Pedestrians' Injuries & Effect of Automobile's Front-End Design

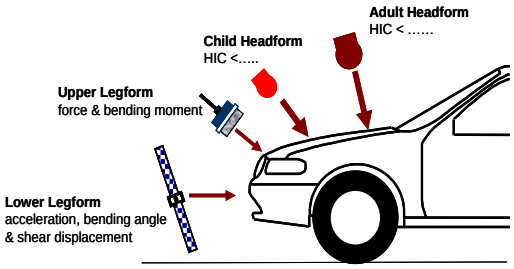
Every year, there are approximately 6000 fatalities (6227 in the year 2018) and many more serious injuries to pedestrians and bicyclists from vehicles in the USA. More recent data[1] show that these numbers have increased by 45% since 2009. These trends have varied over the years but injuries and fatalities to pedestrians and cyclists from automobiles remain a serious issue.

In order to address this and to reduce these injuries and fatalities, it is necessary to (1) reduce the probability of such accidents, and (2) reduce the severity of the impacts when these accidents happen. The first step requires that appropriate traffic rules and infrastructures be implemented to increase the separation between vehicular traffic and other road users. The second step is to investigate designing vehicles' front ends to reduce the severity of impacts when they happen. This is discussed here.

The Law:

Currently, there is no law in the USA governing the structural design of road vehicles for reducing pedestrians' injuries. In the early 80s, an Advanced Notice of Proposed Rulemaking (ANPRM) was issued by the National Highway Traffic Safety Administration (NHTSA) but was cancelled. However, several other countries (Japan, European countries, etc.) have had such laws in place (as described in www.unece.org/trans/main/ wp29/wp29wgs/wp29gen/ wp29registry/gtr9.html) which mandate that certain tests be conducted and that vehicles meet specified performance criteria in these tests.

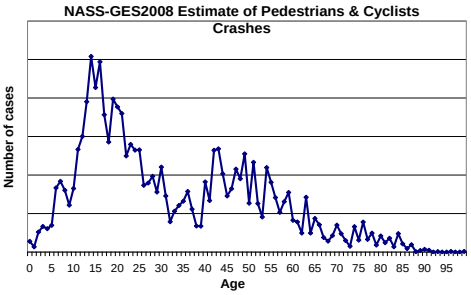
These tests represent (a) head form of an adult and of a child, striking designated parts of the vehicle's upper front; and (b) adult leg forms impacting lower front surfaces. In order to comply with these requirements, the vehicle manufacturers have to implement designs which:



(a) control the structural stiffness of the components in the impact zones (hoods, fenders, headlights, etc.); and/or

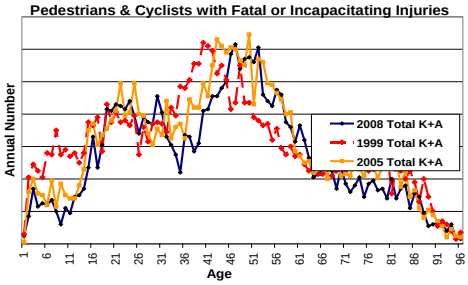
(b) provide adequate 'crush space' underneath the surfaces struck by the impactors. It is also possible that, instead of providing crush space, the manufacturers may meet the law by installing 'active systems' to 'pop up' the hood by a certain amount when impact on the hood is detected, thus creating a crush space when needed. The other available option is to install 'hood airbags', also deployed when an impact is detected by onboard sensors, thus reducing impact-induced forces on the pedestrian's head.

Accident Statistics: Pedestrian Fatalities and Incapacitating Injuries



Distribution with Age:

According to a study published[3] some years ago, the distribution of the number of vehicle crashes with cyclists and pedestrians shows a 'bimodal' trend - (1) sharper peak for children and young adults, and (2) distributed peaks for older adult population.

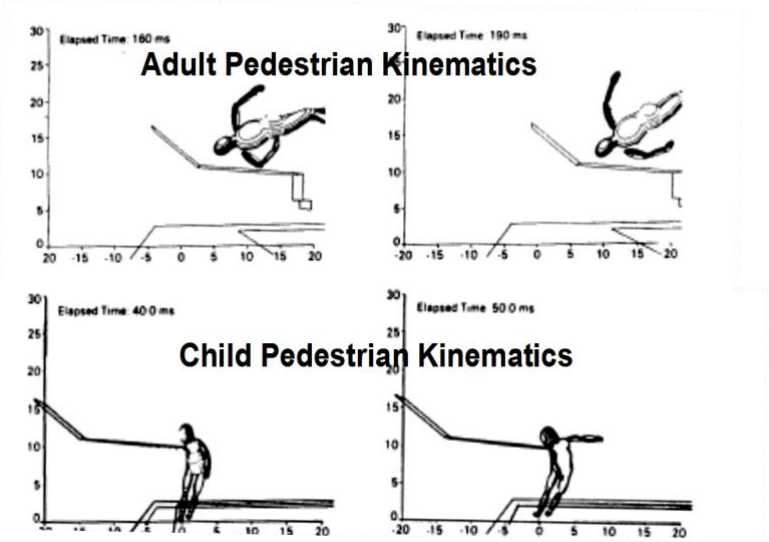


A similar analysis of the number of fatalities and incapacitating injuries among pedestrians showed similar trends. This implies that, when studying countermeasures for injury reduction, both these population groups must be taken into account.

Research on the Effects of Vehicle Design on Pedestrian Injuries

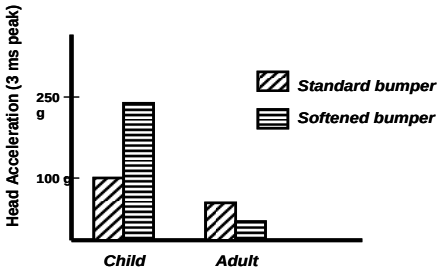
It is known that the front-end (and other) structural components of an automobile are designed to meet multiple requirements for protecting its occupants in various crashes and adding the requirements for pedestrians' protection may appear to be a conflict. However, the crash energies in pedestrian and cyclist impacts are much lower than those involved in protecting the vehicle's occupants in accidents. Thus, it may be possible to decouple the 'structure design domain' for these two categories. Generally, the parts likely to affect a pedestrian's impact severity are the outer surfaces (such as the hood, fenders, pillars, frame around the windshield etc.) and components (such as antenna, headlights, etc).

The necessity of considering both adults and children when discussing steps for improving pedestrian and cyclist safety introduces additional factors in evaluating the design of automobiles. In a paper presented[3] at the Stapp Car Crash Conference, it was demonstrated that due to their anatomical differences, the kinematics and the impact points of a child may differ significantly from that of adults impacted by the same vehicle in an identical accident. The effect of these differences in the anatomy and the impact kinematics may make it likely that some design changes to the front structural components may produce contradictory results for these two segments of population. As described in the above-mentioned study[3], some



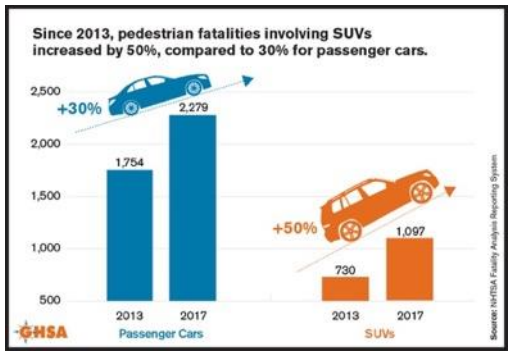
modifications in the vehicle's front structural design were found to increase the probability of injury for child pedestrians, as seen in the 3-D simulation of impacts of adults and of children in crosswalks.

When a vehicle impacts a smaller person (e.g. a child) in a crosswalk, the resulting dynamics, as shown above, is likely to result in the child's head striking the stiffer front edge of the hood. However, it is observed that an adult (a 50th percentile male test dummy in the study) has a different trajectory with the head impacting further up on the hood. The resulting difference in head injury severity is shown here.



Effect of Vehicle Type – SUVs and Pickup Trucks

The geometry of the vehicles' front end has been found to be a major factor[1] in injuries to pedestrians and cyclists. According to recent data, SUVs and pickup trucks have shown a larger increase in the numbers of injuries and fatalities to road users than is the case for passenger cars. This may be partly due to the increased number of such vehicles on the roads. The other significant factor is that the front ends and the bumpers of these vehicles are generally higher than that of passenger cars, leading to the impacted adults' kinematics being closer to that of a child in the 3-D simulations[3] mentioned above. Such increased probability of a bumper hitting higher on the leg, may result in the head impacting near the rigid front of the hood, thus increasing the likelihood of more severe injuries[4,5].



Summary : To reduce the large number of fatal and incapacitating injuries every year to pedestrians and cyclists from vehicles, it is necessary to study possible changes in the front-end designs of automobiles and the effect on all segments of the vulnerable population. This could be done in addition to steps to increase the separation between different road users and reduce number of such crashes.

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1. Governors' Highway Safety Association Report, "*Pedestrian Traffic Fatalities by State: 2018 Preliminary Data",* 2019.
2. Verma, M. Lange, R., Mcgarry, D., "A Study of US Crash Statistics from Automatic Crash Notification Data", Paper 07-0058, *Enhanced Safety of Vehicles Conference, Lyon, France,* 2007.
3. Verma, M. and Repa, B., "Pedestrian Impact Simulation- A Preliminary Study", Paper 831601, *Stapp Car Crash Conference*, San Diego, 1983.
4. Harper J, **"**Pedestrian Struck by Vehicle: Pearls and Pitfalls of ED Management", http://www.emdocs.net/pedestrian-struck-vehicle-pearls-pitfalls-ed-management/, 2017.
5. Marin JL, Lardy A, Laumon B., "Pedestrian Injury Patterns According to Car and Casualty Characteristics in France". *Annals of Advances in Automotive Medicine*. 2011.