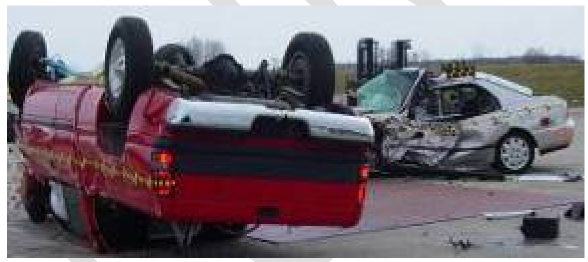
SUV/Pickup Truck Crash with Cars – Side Impacts and Vehicle Occupants' Safety

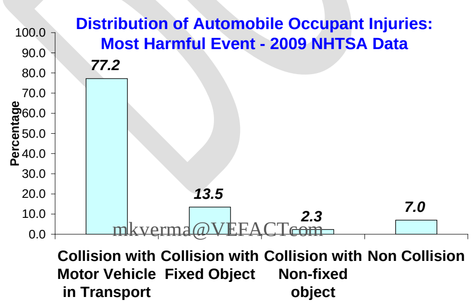
(by Mukul K. Verma)

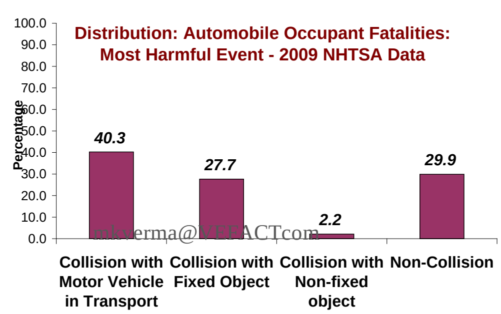
In a crash between a passenger car and an LTV (i.e. 'Light Truck Vehicle' which includes SUVs, pickup trucks & vans), it is generally assumed that the lighter mass vehicle will suffer more damage and that its occupants will likely have higher levels of injury. However, the outcome of such a crash depends on many factors, such as the vehicles' structures, the crash parameters, the effectiveness of safety systems (such as seatbelts, airbags, interior components) etc. There also exist other complicating factors due to the generally higher primary structures of LTVs. Analyses of LTV-to-car crashes therefore require that all these variables be taken into account. This issue, generally known as 'collision compatibility' has been researched for many years. No regulatory requirements exist for this crash condition. It should also be noted that making any design changes in vehicles for improving collision compatibility needs to take into account the existing regulations for safety in other crash modes, some of which may be conflicting to some extent (*see* *see Verma et al, "Relationship of Crash Test Procedures to Vehicle Compatibility"* *Paper 2003-01-0900, SAE Transactions, 2003).*



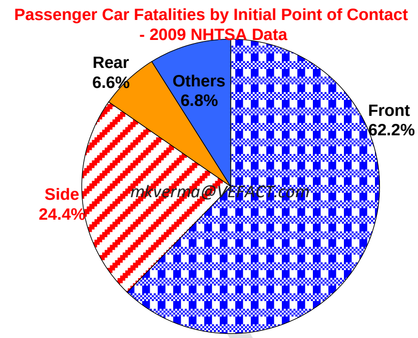
The purpose of this note is to discuss LTV-to-car crashes in which the side impact to the occupant compartment of the passenger car is listed as 'the most harmful event' in the crash database.

Magnitude of the problem: For the year 2009, NHTSA data ("Traffic Safety Facts 2009") state that of the 33,808 traffic-related fatalities and 2,217,000 injuries in the USA, automobile occupants accounted for 24,474 fatalities and 2,011,000 injuries. Further analysis shows that more than 77 percent of these injuries to automobile occupants may





be attributed to their automobile's collision with another motor vehicle in transport. Evaluation of fatality data from the same source show a similar trend - more than 40 percent of all the fatalities among automobiles' occupants were due to their vehicle's crash with another moving vehicle.

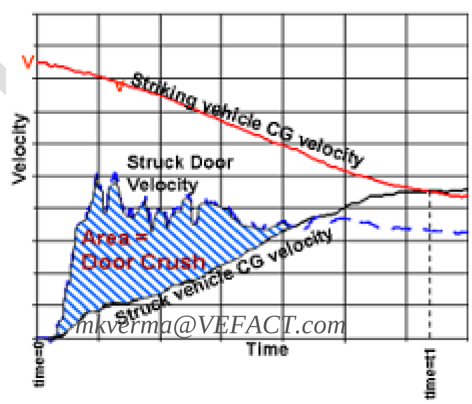


When the fatality data for occupants of passenger cars only (excluding LTVs) are analyzed for the modes of crash, side impacts are seen to account for more than 24% of all fatalities in passenger cars (in *all crashes* for passenger cars and not just the vehicle-to-vehicle impacts).

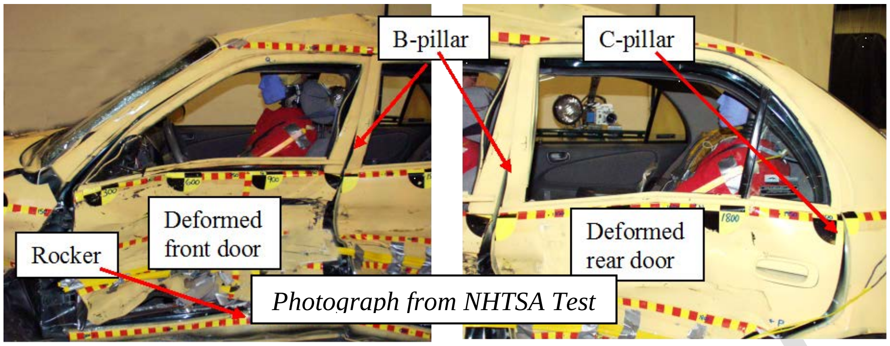
Vehicle Design Factors in Side Impacts: In vehicle-to-vehicle side crashes, a striking vehicle's impact is often on components such as the rocker, the A- and B-pillars and the doors of the struck car. In such cases, relatively small change in the impact configuration (such as higher bumper and front structure on the striking car with respect to the struck vehicle) may lead to entirely different sequence of events for both vehicles.


Photograph from NHTSA Test

Role of Vehicle Structure: An automobile's side structure can dissipate only a small fraction of the crash energy because there is relatively small deformation space available between the exterior surface of vehicle and the occupant. The primary function of the side structure then is to provide structural integrity and to minimize the intrusion of the doors and their impact severity with the occupants. The figure here illustrates the dynamics of the vehicles when the impact is lateral and the striking vehicle is moving with velocity V at the moment of impact. Also, the door of the struck vehicle deforms during the impact and, with respect to the CG of struck vehicle, it will appear to intrude inwards.

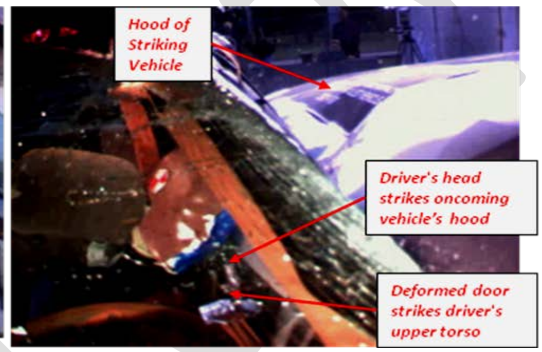


An example of the structural deformation of struck vehicles is shown below from a side crash test conducted by NHTSA. The primary impact to the test vehicle was on the rocker, the doors and the B-pillar and these components show significant amounts of deformation. The deforming interior surface of the front door impacts the driver's pelvis and shoulder (since no side impact airbags were present) as the available clearance is taken up by the



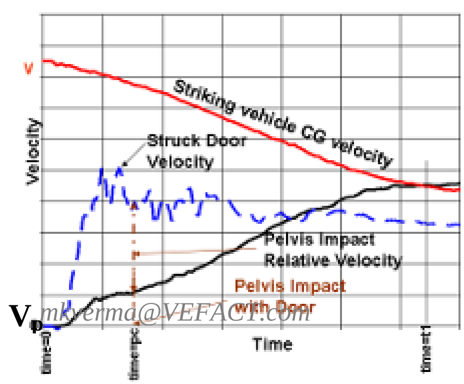
deformation. Further intrusion of the door then causes outward rotation of the driver's head and may lead to its being impacted by the oncoming vehicle as shown below.

Driver in Struck Car - Pre-impact position



Impacting Vehicle Intrusion & Contacts with Driver

The impact severities of the occupants' body segments will depend on the doors' relative velocity and its deformed shape at the instant of impact, as well as on the structural properties of the components packaged inside the door. As shown here, contact with the driver's pelvis occurs at time 'pc' with a relative velocity V_p. Similar impacts of torso, shoulder, head, etc will occur with parts of the vehicle at different instants. When an airbag is deployed, the timing sequence of these impacts is changed according to the airbag's deployed shape.

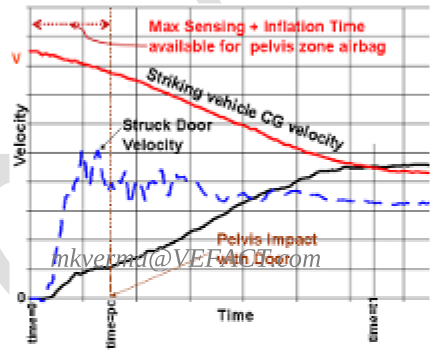


Airbags for Side Impact Protection: Currently, airbags in use for side impact protection of occupants fall into two categories:

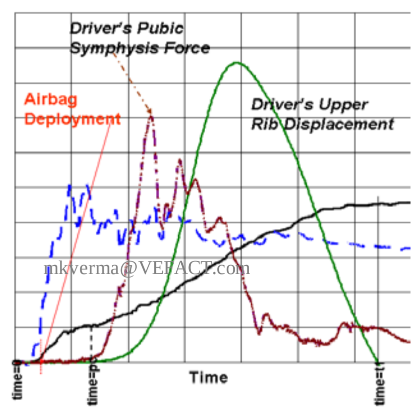
1. ***Pelvis & Thorax airbags*** are mounted in the seat or in the door and when deployed, provide protection for the occupants' pelvis and thorax regions. Their principal function is to distribute the impact load over a larger area of the occupants' torso, eliminating any 'hard contacts' with parts of the door . They also function to reduce the rate of the occupant's acceleration (and thus the impact severity) by deflating at a controlled rate after loading by the occupant.

2. ***Curtain airbags*** are usually mounted in the roof rail area of the automobile. When deployed, they cover the window openings and reduce lateral excursion of the occupants' heads through the nearest opening (the tempered glass in the side windows usually breaks away during the initial part of the impact). Since they function in tension to reduce or eliminate the head impact with external surfaces, they need to be tethered (i.e. anchored to the car's pillars) appropriately.

Sensors for Side Impact Airbag Deployment:
Both of the above types of airbags need to be deployed between the occupant's body and the impacting objects (such as the door). Therefore, sensors for detecting these crashes (and for deploying airbags if needed) must be engineered such that the airbags are in place prior to the instant of impact of the occupant. The time generally available for such sensing and deployment of airbags in lateral impacts is much shorter than in frontal crashes due to the fact that the distance between the vehicle's exterior (outer surface of the door) and the occupant is quite small. In the example of 38 mph side crash, the door may strike the driver's pelvis in 15 milliseconds from the instant of contact of vehicles. Therefore, the combined sensing and inflation time available for pelvis airbag must be less than this value. The sensing requirements also need to incorporate the timing of the impact of other body segments.



Several other requirements determine the location and the properties of these sensors, such as immunity from damage during normal operations or in minor impacts. They also must provide sufficient discrimination between deployment conditions and non-deployment crashes. In many vehicles, such sensors are located in the rocker or in the B-pillar zone as well as in the vehicle interior (near the driver's seat). In the example cited here, the side impact sensors located in the B-pillar and under the driver seat initiated the deployment of airbags at around 5 milliseconds after t=0.



Requirements and Regulations for Occupants' Safety in Vehicle-to-Vehicle Crashes:
There are no regulations that specifically govern occupant safety in LTV-to-passenger car crashes (generally referred to as 'crash compatibility'). However, some procedures have been developed as 'voluntary standards' for enhancing frontal crash compatibility between passenger cars and LTVs. A set


Photograph from NHTSA Test

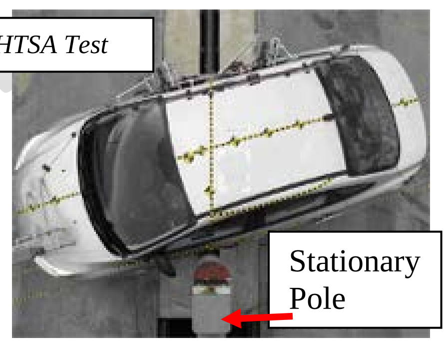
of these have been adopted by manufacturers of vehicles sold in the USA (see *Verma, "Enhanced Vehicle Collision Compatibility - Progress Report of US Technical Workgroup for Front-to-Front Compatibility", paper 07-0291, Enhanced Safety of Vehicles Conference, 2007*). These are intended to enhance protection of occupants of passenger cars in frontal crashes with LTVs. However, the effectiveness of these countermeasures needs to be established by further research (see *US Department of Transportation Report DOT HS 811 621, May 2012, "Evaluation of the Enhancing Vehicle-to-Vehicle Crash Compatibility Agreement: Effectiveness of the Primary and Secondary Energy-absorbing Structures on Pickup Trucks and SUVS"*).

For side impacts between LTV and passenger cars, it may be assumed that regulations (FMVSS214) and ratings tests (Side NCAP and IIHS tests) for side impact safety improve protection in vehicle-to-vehicle crashes as well. A brief description of Side NCAP and of the IIHS Side Impact test procedures is presented below. Although similar in concept, they differ significantly in their test barriers, test configuration, measured responses of occupant (Anthropomorphic test devices or ATDs) and in the rating scale used.

1. Side Impact NCAP Test (NHTSA): This is a part of the New Car Assessment Program and consists of two separate tests whose scores are combined to calculate the side-impact-related 'star' ratings for the vehicle. The first test is an 'intersection' type impact to the stationary vehicle by an MDB of approximately 1367 kg moving at 62.2 km/h. The barrier is crabbed (i.e. the wheels on the barrier are turned) to simulate the case where the struck vehicle is moving in a forward direction .

Photograph from NHTSA Test

NCAP Moving Deformable Barrier Test



NCAP Side Pole Impact Test

The driver is represented by a fiftieth percentile male ATD and the rear passenger by a fifth percentile female ATD. Estimates of 'relative risk' of injury for each seating position are calculated from the measured data.

Post-crash - Driver - NCAP MDB Test

Post-crash- Driver -NCAP Side Pole Test

The second test in the Side NCAP is a pole test (32.2 km/h, 75 degrees oblique impact of the test vehicle into a fixed pole) with a fifth percentile female ATD in the front seat.

The measurements of the dynamic response of the ATDs in the above tests are combined into ‘relative risks’ of injury for front- and rear-seat occupants using NHTSA developed formulae . These are then converted into ratings from one star to five stars for the vehicle’s safety in side impacts.

2. IIHS Side Impact Test: This test consists of a 1500 kg MDB impacting a stationary test vehicle perpendicularly at 50 km/h. Ratings are based both on the vehicle deformations and on the measured responses of the front driver and the rear passenger ATDs. These data for the test vehicle are then compared with IIHS-defined ‘corridors’ for the four categories of ratings (Good-Acceptable-Marginal-Poor) and based on this, IIHS publishes

the ratings for the overall vehicle as well as separately for the structure and for the protection of the occupant’s body segments. In addition, a 'Head Protection' rating is published based on the observed performance of curtain airbags in these tests.
The MDB in the IIHS test is heavier than NCAP MDB and may be thought of as simulating an impact by a light-truck vehicle (LTV) into the test vehicle.

<u>SUMMARY</u> The material above describes some aspects of LTV-to-passenger car side impacts and the factors governing the safety of the cars’ occupants. Statistical data show that vehicle-to-vehicle (and LTV-to-car) crashes are a significant part of the overall traffic safety scenario. The analysis of such crashes requires that the dynamic interactions between the structure of the two vehicles be comprehended in addition to the analysis of each of the vehicles and its crashworthiness.