestrian KSI casualties, with 35% of casualties from impacts with LPVs being pedestrians, compared to 18% for LCVs and 13% for HGVs. As a proportion of all KSI casualties, impacts with OMVs and minibuses are comparable to HGVs and LCVs, however there were a much lower number of casualties. The remainder of this analysis therefore focuses on the accidents involving LPVs, HGVs and LCVs.

STATS19 records the first point of impact for each vehicle. Where the first point of impact was known, the distributions by side of vehicle are summarised in Figure 8.

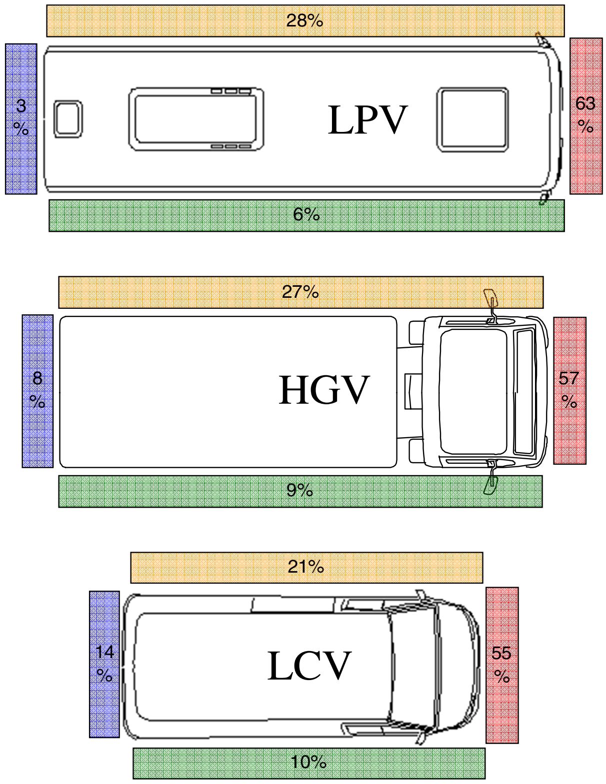

Figure 8. Impact locations for LPVs (top), HGVs (middle) and LCVs (bottom).

For all three vehicle types, most of the KSI casualties are injured in impacts with the front of the vehicle. The second most frequent impact area is the left side, which may be expected in a country where the vehicles are right hand drive because the left side is nearest to the footpath. Impacts to the rear of the vehicle are least frequent for the HGV and the LPV, however, impacts to rear of the LCV are third most frequent. The reasons for this are currently unknown.

At the time of the accidents that resulted in KSI casualties, most of the vehicles were described as "going ahead, other", 63% of LCVs, 65% of HGVs and 70% of LPVs. This category of manoeuvre is a very broad category which captures any vehicle that is not making a specific manoeuvre, and would therefore be expected to be the most frequent manoeuvre. The three most frequent vehicle manoeuvres for each vehicle are illustrated in Figure 9.

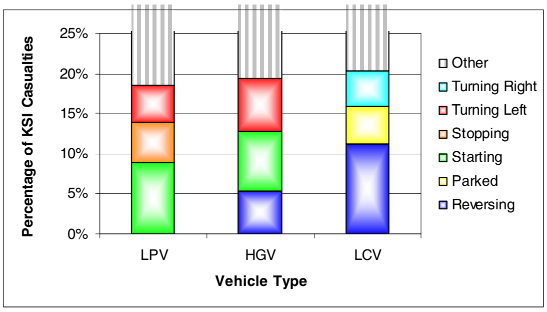

Figure 9. Three most frequent vehicle manoeuvres for KSI pedestrian causalities by vehicle type.

For LPVs the most frequent specific manoeuvre was the vehicle starting from rest, which was also the case for the HGVs. For LPVs this is possibly because many impacts occur as the vehicle is pulling away from a bus stop. For HGVs, the forward blind spot is often a contributory factor in these cases. For LCVs, starting was not one of the three most frequent manoeuvres. Turning left was also more common for LPVs and HGVs than it was for LCVs. This is related to the cut-in effect of the longer vehicles and this is also consistent with the left side of the vehicle being impacted. Stopping was only one of the three most frequent manoeuvres for the LPVs and this is possibly because these vehicles are frequently stopping at bus stops. Reversing was one of the more frequent manoeuvres for both of the goods vehicle categories with it being most frequent for the LCVs. Again, this is consistent with a higher proportion of impacts to the rear of this type of vehicle. For LCVs, turning right and being parked were two of the three most frequent manoeuvres, but these manoeuvres were not seen in the top three for HGVs and LPVs. Accidents where an LCV was parked include roadside assistance vehicles parked on the motorway hard should attending to a broken down vehicle where a second vehicle collides with the LCV pushing it into the LCV driver or the driver of the broken down vehicle who are no longer inside their vehicles. This different pattern may be related to the LCVs being more similar to passenger cars than the other two vehicle types.

If only the fatalities are considered, the most frequent manoeuvres remain the same, albeit with a higher proportion of the fatalities. For example, 71.2% of the HGVs were going ahead other and 8.6% were starting, compared with 64.8% and 7.4% for KSI pedestrian casualties. Also, going ahead on a left hand bend became one of the more frequent manoeuvres for LCVs and LPVs, accounting for 4.1% and 3.8% of fatalities respectively.

The location of the pedestrian at the time of the accident is shown in Figure 10.

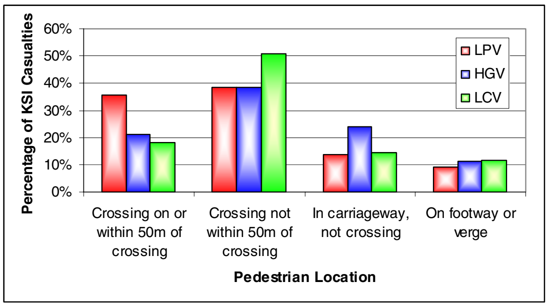

Figure 10. Pedestrian location at time of accident.

For all vehicle types, the majority of the pedestrians were injured while crossing the road. However, for pedestrians injured in impacts with LPVs, similar proportions were crossing on or near a crossing or elsewhere. For pedestrians injured by HGVs or LCVs, most were not on or near a crossing. For HGV impacts, the proportion of pedestrians that were in the carriageway, but not crossing was similar to the proportion that were on or near a crossing.

Figure 11 describes the movement of the pedestrian at the time of the impact.

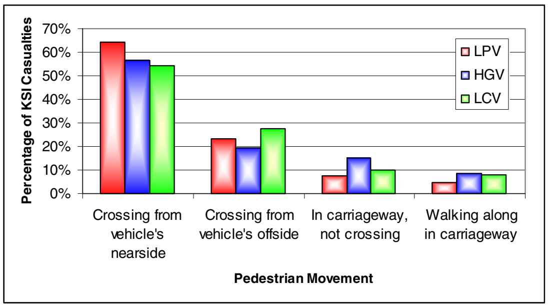

Figure 11. Pedestrian movement at time of accident.

For all three types of vehicle, most of the pedestrians were crossing the road from the vehicles nearside.

<u>HVCIS fatals detailed analysis</u> – The following analysis is based on final release of the HVCIS fatals phase 1 database (April 2006). This release of the HVCIS fatals database was compared with data from STATS19 for accidents involving each of the sample vehicle types to investigate the representativeness of the sample so that findings from analysis of the data can be used to estimate national trends. The database is broadly representative of the national data recorded by STATS 19. Accidents involving HGVs are the most representative, because they are the most numerous and form the largest sample. The data on LPVs is slightly less representative and analysis of accidents involving LCVs should be date restricted to for accidents prior to 1999 in order to avoid bias

(Knight *et al*, 2006), The following analysis of the LCV data has therefore been carried out using an earlier version of the phase 1 fatals database which contains the pilot study data to reduce the bias towards LCV impacts with other larger vehicles.

The data contained 173 pedestrians where the most severe impact was with an HGV, 116 that were impacted by an LPV and 59 pedestrians in impacts with LCVs. Figure 12 shows a comparison of the distribution of differences between impact locations. It is important to note that STATS19 records the first point of impact and the HVCIS data contains multiple impacts and is analysed using the most severe impact. This may explain some of the differences but pedestrian accidents are more likely to involve single impacts than multiple vehicle collisions.

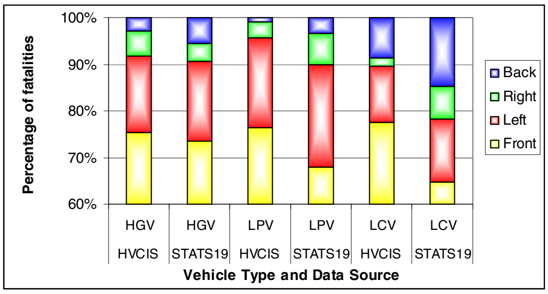

Figure 12. Comparison of impact locations between HVCIS and STATS19 by vehicle type[4].

Figure 12 shows that the representativeness of the data for accidents involving HGVs extends to the distribution of impact location. For LPVs and LCVs the data is less representative and when considering the following analysis, which considers impacts to the front of the vehicle, the data will be under-representing the national picture.

The HVCIS database contains data in addition to what is available from STATS19 such as:

- Driver behaviour factors
- Impact speed
- Cause of death
- More detail on impact location/sequence
- Fatality (pedestrian) behaviour factors

The following analysis compares some of this additional data for the three vehicle types LPV, HGV and LCV, focusing on impacts to the front of the HGV.

[4] The HVCIS data has an additional impact location of the underside of the vehicle. For the purpose of the comparison, the small number of impacts to the underside has been excluded as unknown. For LPVs and LCVs they account for 1.7% of fatalities and for HGVs 1.2%.

The impacts are coded using the direction of force, side and part components of the collision damage classification (CDC) (Nelson, 1980). Figure 13 summarises the impact locations on the front of the vehicles where this was known.

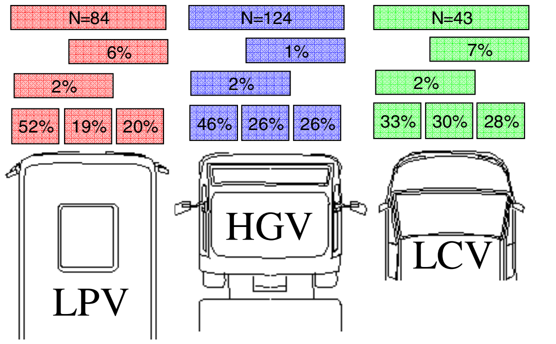

Figure 13. Pedestrian impact location on front of LPV (left), HGV (centre) and LCV (right).

The left side of the front of the vehicle is the most frequent impact location, which is to be expected for right hand drive vehicles because this is the side nearest to the footpath. The proportion of pedestrians in impacts with the front left of the vehicle varies by vehicle type. For LPVs and HGVs approximately 50% of the pedestrians impact the front left, whereas for LCVs the distribution of impact locations is more even. There are some cases where the impact is described as being distributed across two-thirds of the vehicle. In these cases, the exact impact location may not have been clear.

Data on impact speed is taken from witness statements, police calculations or from tachograph charts where they were analysed by the police. The data for impacts between the front of the vehicle and pedestrians is shown in Figure 14.

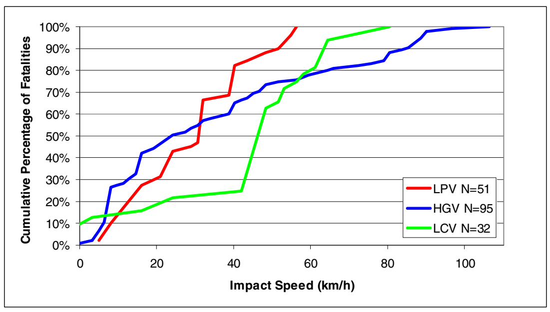

Figure 14. Cumulative percentage of impact speed by vehicle type.

The median impact speed is approximately 25km/h for HGVs, 30 km/h for LPVs and 45km/h for LCVs. Offering protection to pedestrian in impacts up to 40 km/h could protect up to 25% of those in impacts with LCVs, up to 65% of those in impacts with HGVs and up to 80% of those in impacts with

LPVs. However, when considering potential countermeasures, the primary impact with the vehicle may not always be the cause of the fatal injuries. For example the pedestrian could be run over or the secondary impact with the ground may be more severe than the impact with the vehicle.

For impacts with LCVs, 10% of the LCVs have a collision speed of zero which is consistent with frequency of parked LCVs involvement in accidents (Figure 9).

The cause of death is also an important factor when considering potential countermeasures. Figure 15 summarises the cause of death where the information was available.

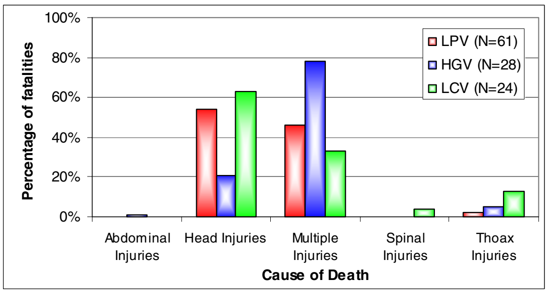

Figure 15. Cause of death for pedestrians in impacts with the front of LPVs, HGVs and LCVs.

For pedestrians in impacts with LPVs or LCVs, the most frequent cause of death in head injuries, however it is not possible to identify whether the injuries were caused by the impact with the vehicle or the impact with the ground. For pedestrians in collision with an HGV, multiple injuries is the most frequent cause of death, which suggests that collisions with HGVs are more severe than impacts with other vehicle types.

Data relating to body regions that sustain serious injury is also collected. The head was the most frequently injured body region. Where the seriously injured body regions were known, 90% of pedestrians in collision with an LPV, 71% of those in collision with an HGV and 83% of those in collision with an LCV sustained a serious injury to the head, either alone or in conjunction with other serious injuries. The head was the sole serious injury for 40%, 34% and 62% of those in collision with LPVs, HGVs and LCVs respectively.

Behavioural factors that were considered contributory to the cause of the accidents are recorded for both the driver and the fatality, which in this case is the pedestrian. Figure 16 shows the proportion of vehicle drivers and the pedestrians that were in collision with the vehicles, the actions of which were considered contributory to the accident. In some cases, the behaviour of both the driver and the pedestrian can be contributory to the cause of the accident and therefore the combined proportions can exceed 100%.

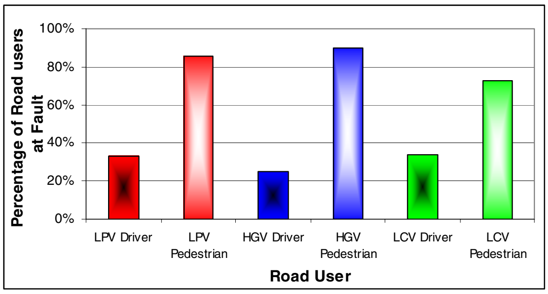

Figure 16. Road users whose behaviour was considered contributory to the accident.

In general, the pedestrians were considered to be at fault more frequently than the vehicle drivers. Lack of attention was considered to be the most frequent type of contributory behaviour for all the drivers and pedestrians. For the pedestrians, the most frequent behavioural factors were:

- Pedestrians in collision with LPV
  - 33% lack of attention
  - 18% alcohol alone or in conjunction with other behaviour
- Pedestrians in collision with HGV
  - 23% lack of attention only
  - 19% inconspicuous alone or in conjunction with other behaviour
  - 18% error of judgement only
  - 15% alcohol alone or in conjunction with other behaviour
- Pedestrians in collision with LCV
  - 42% lack of attention alone
  - 10% alcohol alone or in conjunction with other behaviour

It is necessary to mention that these behavioural factors are not mutually exclusive, for example a pedestrian that is affected by alcohol can sometimes not be paying attention or could make an error of judgement.

DISCUSSION

This paper has presented a summary and a few examples of the research to date. Analyses similar to those of the pedestrians have been carried out for other road users, car occupants, HGV occupants, pedal cyclist, motorcyclists, LPV occupants and others. The analyses will be used to determine parameters for potential countermeasures for some of the most frequently injured road user groups that are involved in accidents with large passenger, goods or agricultural vehicles. It is envisaged that a countermeasure may be effective for a number of road user groups.

The ranking spreadsheet will be used to focus the analysis of potential countermeasures on the larger casualty groups. However, some of the groups that appear high up in the rankings may have been the subject of recent legislation that could affect their position without any further intervention. For example, front underrun protection was recently introduced, however the market penetration has not been sufficient to influence the accident population yet and therefore the position of car occupants in impacts with the front of HGVs in the ranking spreadsheet is unaffected by this measure at this time. The feasibility of identifying a measure that is effective for protecting all car occupants in impacts with HGVs is low and so although top of the ranking spreadsheet, it may be more cost-effective to target some of the other casualty groups.

Smaller casualty groups will also be considered. For example, the number of agricultural vehicle occupant casualties is much lower than the number of pedestrians injured in impacts with HGVs, but the cost of introducing countermeasures may be lower either because of the technology or the smaller vehicle fleet.

CONCLUSIONS

The following conclusions can be drawn from the research to date:

- The literature review showed that most changes to regulations in the past have been supported by estimates of potential benefits and that the predictions have become more comprehensive with time.
- There has been minimal research to consider how effective previous changes to regulations have actually been.
- Analysis of the effect of introducing rear underrun protection systems show that those rigid vehicles that are exempt from the regulations are over-represented in impacts between the front of the car and the rear of the HGV which result in injury, thus suggesting it is an effective measure.
- Analysis of the contribution of accidents involving LPVs, HGVs and LCVs to meeting the UK casualty reduction targets showed that accidents involving HGVs and LCVs have made a contribution that is ahead of the average contribution for all accidents. Accidents involving LPVs have made a contribution that is below average.
- Consideration of the UK accident data within a European context showed that the fatality rate per million population is lower than for most European countries for accidents involving HGVs and LCVs, but is about average for accidents involving LPVs.
- Car occupants in an impact with an HGV were highlighted as the highest priority group of casualties based on both the casualty count and the societal costs associated with the casualties (which accounts for casualty severity). However, there have been recent changes to vehicle design (e.g. front underrun protection systems) that could deliver a significant reduction in this casualty group.
- The detailed analysis of STATS19 showed that the impact configurations for accidents resulting in pedestrian KSI casualties are similar for LPVs, HGVs and LCVs with the front and nearside being the most frequent impact locations. However, there were some differences between vehicle types when considering the manoeuvres that the vehicles were making at the time of the accident with “starting” and “turning left” two of the most frequent manoeuvres for LPVs and HGVs, but not for the LCVs.
- Analysis of impact speeds using the HVCIS fatals database showed that offering protection to pedestrians from LCVs, HGVs and LPVs at speeds up to 40 km/h could prevent up to 25%, 65% or 80% of the fatalities respectively.
- Pedestrian collisions with HGVs were more severe when compared to collisions with LPVs and LCVs. From STAT19, a higher proportion of the KSI casualties were fatally injured and from HVCIS, impact speeds were higher and the cause of death was more often multiple injuries.
- The HVCIS data also indicated that the behaviour of the pedestrians was more frequently contributory to the cause of the accident than the behaviour of the drivers of the vehicles.

FUTURE WORK

To date, this research project has identified the most frequently injured casualty groups for different types of accident. A range of countermeasures will be identified to reduce the frequency or severity of the casualties from accidents involving the vehicle types described in this paper.

The information from the ranking spreadsheet will be combined with the information collected during the literature review and the countermeasure assessments to identify priority areas for future research and effective safety countermeasures. The final project report is due for publication in late summer 2007.

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