Laminated Side Glazing
Implications for Vehicle Occupant Safety

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ABSTRACT

Analysis of real world data from the United Kingdom (CCIS), France (LAB) and Germany (GDV) indicates that the installation of laminated glazing in the side and rear windows to act as a deterrent against vehicle crime is likely to offer additional benefits. The results indicate that the incidence of occupant ejection, which frequently occurs through these glazing areas, is likely to be reduced. Consequently the incidence of fatal and serious injury will also be reduced since ejected occupants have a higher risk of experiencing these injuries. Any increase in the incidence of occupant entrapment due to door jamming alone is not likely to be a problem. In fact the installation of laminated glazing is likely to be beneficial.

Keywords: Ejection, Entrapment, Laminated Glazing, Glass

THE SIDE AND REAR GLAZING AREAS of most passenger cars are made of toughened glass. This type of glass is easy to shatter using simple tools and form one of the weak links in vehicle perimeter security. Consequently they are a frequent source of illegal entry into vehicles for the purposes of smash and grab theft or to cause physical assault on vehicle occupants. In order to combat this problem, laminated side glass, which is more difficult to break than toughened glass, has been developed. This type of glass is already being offered in some recent European models of cars. The trend suggests that most passenger cars will be fitted with laminated side glazing in the future.

Laminated glazing requires a greater amount of force for it to be broken or penetrated and takes a longer time for a sufficiently large hole to be created. An example of this is the Enhanced Protective Glass (EPG) which is a sandwich of 2 pieces of heat-strengthened glass (2.1 mm thick) with a homogeneous interlayer of plasticized polyvinyl butyral or PVB (0.76 mm thick). EPG can resist an aggressive attack for 20 – 30 sec compared to toughened glass which would resist the attack for only 1 – 2 sec (Lu et al. 2000). Furthermore toughened glass breaks into small cubicle shapes with sides equal in dimension to the width of the glass while the glass in laminated side glazing breaks into shards but still adheres to the interlayer. Three times the amount of kinetic energy of a blunt object is required to break laminated glass compared to the amount of kinetic energy required to break toughened glass (Clark et al 2000).

Side windows are also the most frequent (40%) apertures through which occupants are ejected during a crash (Huelke et al. 1971, Hedlund 1979, Clarke and Sursi 1989, Clarke 1989, Morris et al. 1993, Hassan and Mackay 1999). The properties of laminated side glazing installed at these windows suggest that the incidence of occupant ejection is likely to decrease and correspondingly the incidence of occupant entrapment may increase. Therefore these two issues need to be addressed.

Occupant ejection from motor vehicles has long been considered to be a contributor to death and serious injury in motor vehicle crashes (Campbell 1966). Over one quarter of fatalities in collisions occur as a result of ejection (Huelke and Gikas 1966, Hedlund 1979, NHTSA 1995). Indeed occupant retention within the vehicle during a collision is much more desirable since the risk of serious and fatal injuries is less (Morris et al. 1993, Hassan and Mackay 1999). A USA study estimates that some 19% of fatal injury ejections and 14% of serious injury ejections could be prevented annually if ejection mitigating glazing is used in the right and left front windows of passenger cars, light trucks and vans (NHTSA 1995). Therefore it would appear that the use of laminated glazing in the side and rear windows of cars is likely to be beneficial.

However the penetration properties of laminated glazing would also suggest that the incidence of occupant entrapment is likely to increase. Under such circumstance, the escape route of the entrapped occupant should not be compromised. Furthermore access to injured occupants requiring urgent medical attention should not be hindered by the presence of laminated glazing in order to avoid worsening the injury status of the occupant. Previous studies have shown that this is not likely to be a significant problem (Morris et al. 1993, Hassan and Mackay 1999).

There appear to be only two studies carried out in Europe which address the issue of laminated glazing in side windows (Morris et al. 1993, Hassan and Mackay 1999). These two studies use data from the same database (Co-operative Crash Injury Study) although analysis is performed using samples from two different time frames. Therefore this study was performed using sample sets from three different European countries (United Kingdom, France and Germany) and used to identify whether similar findings were observed in each of the data sets.

The aim of this study was to assess the probable merits of introducing laminated side glazing for reducing ejection. The study further considered the possible effect of introducing such changes to the incidence of entrapment.

METHODOLOGY

The data for this study were extracted from three European databases containing details of passenger cars involved in real world collisions and the casualties and their injuries. The UK data were obtained from the Cooperative Crash Injury Study (CCIS) database, the French data were obtained from the Laboratory of Accidentology, Biomechanics and human behavior (LAB) database and the German data were obtained from the GDV database. There are some differences between these databases in terms of the criteria applied for selecting vehicle crashes for examination and inclusion in the database. Consequently there are some differences between the three datasets used in this study.

The Cooperative Crash Injury Study forms part of an on-going study in the UK into vehicle crash performance and occupant injury (Hassan et al. 1995, Mackay et al. 1985). The study follows an established protocol to select vehicle crashes for examination and inclusion in the database. All police reported accidents are scrutinised on a daily basis to identify cars which are seven years or younger in age and towed to a recovery garage or vehicle dismantlers. A stratified sampling procedure is applied for the selection of eligible vehicle crashes. This has allowed on average, some 50% of the killed and serious injury cases and a further 15% of slight injury cases and 10% damage only accidents as defined by the UK Department of the Environment, Transport and Regions to be included in the database from defined geographical sampling areas in the UK. A total of over 1,300 passenger car crashes are examined annually. The sample thus represents all levels of injury outcome while being biased towards the more serious and fatal cases.

The selected vehicles are examined within a few days of the crash to record details of the damage profile, identify evidence of occupant's contact causing injuries and assess the performance of the safety features. The occupant injury data is obtained from the Accident and Emergency departments of hospitals and H. M. Coroner's post mortem reports. The information collated is used to compile a case.

The LAB follows a similar protocol to CCIS for selection of vehicles for inclusion in the database. The LAB's teams investigate accidents in a district located west of Paris including urban and rural road network. All accidents involving any make and model of car in which at least one injury occurred are selected for in depth investigation on a daily basis. Some 350 cars per year are investigated.

The GDV data is based on the data material from 15,000 car/car and 1,130 single car collisions used as the basis for the "Vehicle Safety 90" (VS90) study (Langwieder 1994, Langwieder 1998). The data for this study was selected by applying a selection criteria which required that at least one occupant of the cars involved in the collision should have suffered an injury of AIS ≥ 3 severity. This resulted in a sample of 831 car to car collisions and 324 single car collisions available for in-depth analysis. The collisions were analysed on a case by case basis by engineers and physicians. The case analysis also included other information available in the form of documentation, reconstruction and photographic material from other institutions.
The following criteria were applied to select the samples for this study from the three databases.

CCIS database
- Crashes: Only crashes which occurred between June 1992 and May 1998 are included.
- Vehicles: The struck vehicle had to be a passenger car less than 7 years old at the time of the crash.
- Severity: Only tow-away crashes are included.
- Injury: At least one occupant was injured at MAIS ≥ 1 severity level.

LAB database
- Vehicles: The struck vehicle had to be a passenger car less than 7 years old at the time of the crash.
- Severity: Only tow away crashes are included.
- Injury: At least one occupant was injured at MAIS ≥ 1 severity level.

GDV database
- Vehicle: The struck vehicle had to be involved in a crash in 1990 and later.
- Severity: Car to car and single car crashes which had undergone deformation, but in practice, all cars towed away.
- Injury: Only crashes in which at least one occupant received an injury of MAIS ≥ 3 severity level.

The injuries were coded according to the Abbreviated Injury Scale (AIS) using the 1990 version (AAAM 1990). The most severe injury rating is used to define the overall injury severity status (MAIS) of the occupant in this study.

The sample sets available from each of the three databases are shown in table 1. The total number of vehicles and the total number of occupants are also shown. These samples are used in the following analysis, which relates to occupants who were ejected and occupants who were trapped.

Table 1 : Distribution of vehicle body types.

Body style of Vehicle	Source of data					
	CCIS		LAB		GDV	
	No	%	No	%	No	%
Saloon	1182	22.0	291	16.4	751	30
Hatchback	3680	68.6	1299	73.0	1753	70
Estate	333	6.2	122	6.3	195	6.4
Van	171	3.2	76	4.3	-	-
Offroad	-	-	-	-	39	1.5
Total	5366	100.0	1778	100.0	2738	100.0
No of Occupants	*8460*		*2928*		*5265*	

The total sample size shown in the following analysis may differ for each variable under consideration as all of the information for all of the variables may not available. This reflects the nature of real world databases. Therefore the analysis only includes cases with known values for the variable under investigation. This results in variability in the total sample size for different sections of the analysis.

The findings are validated by applying statistical tests wherever permissible. The rejection of the null hypothesis is set at probability levels of less than 5%.

EJECTION

Occupant ejection was deemed to have occurred after careful study of the data obtained from vehicle examination, injury details and their causes by trained experienced crash investigators. Ejection was classed as either complete or partial. Complete ejection of an occupant occurs when the whole body of the occupant egresses to the outside of the vehicle and remains outside of that vehicle following completion of the collision event. Partial ejection occurs when some part of the occupant's body egresses through a portal of the vehicle body and contacts an external object.

Ejection was classed as either complete or partial in the CCIS and LAB databases. Only complete ejection was classed in the GDV database. The incidence of the types of ejection is shown in table 2. The ejection rate varies between 3.25% to 5.6%. The higher rates of ejection in the French and the German databases are due to these samples being biased towards more severe injury crashes. In fact the Germany data relates to crashes with a MAIS $\geq$ 3 injury outcome. The incidence of complete ejection is higher for single vehicle collisions compared to that for car to car collisions in this sample. The single vehicle collisions include rollovers, which are a more violent type of crash and have a higher tendency to result in an ejection.

Table 2 : Type and incidence of ejection.

Type of ejection	Database			
	CCIS All	LAB All	GDV Car to car	GDV Single car
Partial	197	50	-	-
Complete	78	113	56	150
Total	275	163	206	
Ejection rate	*3.25%*	*5.6%*	*3.9%*	

Ejection tends to result in more severe injuries to the occupants. Table 3 compares the risk of an ejected occupant receiving a fatal injury compared to that for a non-ejected occupant. The incidence of being killed is higher among those occupants who are ejected. The risk of being killed is over 8 times higher for ejected occupants in the CCIS and the LAB samples. The GDV sample, which is biased towards more severe crashes, where at least one occupant has received and injury of MAIS 3+ severity, also shows that the risk of being killed is higher for occupants who are ejected. Fatal injury outcome is twice as likely in single car crashes and 5 times as likely in car to car crashes for occupants who are ejected.

Table 3 : Comparison of injury severity for ejected and non-ejected occupants.

Severity of injury	CCIS All (%)		LAB ALL (%)		GDV Car to car (%)		GDV Single car (%)	
	Not eject	Eject	Not eject	Eject	Not eject	Eject	Not eject	Eject
Killed	3.5	30.9	4.7	37.4	9.9	48.2	15.4	30.7
Not killed	96.5	69.1	95.3	62.6	90.1	51.8	84.6	69.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	7622	269	2765	163	3080	56	920	150
Chisq	454.8374		258.5849		83.8329		38.6313	
df	1		1		1		1	
p <	0.0001		0.0001		0.001		0.001	

A similar observation is also made when the risk of life threatening injuries to ejected occupants is considered. Occupants were classed into two groups, those sustaining injuries of MAIS 0, 1 & 2 and those sustaining injuries of MAIS $\geq$ 3 as shown in table 4. The relationship between injury severity and ejection status is highly significant. Over half of the ejected occupants in each of the samples sustained severe to fatal (MAIS ≥ 3) injuries compared less than half of the non-ejected occupants in the GDV sample and less than 15% of the non-ejected occupants in the CCIS and the LAB samples. A risk of 2 times higher for the ejected occupants in the more severe injury biased GDV sample and 5 times higher in the CCIS and the LAB sample is observed. This would strongly suggest that occupant retention within a vehicle during collisions is desirable.

Table 4 : Comparison of injury severity (MAIS) for ejected and non-ejected occupants.

Injury severity (MAIS)	CCIS All (%) Not eject	Eject	LAB ALL (%) Not eject	Eject	GDV Car to car (%) Not eject	Eject	GDV Single car (%) Not eject	Eject
0 - 2	90.1	49.1	86.1	38.6	65.8	28.6	57.7	28.3
3 - 6	9.9	50.9	13.9	61.4	34.2	71.4	42.3	71.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N	7581	267	2765	163	3080	56	920	150
Chisq	430.4300		250.4995		59.9894		49.2785	
df	1		1		1		1	
p <	0.0001		0.0001		0.001		0.001	

The type of ejection may also influence the severity of injury as shown in table 5. Only data from the CCIS and the LAB samples are considered since the GDV sample only includes the data for complete ejection. Analysis of the CCIS sample shows that occupants who are completely ejected are significantly more likely to sustain severe to fatal (MAIS ≥ 3) injuries. Some 71% of the occupants who were completely ejected sustained injuries of MAIS ≥ 3 severity. On the other hand over half of the occupants who were partially ejected sustained injuries of a minor nature (MAIS ≤ 2). Such a significant association between type of ejection and injury outcome is not seen in the LAB sample. A possible explanation could be that the LAB sample is highly selective and includes very little variability.

Table 5 : Comparison of injury severity by type of ejection.

Injury severity MAIS	CCIS Complete %	CCIS Partial %	LAB Complete %	LAB Partial %
0 - 2	29.2	56.4	44.2	26.0
3 - 6	70.8	43.6	55.8	74.0
Total	100.0	100.0	100.0	100.0
N	72	195	113	50
Chisq	13.673		4.3959	
df	1		1	
p <	0.001		NS	

The CCIS, the LAB and the GDV databases contain data from countries that enjoy high seat belt usage rates. Analysis of the CCIS and LAB samples indicate a significant association between the type of ejection and use of seat belts given that an ejection has occurred as shown in table 6.

The chances of being completely ejected, should an ejection occur, are reduced when a seat belt is worn. Less than 10% of the occupants in the two samples who used a seat belt experienced a complete ejection. Indeed even in the more severe crashes (GDV sample), only about 13% of the occupants who wore a seat belt experienced a complete ejection. The analysis suggests that in high seat belt use countries, partial ejection is more likely to occur rather than complete ejection given that an ejection has occurred.

Table 6 : Seat belt use and the type of ejection.

Restraint use status	CCIS Complete %	CCIS Partial %	LAB Complete %	LAB Partial %
Used	9.1	64.5	6.5	56.2
Not used	90.9	35.5	93.5	43.8
Total	100.0	100.0	100.0	100.0
N	66	166	107	48
Chisq	57.3059		28.9076	
df	1		1	
p <	0.001		0.001	

The seat belt use status and ejection portal of the ejected occupants in the CCIS and LAB database were known. There were 220 occupants in the CCIS sample of whom 182 were seated in the front seats. Similarly there were 154 occupants in the LAB sample of whom 109 were seated in the front seats.

The side window was the most frequent egress route for restrained occupants seating in the front seats who were partially ejected (table 7). Some 72 of the 100 restrained occupants in the CCIS sample and 22 of the 24 restrained occupants in the LAB sample were partially ejected through the side window. The side window was also the most frequent egress route for unrestrained front seat occupants. Some 17 of the 43 unrestrained front seat occupants in the sample were partially ejected through the side window. Similarly 24 unrestrained front seat occupants were completely ejected through the side window and another 12 occupants were partially ejected through the side window. Ejection through side windows by rear seat occupants was low. The side windows as a frequent egress route would suggest that the installation of alternative glazing to these portals is likely to significantly reduce the incidence of ejection.

Table 7 : Egress routes by ejection type and restraint use

Ejection Route	Restrained Complete CCIS	Restrained Complete LAB	Restrained Partial CCIS	Restrained Partial LAB	Unrestrained Complete CCIS	Unrestrained Complete LAB	Unrestrained Partial CCIS	Unrestrained Partial LAB
Number of Front Seat Occupants								
Windscreen	6	-	5	-	12	6	8	3
Side Window	-	1	72	22	2	24	17	12
Side Door	-	2	7	2	9	22	5	1
Tailgate / Rear window	-	3	2	-	3	7	-	-
Sunroof	-	-	2	-	3	-	2	1
Not Known	-	1	12	-	4	2	11	-
Total	6	7	100	24	33	61	43	17
Number of Rear Seat Occupants								
Windscreen	-	-	-	-	9	2	-	1
Side Window	-	-	2	2	2	6	3	1
Side Door	-	-	-	-	5	5	-	1
Tailgate / Rear window	-	-	1	1	2	23	-	-
Sunroof	-	-	-	-	1	-	-	-
Not Known	-	-	-	-	4	3	5	-
Total	0	0	3	3	23	39	12	3

It is also noteworthy that ejection through the front window accounted for 40 (18%) in the CCIS sample and 12 (8%) in the LAB sample. All of these windscreens were laminated glass and the great majority were bonded to the bodyshell. However windscreen ejection cases represent very severe crashes with gross distortion of the bodyshell and windscreen aperture and do not represent the likely performance of laminated glass if used in a side window installation. The 98 (45%) side window ejection cases in the CCIS sample and the 68 (44%) of similar cases in the LAB sample were mainly more typical crashes where the bodyshell and door apertures were not grossly distorted. These were mainly intersection collisions and rollovers.

There were 6 restrained front seat occupants in the CCIS sample who were completely ejected during the collisions. These vehicles received very severe impacts result in gross deformation of the vehicle and significant compromise of the occupant compartment.

The distributions of the incidence with which the different body regions of the ejected occupants are injured are shown in table 8. The cervical spine is included in the head/neck region, the thoracic spine is included in the thoracic region and the lumbar spine is included in the abdomen region. The head/neck region is the most frequently injured body region followed by the extremities. The incidence is even higher in the more severe crashes as seen in the LAB and the GDV samples. Occupants with injuries to the thorax region also account for a substantial proportion. The incidence of injuries to the face region is also higher in the more severe crashes. This would suggest that any measure which helps to reduce the incidence of injury to the head/neck, face and thorax regions which all house vital organs would be beneficial.

Table 8 : Distribution of body regions injured.

Body Region	CCIS All %	LAB All %	GDV Cc %
Head/Neck	55.3	77.2	62.7
Face	15.2	46.7	23.9
Thorax	34.4	36.8	16.4
Abdomen	21.3	23.7	22.3
Extremities	40.1	62.3	53.7
External	90.0	-	-
No. of Occupants	197	114	67

Cc – car to car

Ejections mainly occur in side impacts (table 9). Complete ejections accounted for 40% in the CCIS and 30% in the LAB samples. In the more severe crashes (GDV sample), complete ejections account for 75% in car to car collisions and 45% in single car crashes. Partial ejections also have a high incidence of occurrence in side impacts, accounting for 60% in the CCIS sample and 53% in the LAB sample. Complete and partial ejections also occur with a significant incidence during rollover collisions. The incidence of complete ejections during rollover collisions ranges from 20% in the CCIS sample to 43% in the LAB sample. In the GDV sample the high incidence (40%) of ejections is in the single car rollover collisions. Partial ejections account for 17% in the CCIS sample and 32% in the LAB sample.

Table 9 : Distribution of impact types for ejected occupants.

Type of Impact	Type of Ejection: Complete				Partial	
	CCIS All %	LAB All %	GDV Cc %	GDV Sc %	CCIS All %	LAB All %
Rear	5.1	7.5	3.6	3.8	2.0	2.1
Front	29.5	12.1	11.0	11.3	18.3	10.6
Side	39.8	29.9	74.5	45.3	60.4	53.1
Rollover	20.5	43.0	10.9	39.6	16.8	32.1
Unclassified	5.1	7.5	-	-	2.5	2.1
Total	100.0	100.0	100.0	100.0	100.0	100.0
No of cases	78	107	55	106	192	47

Cc – car to car Sc – single car

The side windows being the most frequent portal for ejections explain the high incidence of side impacts and rollover collisions. This would suggest that the installation of an alternative form of glazing in side windows would lead to a reduction in the incidence of ejection.

ENTRAPMENT

The installation of the intrusion resistance glazing in side windows of cars may indeed help to reduce the incidence of ejection while at the same time this measure may increase the incidence of occupant entrapment. The increase in entrapment is envisaged since any glazing material, which is difficult to penetrate from the outside of the vehicle, may also be difficult to penetrate from inside of the vehicle if occupants need to be evacuated or urgent medical assistance needs to be offered.

Entrapment can occur due to door jamming, obstruction of the door opening, intrusion of the occupant compartment, seat belts and other factors. Entrapment due to door jamming alone and an occupant sustaining slight injury or no injury would normally imply that the occupant still retains the freedom of movement in the vehicle. It is this freedom that should not be compromised by the introduction of alternative glazing or else such freedom and hence the ability to escape by other means will be limited.

Therefore occupant entrapment due to door jamming alone is also investigated in this study. Door jamming was defined in this study as instances where the door was jammed in the frame as a result of a collision. Instances during which the door required a greater amount of manually applied force than that required for normal operation to open the door were also included in this definition. Entrapment was defined as instances when all side doors of the vehicle, nearest the occupant, were jammed post collision. The occupants were not prevented from exiting the vehicle due to any other reason; for example, the driver was considered to be trapped if both the front doors were jammed and so on.

The distribution of occupants trapped due to various configurations of door jamming is shown in table 10. The instances where both front doors are jammed in vehicles with two side doors and both front doors or both rear doors in vehicles with four side doors are considered to meet the entrapment definition. These samples of occupants were further analysed to identify the proportion of occupants who were free to move within the vehicle and thus wholly meet the definition of entrapment. There were 627 occupants in the CCIS sample and 117 occupants in the LAB sample who met this definition. There were 355 occupants who were considered to have been trapped in the GDV sample, which only includes data relating to frontal collisions.

The entrapment rate was also identified and was defined as the proportion of cars with both the front doors jammed in two door cars and either both front doors or both rear doors or all four doors are jammed in four door cars. Furthermore at least one occupant (front seat occupant or rear seat occupant) was considered to trapped in a two door car with both front doors jammed. In a four door car at least one front seat occupant was considered to be trapped when both front doors were jammed or at least one rear seat occupant was considered trapped with both rear doors jammed or at least one occupant was considered to be trapped when all four doors were jammed. Therefore the entrapment rates shown in table 11 relate to vehicles regardless of the number of occupants in the vehicle who meet the definition of entrapment.

The entrapment rate for two door cars is approximately 25.0% and that for four door cars also averages at 25.0%. The entrapment does not appear to be dependent on the injury severity outcome since the rates across the three databases are very similar.

Table 10 : Distribution of occupants entrapped due to configuration of doors jammed.

Location of Jammed Door	Seating Position of Trapped Occupant	Number of Side Doors: Two No	Two %	Four No	Four %
CCIS					
Front Offside	Driver	428	54.3	802	54.4
Front Nearside	Front Seat Passenger	125	15.9	176	11.9
Both Front	All Front Seat Occupants	**197**	25.0	**327**	22.2
Both Front	All Rear Seat Occupants	**38**	4.8	-	-
Rear Offside	Rear Offside Passenger	-	-	54	3.7
Rear Nearside	Rear Nearside Passenger	-	-	49	3.3
Both Rear	All Rear Seat Occupants	-	-	***65***	4.4
Total		788	100.0	1473	100.0
Entrapment rate		*25.0*		*25.8*	
LAB					
Front Offside	Driver	115	57.9	119	47.2
Front Nearside	Front Seat Passenger	27	13.6	24	9.5
Both Front	All Front Seat Occupants	**49**	24.6	**20**	7.9
Both Front	All Rear Seat Occupants	**8**	3.9	5	2.1
Rear Offside	Rear Offside Passenger	-	-	24	9.5
Rear Nearside	Rear Nearside Passenger	-	-	20	7.9
Both Rear	All Rear Seat Occupants	-	-	**40**	16.0
Total		199	100.0	252	100.0
Entrapment rate		*24.6*		*23.9*	
GDV- *Front to front collisions both front or rear doors jammed*					
Both Front	Driver	92	24,2	130	21,3
Both Front	Front Seat Passenger	34	8,9	52	8,5
Both Front	All Front Seat Occupants, i.e. drivers and/or passenger entry.	92	24,2	182	21,3
Both Front	All Rear Seat Occupants	-	-	-	-
Rear Offside	Rear Offside Passenger	-	-	-	-
Rear Nearside	Rear Nearside Passenger	-	-	-	-
Both Rear	All Rear Seat Occupants	29	7,6	18	3,0
Total		340	100.0	610	100.0
Car related entrapment rate		*24,2*		*24,3*	

The injury severity distributions of the occupants considered to be trapped in the CCIS sample (627), the LAB sample (117) and the GDV sample (355) are shown in table 11. The occupants who were uninjured or sustained the slight severity of injury (minor cuts and bruises) can be considered to be able to move freely within the vehicle. There were 256 (41%) occupants in the CCIS sample and 67 (57.3%) occupants in the LAB sample who were either uninjured or sustained a slight severity of injury. The corresponding data in the GDV sample is presented in terms of MAIS score of the occupant. Occupants with a MAIS 0 to 2 can be considered to have sustained either no injuries or slight to moderate (minor cuts and bruises) level of injury. Some 20% of the occupants in car to car collisions and 18% of the occupants in single car collisions sustained no injuries or slight to moderate level of injuries in frontal impacts. The lower proportions of occupants with this level of injuries in the GDV sample can be explained by the fact that this sample is biased towards the more severe crashes.

Table 11 : Distribution of injury severity of trapped occupants.

Injury Severity	CCIS		LAB	
	No	%	No	%
Fatal	82	13.1	25	21.4
Serious	253	40.4	25	21.4
Slight	223	35.6	49	41.8
Uninjured	33	5.3	18	15.4
Severity N/K	36	5.7	-	-
Total	627	100.0	117	100.0

GDV		
Injury Severity	Car to car collisions	Single car collisions
(MAIS)	%	%
0	0.3	0.5
1 – 2	19.7	17.4
3 – 5	47.2	42.1
6	32.8	39.7
Total	100.0	100.0
Number of cases	246	109

The proportion of occupants with the lesser severity of injuries is likely to increase in the future due to advancement in occupant safety features in passenger cars and improved trauma care. A recent UK study indicates that the incidence of fatal and serious collisions have been decreasing over the last decade (Hassan and Mackay 2000). Correspondingly there has been an increase in the incidence of slight and non-injury collision.

The type of impacts in which the uninjured and slightly injured occupants were involved is shown in table 12. Side and front impacts were the most frequent impact types. A third (34%) of the occupants in the CCIS sample and a quarter (24%) of the occupants in the LAB sample were involved in side impacts. A similar incidence rate is observed for frontal impacts. Over a half of the occupants in the car to car collisions (54%) and single car collisions (57%) in the GDV sample were involved in side impacts. The involvement rate for occupants involved in front car to car collisions (43%) and single car collisions (23%) is lower. Side impacts, rollovers and rear impacts in the CCIS and the LAB samples are over represented in this study. Their distribution is generally less in studies, which include all types of impacts. The dissimilarity between the distribution of impact types in the GDV sample compared to the CCIS and the LAB samples reflects the bias of the sample towards more severe crashes.

Table 12 : Distribution of impact types for uninjured and slightly injured occupants.

Impact	CCIS	LAB	GDV	
Type	All %	All %	Cc %	Sc %
Rear	13.7	16.4	2.6	0.9
Front	31.6	25.3	42.9	22.7
Side	33.6	23.8	54.1	56.8
Rollover	18.0	22.4	0.4	19.5
Unclassified	31.	12.1	-	-
Total	100.0	100.0	100.0	100.0
Number of cases	256	67	246	109

Cc – car to car Sc – single car

CONCLUSIONS

The following conclusions arise from the study.

- Installation of intrusion resistance glazing in the side windows and rear windows of cars is likely to be beneficial.
- The incidence of occupant ejection will be reduced which may result in a corresponding increase in occupant entrapment.
- Occupant entrapment is not likely to be a major problem.
- However it has to be assured that in collisions with severe side intrusion where the alternative glazing has lost integrity as a result of breaking and folding, no additional injury risk may occur.

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This paper uses data from the United Kingdom Co-operative Crash Injury Study, from the French LAB and the German GDV databases

The IFM runs the accident research of the German Insurance Association and collects the data from all German insurance companies. The insurers data are enlarged by cooperation with police and hospitals. The accidents are reconstructed and analyzed in a joint technical/medical analysis.
Further information is available at http://www.gdv.de/fachservice/index.html.

CCIS is managed by TRL Limited on behalf of the Department of the Environment, Transport and Regions (Vehicle Standards and Engineering Division) who fund the project with Autoliv, Ford Motor Company, Honda R&D Europe, LAB, Toyota Motor Europe and Volvo Car Corporation. The data were collected by teams from the Birmingham Automotive Safety Centre of the University of Birmingham; the Vehicle Safety Research Centre of the University of Loughborough; Vehicle Inspectorate Executive Agency of the DETR. Further information on CCIS can be found at http:/www.ukccis.com/

The LAB (Laboratory of Accidentology, Biomechanics and Human Behaviour) is a common structure of the French car manufacturers. It has been working on accidentology and biomechanics for more than 30 years and has been involved in many international activities in these fields. Since the early seventies, LAB has built a very important detailed accident database containing more than 12,000 cars, 20,000 occupants and 52,000 injuries.

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