CAR AND TRUCK COLLISIONS REVISITED

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ABSTRACT

With the increasing trend in the use of light goods vehicles (LGVs) instead of heavy goods vehicles (HGVs) to transport goods for local deliveries, we decided to compare the type and severity of real life collisions between cars and HGVs, and cars and LGVs, looking at the severity of the impact with respect to the occupants of the cars. To this aim, the Co-operative Crash Injury Study was used to study impacts of the above types. It was decided to compare car frontal impacts with a principle direction of force of between 11 o'clock and 1 o'clock due to the frequency of this type of accident. 198 car vs HGV and 148 car vs LGV accidents were studied involving 456 front seat car occupants. Only front seat occupants wearing a seat belt were included in the analysis. The collisions were analysed to gather information on type of impact, severity of impact, and occupants were studied to consider types of injury and causation of these injuries.

CRASH INVESTIGATORS have been interested in the effects of collisions between cars and heavy goods vehicles (HGVs) for decades (Mackay and Walton, 1984; Rechnitzer *et al*, 1993; Walz *et al,* 1990;), the collision between a car and an HGV being one of the most dangerous (Grüttert *et al*, 1989). The common focus of attention has been on the mismatch of vehicle mass and the heights of the stiff strucures. In this study, the stiff structure represents energy absorbing structures such as longitudinals and the front crossmember. In both cases, the car is disadvantaged. In an impact with an HGV, the greater mass of an HGV compared to that of a car produces an adverse mass ratio effect for the lighter vehicle. A car's velocity change can sometimes equal the closing speed of the two vehicles (Mackay and Walton, 1984). While the mismatch between the masses of cars and HGVs is unavoidable, the mismatch of vehicle structures is not necessarily.

The mismatch of vehicle stiff structures leads to the high incidence of underride when a car is in collision with an HGV. Car stiff structures are relatively low to the ground and are compatible with other cars. Not only are an

HGV's stiff structures much higher than that of cars, but they are relatively unyeilding and undeformable, and are of a relatively 'open' physical form. The result of an impact between a car and an HGV, therefore, results in the car's stiff structures underrunning the HGV's stiff structure, the main deforming elements then becoming the passenger compartment area, the A pillars and roof structure in the case of a front impact. In some cases, the car will only come to rest when the car's stiff structures have impacted the HGV's wheel or other suspension or drivetrain assemblies (Grüttert, *et al.* 1989).

In order to correct this disparity, front, side and rear underrun bars have been advocated; side and rear bars having been introduced as part of legislation in Europe for goods vehicles over 3.5 tonnes gross vehicle weight. Despite this move, front underrun protection has not been introduced even though it has been suggested that front of car to front of HGV collisions are the most frequent and fatal type of collisions (Soret, 1989).

Because of underrun, occupant death is attributable to severe injuries to the upper body and head regions (Adiv and Ervin, 1989; *cited by Rechnitzer et al, 1993*). This is a type of impact in which the use of seat belts is relatively ineffectual. Mackay and Walton (1984) predicted that when madatory seat laws were introduced in 1983, the proportion of HGV underrun deaths would increase.

In addressing the overall problem of cars colliding with HGVs, it is proposed that some of the same structural relationships between HGVs and cars are similar to those found in light goods vehicles (LGVs) and cars, although to a greater extent in the former. For the purposes of this study, the definitions of HGVs and LGVs are those laid down by the Department of Transport (1994). A visual assessment of the matching of stiff structures in LGVs and cars would indicate that in some cases, such as with the 1.5 tonne flat-bed type of pick-up truck, the stiff structures are significantly higher than that of cars (55cm from ground to bottom of chassis and 70cm from ground to overhanging bed/body for instance). With LGVs there is still a problem with respect to the mass-ratio effect although not as severe. With an increasing use of LGVs, the issue of car vs LGV collisions and occupant injury is also addressed in the following study. Particular emphasis will be placed on the injuries received by occupants of the cars striking either HGVs or LGVs, comparing the types of injuries sustained and the assemblies struck in the different types of impact.

METHOD

Our database contains information on 4231 vehicles in which there were 7092 occupants involved in traffic crashes. The data form part of an ongoing Co-operative Crash Injury Study (CCIS) for vehicle crash performance and occupant inury undertaken between November 1983 and May 1992 (Mackay *et al.*, 1985). The cars were examined at garages within a few days of the collision to analyse the nature of each accident and understand the causes of occupant injuries. Injury data was obtained from hospital medical records and injury severities were rated according to the Abbreviated Injury Scale (AIS), 1985 revision (AAAM 1985)

CASE SELECTION CRITERIA

The cars suitable for inclusion in this study were selected by applying the following criteria;

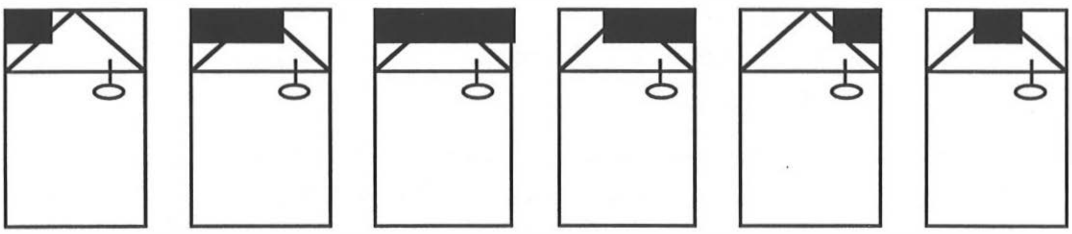
(i) The vehicle received a direct impact to the front with a principle direction of force (PDF) between 11 o'clock and 1 o'clock.
(ii) There was at least one front seat occupant in the car who was known to be restrained.

In all, 198 vehicles which had collided with HGVs, and 148 vehicles which had collided with LGVs were available for analysis. It was found that a total of 259 occupants (198 drivers and 61 front seat passengers (FSPs)) were involved in collisions with HGVs and 197 occupants (148 drivers and 49 FSPs) in collisions with LGVs.

RESULTS

The horizontal distribution of impacts for HGVs and LGVs for the front of the cars was found to be similar (figure 1). It shows that in almost half of the impacts, over two thirds of the car front areas were involved. As would be expected, the offside of the car also suffered more heavily than the nearside (with almost twice the rate of accidents)

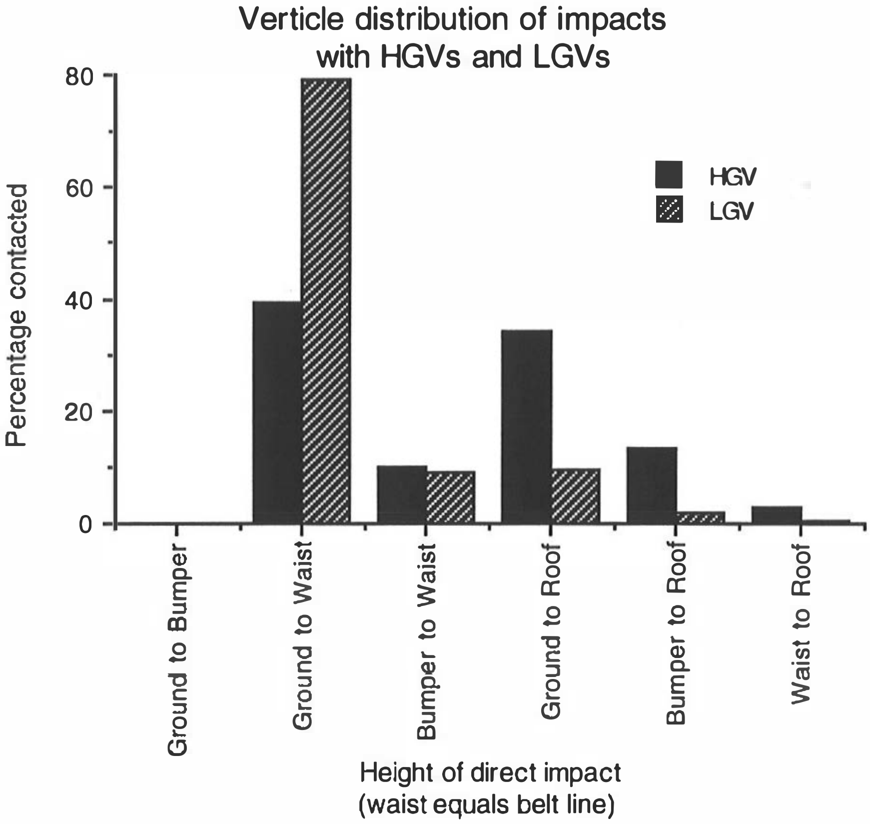
figure 1 - Horizontal distribution of impacts by HGVs and LGVs



HGV	16 (8%)	20 (10%)	87 (44%)	36 (18%)	37 (19%)	2 (1%)
LGV	16 (11%)	10 (7%)	61 (41%)	31 (21%)	20 (19%)	2 (1%)

In the vertical distribution of impacts, as would be expected, it was found that HGVs impacted higher on the car than LGVs (figure 2). For almost 90 % of cars struck by LGVs, impacts were below glass level while this figure was only 50 % for HGVs.

figure 2



Initially, ETS was used as an indicator of impact severity and was calculated using the Crash 3 program (Noga and Oppenheim, 1981). The ETS could not be calculated for impacts in which the stiff structure of the car was not engaged, or the impact direction was non-horizontal, or an underrun type of impact had been experienced, or other structures such as a road wheel (during an offset impact) had absorbed the impact energy. This allowed ETS to be calculated for 70 of the 198 cars which collided with HGVs (35%) and 106 of the 148 cars which collided with LGVs. A significant difference could not be observed between the distributions of the ETS for cars in collisions with HGVs and LGVs (figure 3).

Because ETS was not calculated for all vehicles, maximum crush was used as a measure of impact severity. The distribution of the maximum crush experienced by the cars in collision with HGVs and LGVs are compared in figure 4. It was found that the median values for crush for HGVs and LGVs were 64 cm and 48 cm respectively. Using the Median test, the difference in the median crush for the two types of impact were found to be highly significant ($p<0.005$). This indicates that the types of impacts that cars were suffering with LGVs were less severe than those with HGVs.

figure 3

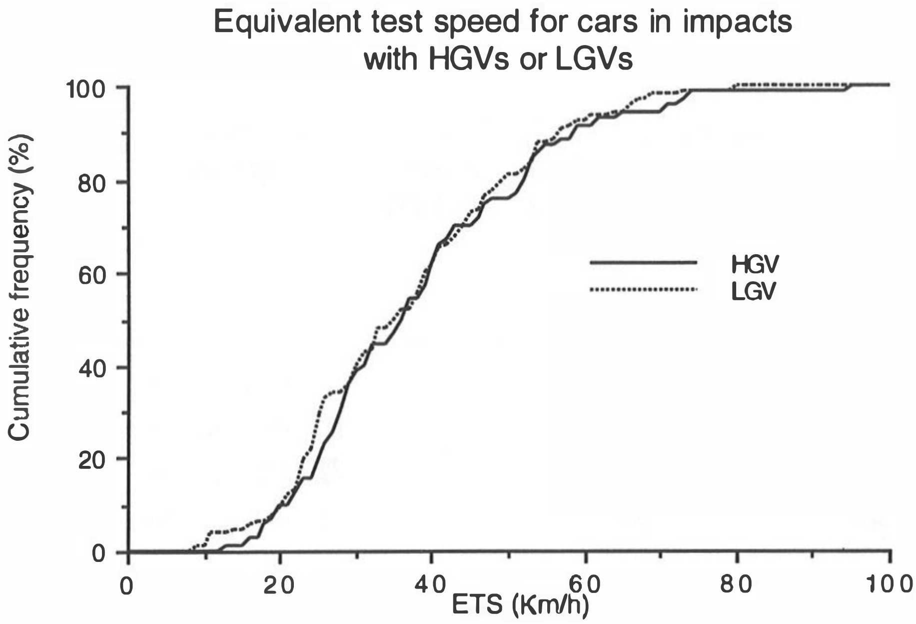
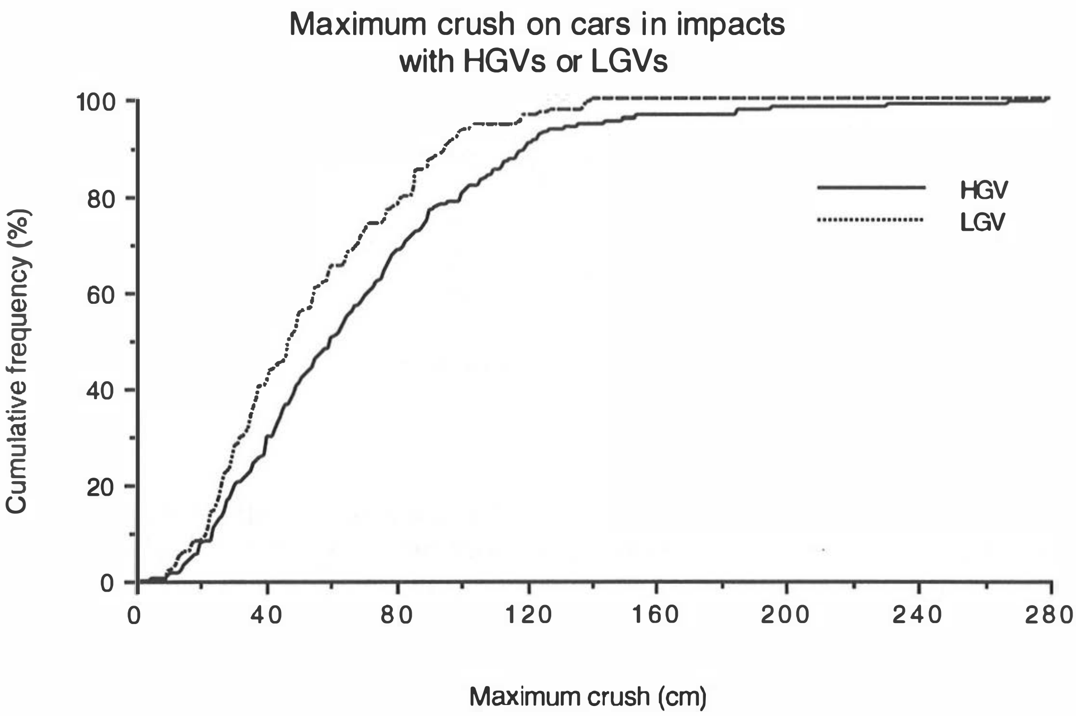
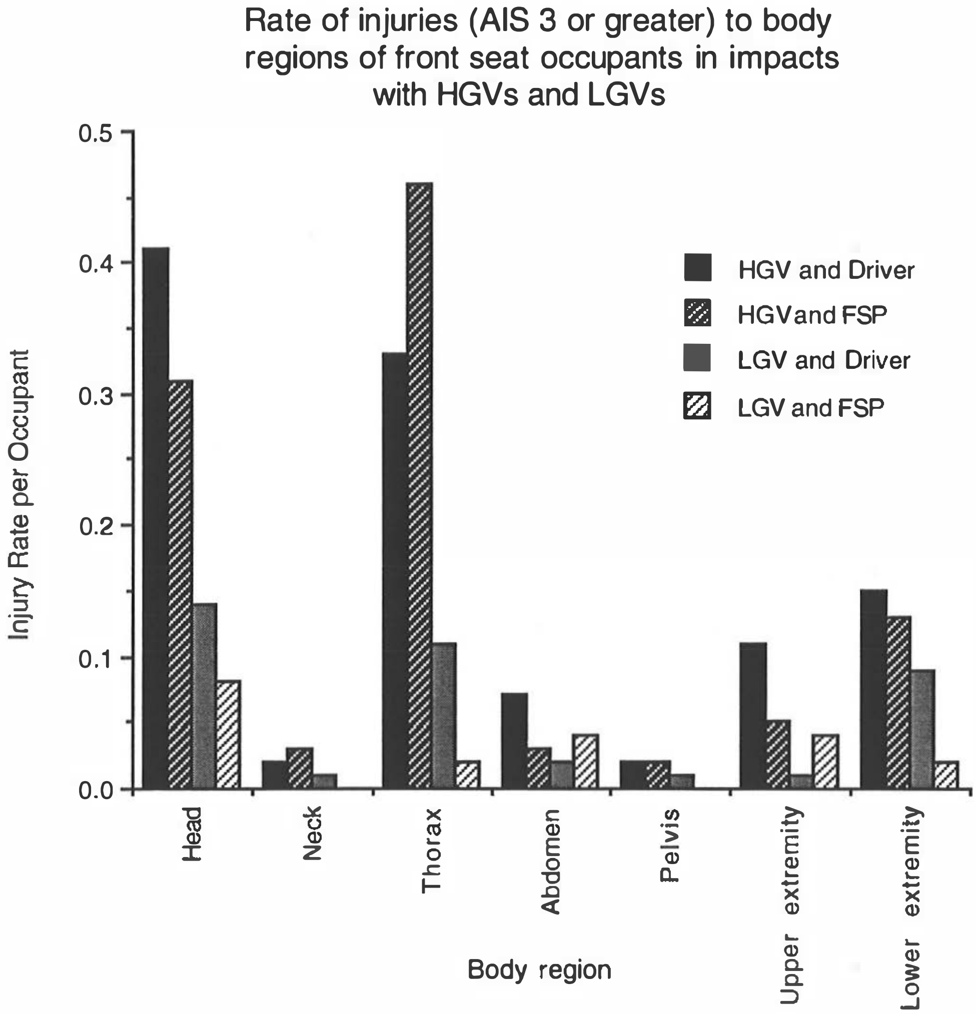


figure 4



The injuries that occurred within the cars were then considered. It was found that 284 injuries which had an AIS score of 3 or higher were recorded for occupants of cars in impacts with HGVs (a rate of 1.1 per occupant). The equivalent for LGVs was 71 injuries (a rate of 0.36). The injuries were grouped into body regions to consider which areas were most likely to be affected. The regions were head, neck (including cervical spine), thorax (including thoracic spine), abdomen (including lumbar spine), pelvis, upper extremity and lower extremity. Figure 5 gives the injury rate of drivers and front seat passengers separately.

figure 5



These data indicate that the main injuries of AIS 3 and greater are occurring to the head and thorax of occupants in impacts with HGVs. Figure 6 shows the contacts generating these injuries for drivers in impacts with HGVs for the head and thorax. It shows that the steering wheel caused over 50% of the injuries to the chest, whereas the windscreen, A-pillar and Roof caused over 50 % of the injuries to the head. The other vehicle caused about 25 % of injuries to both the head and chest. Only 14% of injuries were caused by the seat belt. For the FSP (figure 7) the main contact for the head was with the A pillar although there are significant contacts with the windscreen, facia and bonnet surface. For the chest, the main contacts are with the facia and the seat belt although there is a contribution from the other vehicle.

A comparison was then made with the types of contacts (to the same body regions) that those in impacts with LGVs suffered. For drivers, it was found that the injuries were due to contacts with the steering wheel and the other vehicle were still the main source. However there were few injuries (13 contacts with the steering wheel and 5 with the other vehicle and only one other contact). For the FSP only 10 contacts in total were listed and therefore were not examined.

figure 6

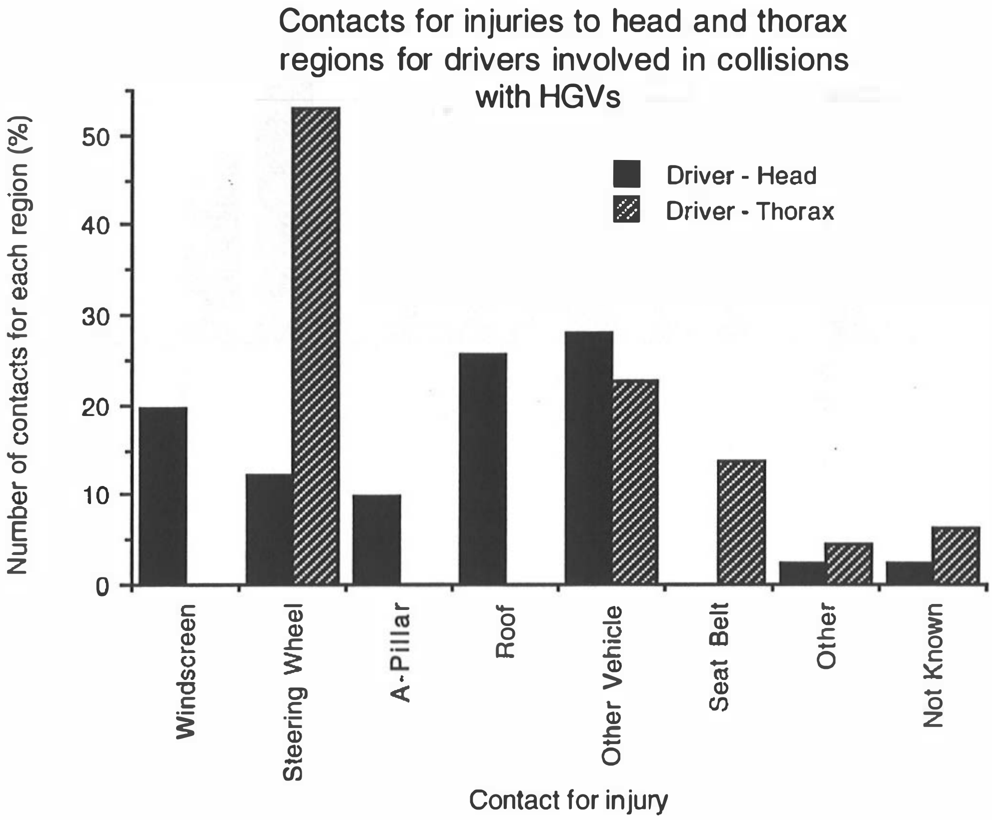
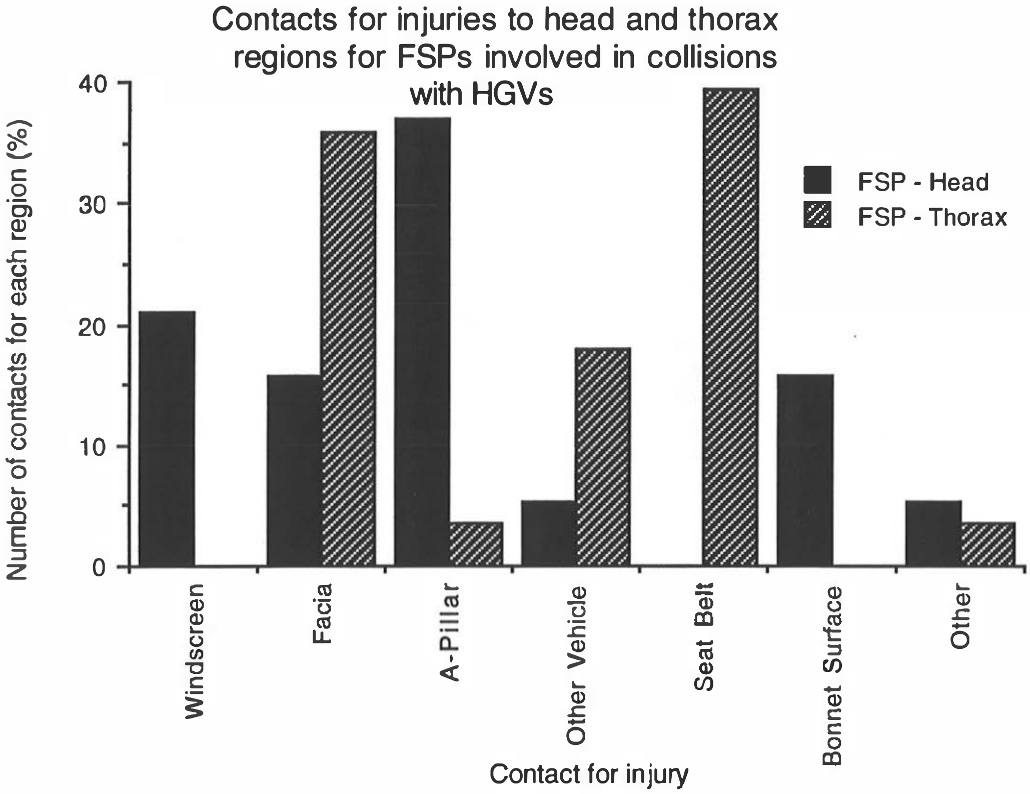


figure 7



DISCUSSION

Currently in the United States, pick-up trucks (eg LGVs), vans and sport utility vehicles make up over 40 % of new vehicle production. Similar vehicles within the European Union make up a much smaller proportion of the vehicle fleet (about 12 %), but that sector is growing quickly and some projections suggest that these vehicles will become just as popular in Europe as they are in the United States. Passenger car compatibility is governed largely by the standards which relate to bumper height and strength in the US even though such requirements are not safety standards as such and do not apply in Europe. LGVs, vans and utility vehicles in the United States do not have to meet the same requirements and in many such vehicles, bumper lines and stiff structures are considerably higher than for passenger cars.

As this study shows, the car/LGV collision is a relatively hostile crash in which intrusion at head and chest level is associated with serious injuries to restrained occupants. Thus if there is a major growth in LGVs in Europe, compatibility between vehicles in crashes will be significantly reduced. This has ramifications beyond just frontal crashes considered in this paper. The lateral collision condition specified in the current EU directive for example does not address the typical car/LGV interaction at all.

For car/HGV collision, it was found that contact with the streering wheel was attributed to over 50 % of injuries to the thorax and over 10 % of injuries to the head for drivers. For FSPs the facia accounted for 35 % and 15 % of injuries to the thorax and head respectively. It may be found that these injuries are reduced by the introduction of airbags into modern cars (if the collision is of the type to 'fire' the airbag). The other vehicle accounted for over 20 % and 25 % of injuries to the drivers thorax and head and about 20 % and 5 % of equivalent injuries to FSPs. This may be reduced by improvement of the relative heights of stiff structures

The data in this study shows that the velocity change distributions between collisions with HGVs and LGVs are not greatly different and clearly the crush at head and chest level is the major injurious factor. Market forces will not address this problem and therefore future regulations in Europe need to be considered now to pre-empt as far as possible the situation which has arisen in the United States.

ACKNOWLEDGEMENTS

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