Mackie research & consulting
optimising human systems

1st Floor, 642 Great South Rd
Ellerslie Auckland
PO Box 11029, Ellerslie
Auckland 1542
Ph. 09 579 2328
www.mackieresearch.co.nz

Speed/injury Risk Curves

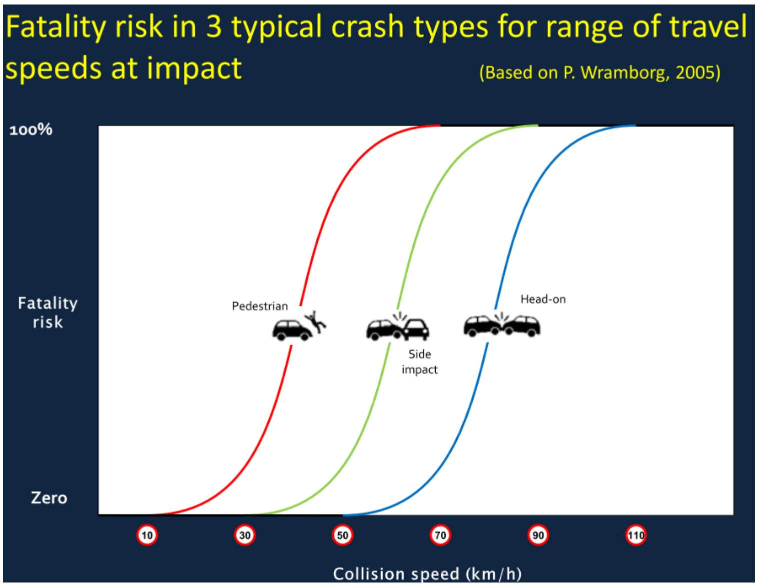
Analysis of evidence and considerations for updated curves

Richard Scott and Hamish Mackie

Background

Many research studies have demonstrated the increasing risk of injury and death associated with increased speed or deceleration force. In order to visually represent these studies graphs of the relationship have been formulated and then simplified into graphics as an educational tool.

Figure 1. Commonly used speed/fatality risk curves



Some of the accuracy of the shapes of the curves was lost in order to make the diagrams easy to understand. The diagram commonly used (Figure 1) was based on one conference presentation by Wramborg (2005).

Much of the earlier research was based on fleets and accidents in the 1960’s 70’s and 80’s.

More recent research findings are reported within the context of:

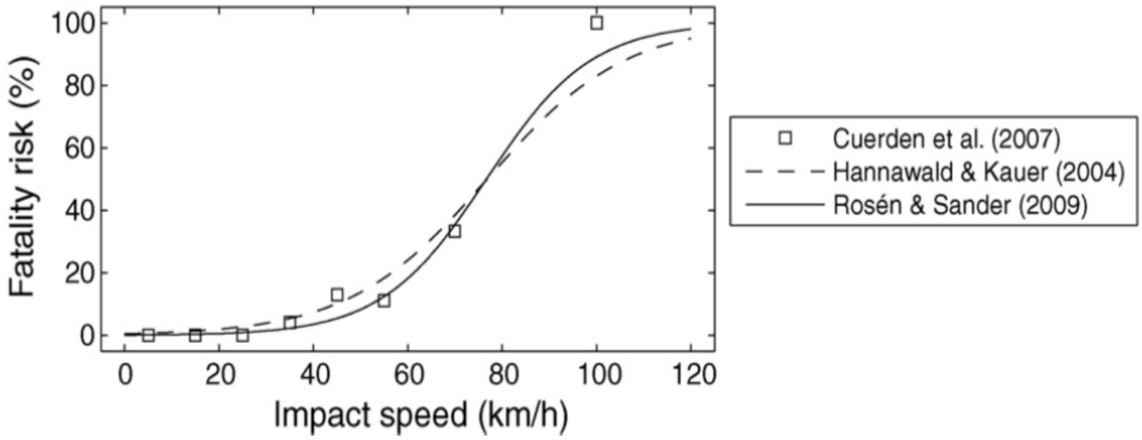
- modern fleets (better seatbelts, airbags, crumple zones, electronic stability control, antiskid braking, and other technologies),

- large data sets especially of minor injuries
- modern emergency services.

Therefore a revised set of graphics to explain the relationship is appropriate.

A review of the literature confirmed that more recent studies (e.g Figure 2 below) have risk curves that are generally less steep and inflect at higher speeds.

Figure 2. The fatality rate of pedestrians in crashes with cars. (Rosen et al 2011)



Pedestrian accidents are usually measured in terms of impact speed whilst side impact and head on injury crashes typically use delta-v (change in velocity immediately following impact). In order to have a consistent speed measurement delta-v has been converted to impact speed.

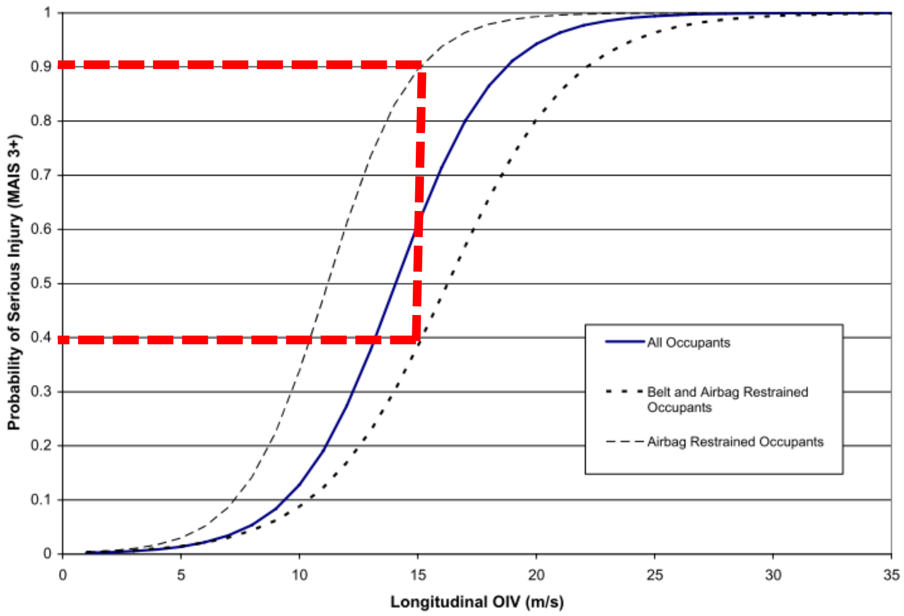
Research has also explored the differences in risk by age and there is clearly a much higher risk of severe injury and death for those over 60. Typically double that of those under 60. Injury risk by vehicle type also shows a significant variance in outcome especially for pedestrians (Tefft, B. AAA). Some research studies do not include SUVs and trucks which provides obvious limitations.

A major limitation is that many studies do not include data for individuals under-14 years of age, although in some that do, survivability is shown to be higher for this age group. Caution is needed when interpreting this though as the levels of protection may different for the different age groups. A child in properly fitted seat in the rear of a vehicle may have more protection than an adult driver in the front. It is almost certain that the data does not include driveway crashes where a child has been backed over.

Other research (Gabauer and Gabler 2006) compared those wearing seatbelts in cars with airbags and those not wearing seatbelts in cars with airbags. In cars with airbags and seatbelts, at 15 m/s (54km/hr) those not wearing seatbelts have a 90% chance of serious injury compared to 40% for those wearing seatbelts (Figure 3). The risk curves for vehicles without airbags are likely to be higher again.

Given the range of variables that might alter these curves, a more accurate depiction of risk would be a range rather than a line based diagram.

Figure 3. Injury risk and seatbelt use.



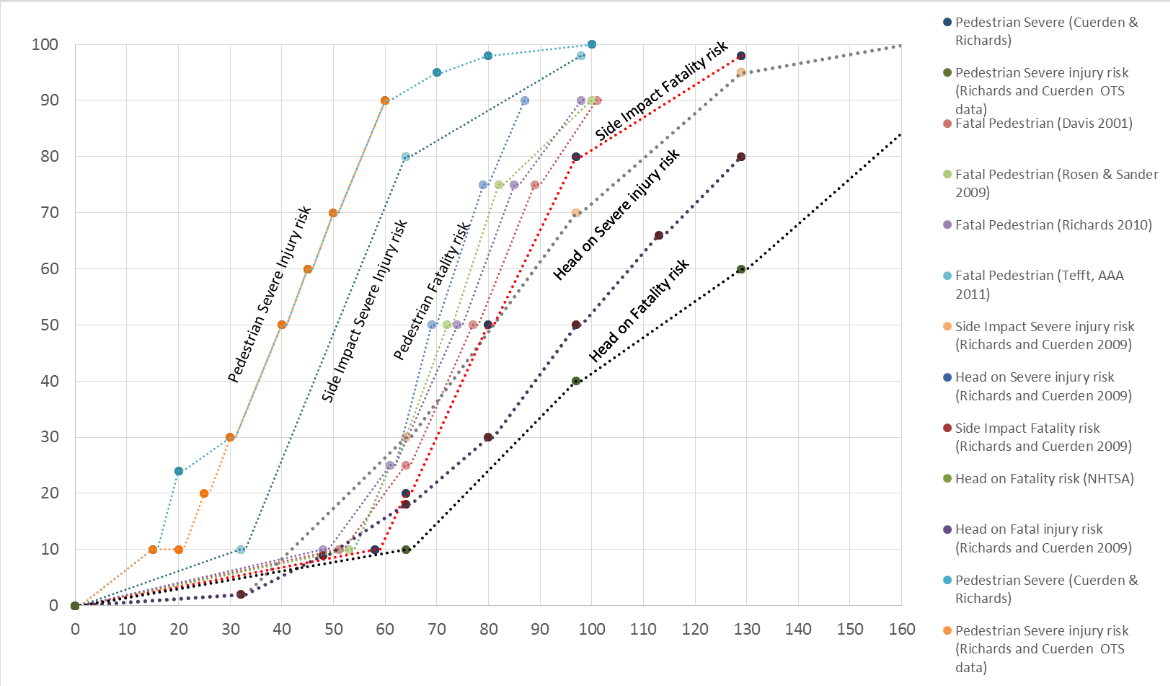
Improvements in emergency care, vehicle design and even pavements will over time further improve the survivability of accidents and therefore fatality risk curves are also likely to change. Based on this, an also the greater amount of data that is available for serious injury data, in the future severe injury based measures may be more useful. This would also allow greater alignment with Safer Journeys where the reduction of both fatal and serious injuries are an ultimate goal.

Review of speed/injury risk curves

Mackie research has completed a literature review and compared various studies to develop a new set of speed risk curves. From this analysis much less emphasis has been placed on earlier research due to issues around the fleet, emergency care and also earlier bias in the data towards severe and fatal injuries. All of the data sets have more data in the mid-range 40-80km/hr and less at higher speeds, which means that the confidence given the relationship between speed and injury risk at higher speeds is usually high. It would be preferable if the diagram could reflect this decreasing confidence at higher speeds. More recent studies have been used to develop potential risk curves for a new diagram. Each set of data represents the risk profile of a particular country and its fleet within the context of the healthcare system of that country. There will be variances in risk profiles by country due to these differences.

Rather than using one data set, research from several different countries and studies have been used in order to attempt a more complete data set (Figure 4).

Figure. 4 Speed risk curves for fatality and severe injury



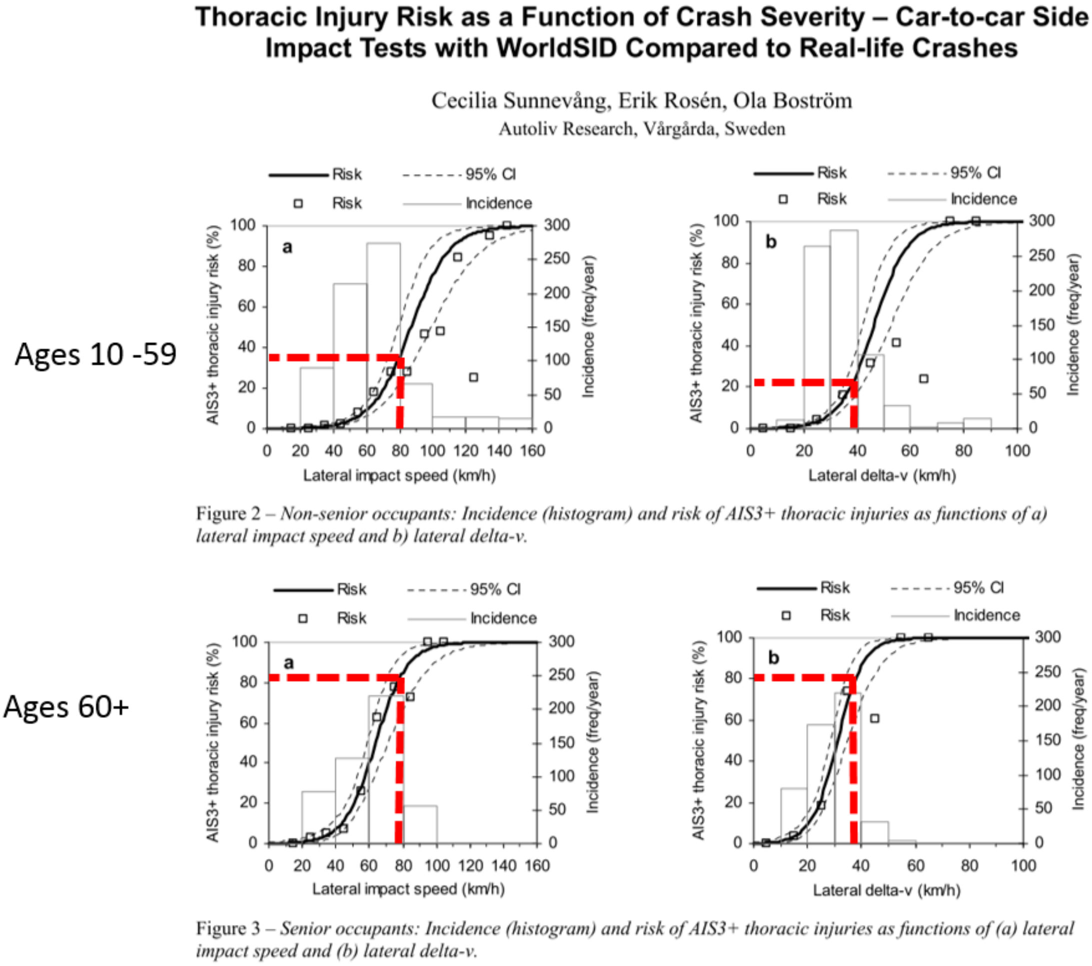
The existing commonly used diagram was focused on fatality risk. It is suggested that the new diagram use severe injury and fatality risk either separately or together. Generally, the risk of pedestrian fatal injury is at higher speeds than the original curves (to a surprising degree) and also the risks for side impacts and head-on accidents are much closer together than represented in the original diagram. It will be difficult to achieve accuracy and a visually understandable diagram.

As suggest earlier, there is considerable variance in risk of injury by

- vehicle type (especially between cars compared with buses and trucks)
- vehicle age
- age of occupants/pedestrians
- use of seatbelt and/or airbags
- variances in the angle of the vehicles for side and head on impacts.

For example, Figure 7 below shows that older occupants (60+) in side-on crashes have significantly higher risk of injury. The data also shows that the incidence of accidents in the lower speed ranges are much more common and therefore the confidence is much greater for lower speeds.

Figure 7 Variance in injury risk by age for side impact crashes


Thoracic Injury Risk as a Function of Crash Severity – Car-to-car Side Impact Tests with WorldSID Compared to Real-life Crashes

Cecilia Sunnevång, Erik Rosén, Ola Boström
Autoliv Research, Vårgårda, Sweden

Figure 2 – *Non-senior occupants: Incidence (histogram) and risk of AIS3+ thoracic injuries as functions of a) lateral impact speed and b) lateral delta-v.*

Figure 3 – *Senior occupants: Incidence (histogram) and risk of AIS3+ thoracic injuries as functions of (a) lateral impact speed and (b) lateral delta-v.*

Revised estimated speed/injury risk curves

These diagrams (Figures 6 and 7) are intended to summarise the known data for impact speed and risk of serious and fatal injuries. It should be noted that the true variability of circumstances possible in crash situations are not represented by the curves. For example, the pedestrian fatality risk curve does not increase sharply until impact speeds reach 60 km/h, yet in New Zealand we know that pedestrians have been killed by buses at approximately 30 km/h. For this reason a dashed line has been added to show the increased level of frailty in situations where elderly people or heavy vehicles may be involved.

Figure 6. Fatality risk and impact speed potential diagram

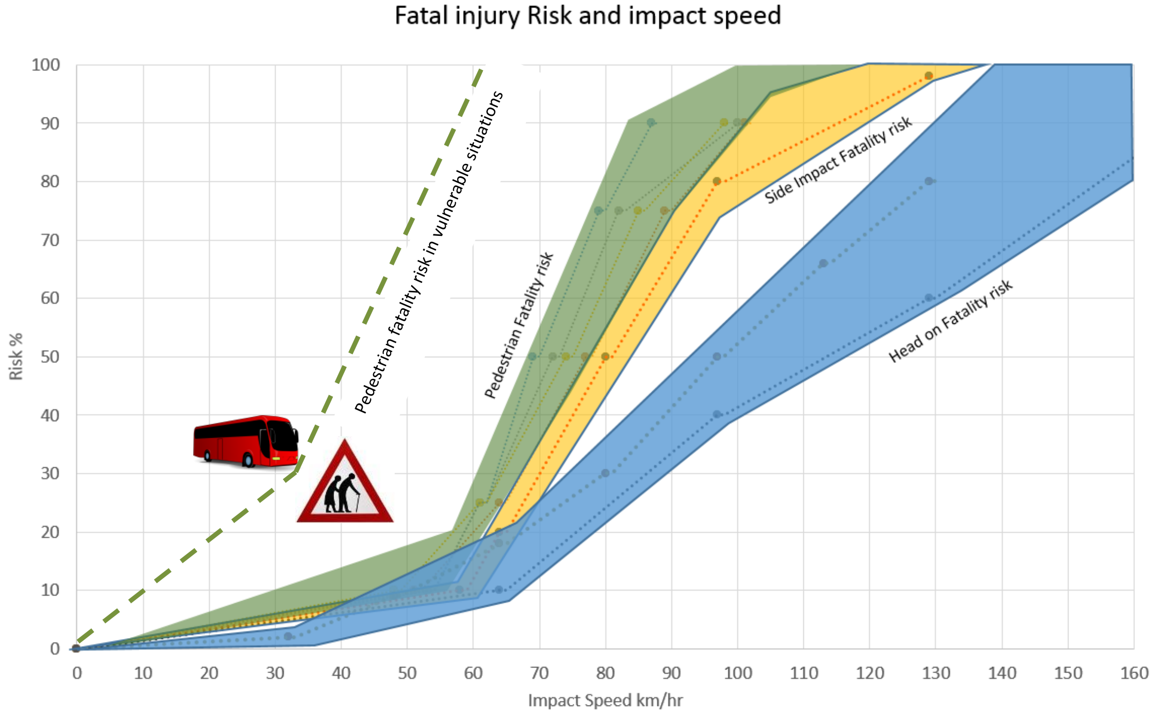


Figure 7. Severe injury risk and impact speed potential diagram

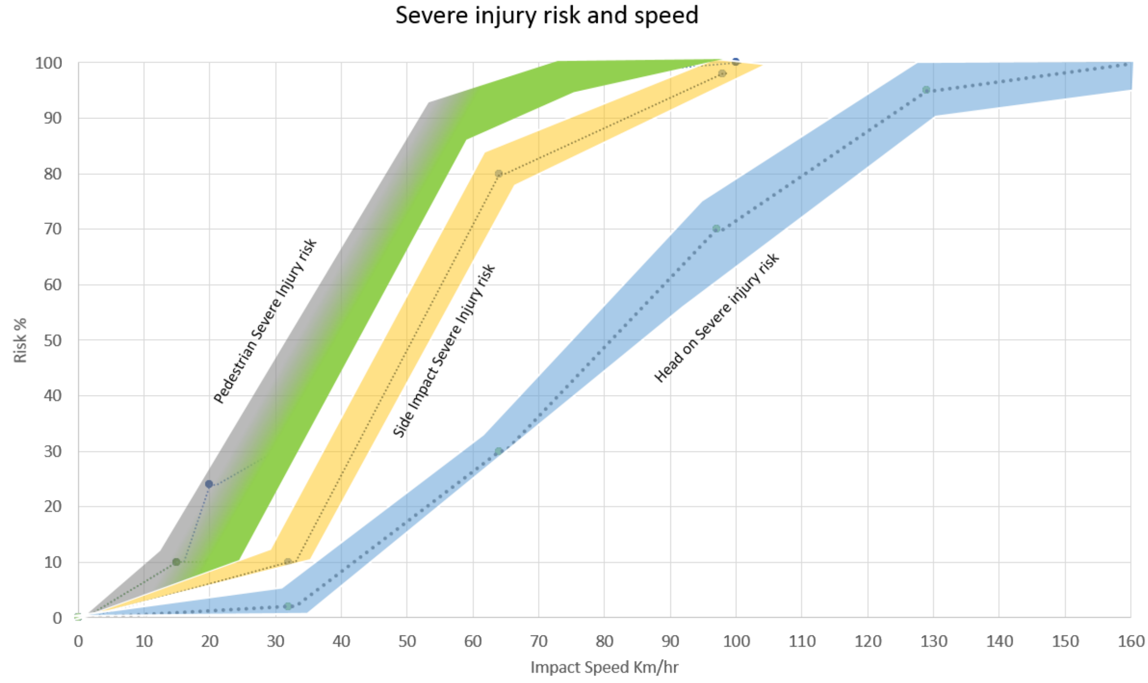
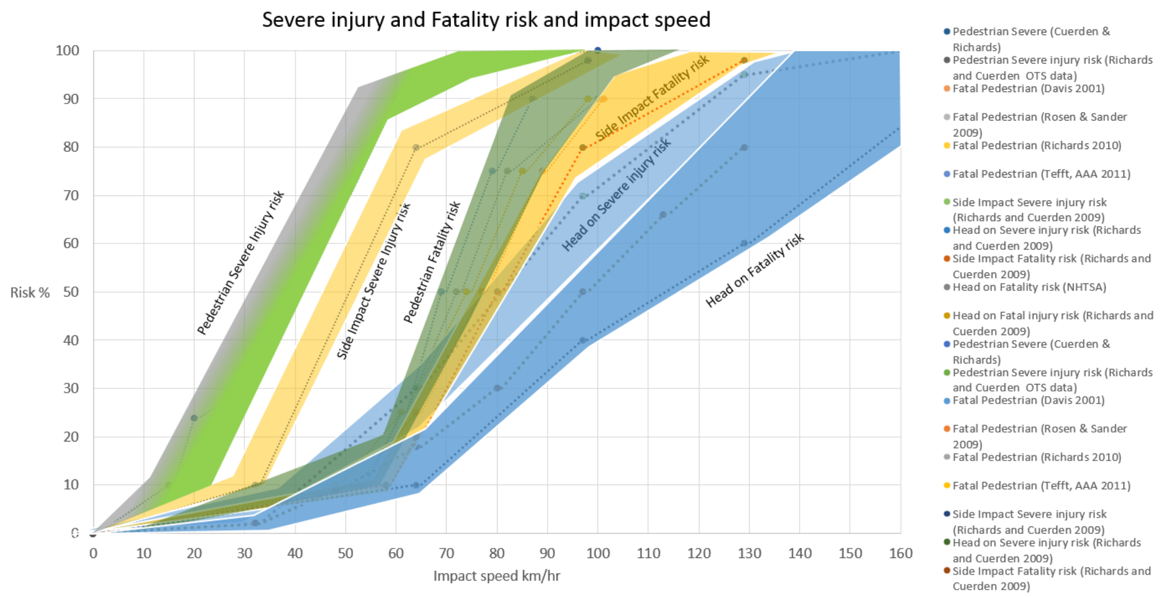


Figure 8. Combined Severe and Fatality risk curves



Discussion

All studies show that speed is a major factor in the severity of injury and likelihood of death in pedestrian, side impact and head on crashes. The literature suggests that survivability has improved over time for any given speed, which poses a challenge when it comes to communicating the benefits of safer or lower speeds.

However, no design project (in any discipline) should design to an average population profile. Human Factors and ergonomics design usually use 90%ile people (for whatever measure is important) for design criteria (e.g. aircraft seats, clothing sizes etc). It would make sense that design speeds also considered 90%ile collision situations (in terms of frailty). For example, for pedestrians, this might mean that an appropriate speed/fatality risk profile curve follows a profile that is relevant for older people and where heavy vehicles are involved. Interestingly if this approach was taken, then the curve would be very similar to the original curve proposed by Wramborg!!!

References

Richard Cuerden, David Richards, Julian Hill. *Pedestrians and their survivability at different impact speeds* TRL United Kingdom. Proceedings of the 20th International Technical Conference on the Enhanced Safety of Vehicles (ESV), June 18-21, 2007; Lyon, France.

D.J.Gabauer, H.C. Gabler (2006). *Comparison of Delta-v and occupant impact velocity crash severity metrics using event data recorders.* Centre for Injury Biomechanics Virginia Tech Blacksburg, Viginia.

Hoskulder R.G Kroyer, Thomas Jonsson, Andras Varhelyi. (2013). *Relative fatality risk curve to describe the effect of change in impact speed on fatality risk of pedestrians struck by a motor vehicle.* Accident Analysis and prevention 62

W.A. Leaf and D.F. Preusser. (1999). *Literature Review on Vehicle Travel Speeds and Pedestrian Injuries Among Selected Racial/Ethnic Groups.* U.S. Department of Transportation National Highway Traffic Safety Administration 400 Seventh Street, S.W. Washington, D.C. 20590

Literature review of pedestrian fatality risk as a function of car impact speed. Erik Rosen, Helena Stigson, Ulrich Sander (2010). Accident Analysis and Prevention 43 (2011)

Helena Stigson, Anders Kullgren, Eric Rosen (2012). Injury risk functions in frontal impacts using data from crash pulse recorders. Folksam Research, Autoliv research.

Cecilia Sunnevang, Erik Rosen, Ola Bostrom. (2010). *Thoracic injury risk as a function of crash severity – Car to car side impact tests with WorldSID compared to real-life crashes.* Autoliv research, Vargarda Sweden.

Brian C. Tefft (2011). *Impact speed and a pedestrian's risk of severe injury or death*. AAA Foundation for Traffic Safety

Wramborg, P. (2005) A new approach to a safe and sustainable road structure and street design for urban areas. Proceedings of the Road Safety on Four Continents Conference, Warsaw, Poland.