# What are Survivable Speed Limits for a Safe System Approach – Some Evidence

**Raphael Grzebieta (PhD)**

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*Adjunct Professor, Victorian Institute of Forensic Medicine - Monash University*

VICTORIAN INSTITUTE OF FORENSIC MEDICINE

TARS Research

UNSW THE UNIVERSITY OF NEW SOUTH WALES

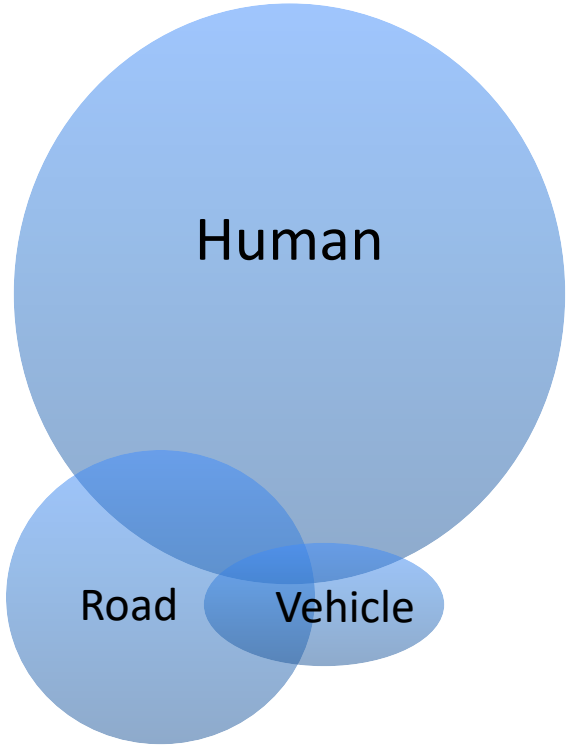
# Pedestrian impact

Graphic demonstration of how head injuries occur in pedestrians impacts at high speed

*Old TAC advertisement encouraging drivers to slow down from **70 km/h to 60 km/h** in urban streets – before we had 50 km/h maximum limit in built up urban environments & **before Safe System Approach** introduced in 2004.*

# Humans are a big problem

## *- to err is human*




- Human factors contribute in 90-95% fatal crashes
- ***Deduction***: we try to change the human problem
- We try to make them obey laws and not make mistakes
- But… humans can't be totally fixed, … sometimes ***they don't want to be***, so…

# Humans are a big problem

## *- to err is human*

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# Vision Zero - An ethical approach to safety and mobility

Claes Tingvall and Narelle Haworth
Monash University Accident Research Centre

Paper presented to the 6th ITE International Conference Road Safety & Traffic Enforcement: Beyond 2000, Melbourne, 6-7 September 1999.

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**ABSTRACT**

Vision Zero is a philosophy of road safety that eventually no one will be killed or seriously injured within the road transport system. This paper describes Vision Zero and its view that safety cannot be traded for mobility. The applicability of Vision Zero to Victoria in the short- and long-term is discussed.

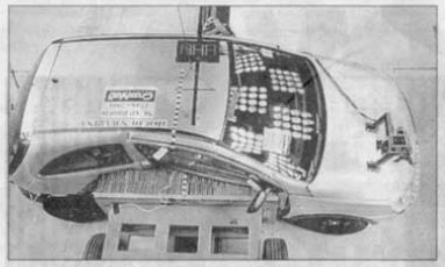
Rechnitzer, G., and R. H. Grzebieta. **Crashworthy Systems - A Paradigm Shift in Road Safety Design.** *Transport Engineering in Australia*, Vol. 5, No. 2, 1999. (Also in *Proc., Aus Top Tec Topical Technical Symposia*, Society of Automotive Engineers Australia, Melbourne, 1999).

Grzebieta, R. H., and G. Rechnitzer. **Crashworthy Systems - A Paradigm Shift in Road Safety Design (Part II).** *Transport Engineering in Australia*, Vol. 7, No. 1–2, 2001.

March 2002

Herald Sun, Friday, March 1, 2002 www.heraldsun.com.au

"We have designed the system to produce an amazingly consistent toll"



**Just testing:** a side impact test on a Holden Barina.

**Real thing:** a car chase ends on Princes Bridge.

**Lucky:** an unexpected off-road experience.

# Deadly design

## We can build roads that eliminate death

By RAPH GRZEBIETA and GEORGE RECHNITZER

DESPITE all the increased education, media images of horror crashes, speed cameras, booze buses and drowsy driver blitzes, our road toll continues to rise.

In fact, the increase in road deaths has been alarmingly constant over the past decade — even before the latest jump.

Our national road toll is now equivalent to three Jumbos crashing each year, killing all on board. The same shocking numbers are injured.

It makes us realise that in Australia we have designed, and continue to design, a road-vehicle system where fatal crashes are regular and inevitable.

Vision Zero also moves right away from the blame-the-drivers-and-road-users approach to one where the overall safety of the road system is the responsib-

And yet we still have road design standards that accept that 85 per cent of errant vehicles that leave the road should recover within that clear zone.

So what happens to the 15 per cent of drivers who do not recover? They and their passengers end up dead or hurt.

Road and vehicle designers and policy

and ignore the fact that we have, in effect, allowed moving guillotines on the road. Seat belts and airbags will not help you in this type of crash.

The question is, should Darren have paid the ultimate price for his tragic mistake of driving while drunk?

A law requiring trucks to fit under-run barriers

achieve the reductions demanded by state and federal safety bureaus.

The only way to dramatically reduce the road toll is to change the system so it is more tolerant of human error.

More importantly, the main thrust behind the design of new road systems must be based on a person's ability to withstand injury — not a cost benefit ratio.

After all, how much is your life really worth?

RAPH GRZEBIETA and GEORGE RECHNITZER are members of the Road Safety and Crashworthiness Systems research team at Monash University.

**Ouch:** a mum and her baby daughters sur this power pole crash in Hobart.

April 2002

p18 www.heraldsun.com.au Herald Sun, Tuesday, April 9, 2002

Herald Sun EDITORIAL

**Risk escalates:** side impacts wreak more destruction even at lower speeds.

# Designs for death

Raphael Grzebieta and George Rechnitzer

POLICE and the Victorian Government are to be commended on attempts to crack down on young drivers who speed.

However, the debate about the road toll must be elevated and widened beyond a knee-jerk reaction of blaming idiots behind the wheel.

Even if police are successful in reducing the speed of young and inexperienced drivers to posted limits, there are still road hazards drivers can collide with and dangerous vehicles, such as four-wheel drives, trucks and trams, that they can be struck by.

In these instances, the risk of being killed is very high — even at quite low speeds.

Driving at the posted limit does not necessarily mean you will survive a crash if you have one, although your chances of surviving are certainly better than if you are speeding.

Our new cars are designed to save an occupant in a car crashing flush into a concrete wall at only 57km/h. Into a tree (or pole), this survival speed drops to about 40km/h.

If the car hits the tree side on, and the tree is lined up with your head as you slide towards it, the threshold above which injury can occur is around 30km/h. But this is only if you are lucky enough to have a car with a side air curtain or side air bag for your head.

Without the air curtain or bag the injury threshold drops to around 20km/h or even less.

It's the same situation in side impact crashes. If a 4WD crashes at a right angle into a small suburban car, the driver (and passenger sitting directly behind) in the struck vehicle will suffer massive head and chest injuries at as low as 30km/h.

Hit the back end of a tow truck without an under-run barrier and you will be decapitated at 40km/h.

It is all too easy to blame the drivers in three recent fatal accidents — the Ben Hollioake tragedy, a car hitting a tree in Canterbury and a 4WD roll-over in a bayside suburb. But had the brick wall in Perth and the tree in Canterbury been protected with crashworthy barriers these people might be alive today.

And if Australia had a 4WD rollover standard and the roof of the 4WD and restraints been better designed, the young victims would have walked away unhurt.

Princess Diana would be alive today if a barrier had been in front of the columns in that Paris tunnel.

Sweden has already provided us with a template to follow with their Vision Zero philosophy.

**How about distributing some blame towards our killer road-vehicle system?**

They believe "no foreseeable accident should be more severe than the tolerance of the human in order not to receive an injury that causes long term health loss" and that "life and health can never be exchanged for other benefits within the society".

The philosophy also states that whenever someone is killed or seriously injured, necessary steps must be taken to avoid similar events. That is, the system needs to be redesigned or changed.

So how about distributing some blame towards our killer road-vehicle system, which we all accept without question?

HOW about distributing some blame to those people responsible for the introduction (or lack) of standards and design rules that protect us against irresponsible manufacturers and designers who know little or don't care about crashworthiness?

When are we going to make the paradigm shift and broaden our perspective?

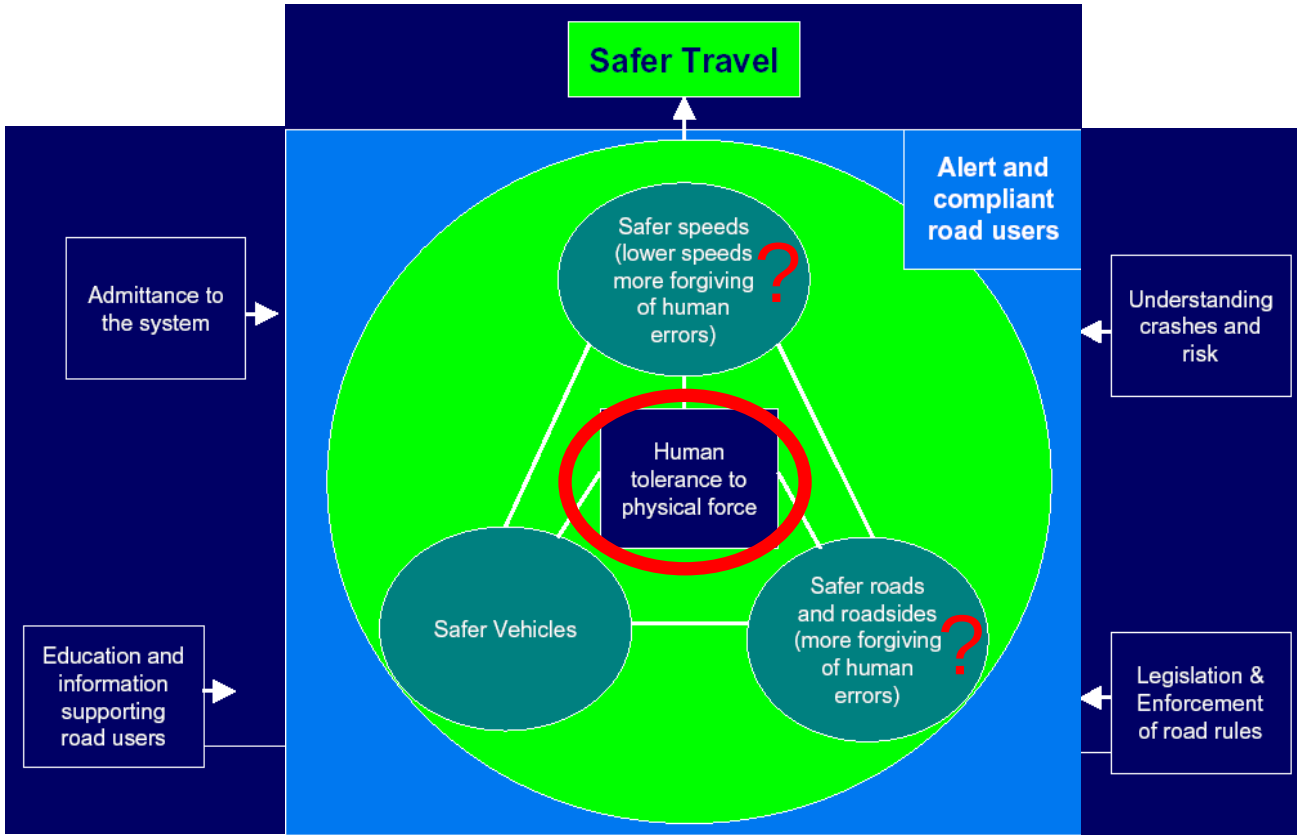
When are we going to accept that our road transport system cannot tolerate human error very well and that defensive driver training and speed cameras will not overcome the fundamental problems where death and injury result at very low speeds?

Soon we hope. Especially for the sake of those people dying and being hurt and their families.

ASSOCIATE PROFESSOR RAPHAEL GRZEBIETA and senior research fellow GEORGE RECHNITZER specialise in accident research at Monash University.

# *Safe System* principles

Focus on Biomechanics Criterion instead of cost benefit




**OECD & International Transport Forum (ITF)**

**International Working Group Members (25 countries) chaired by Eric Howard –ex head of road safety at VicRoads**

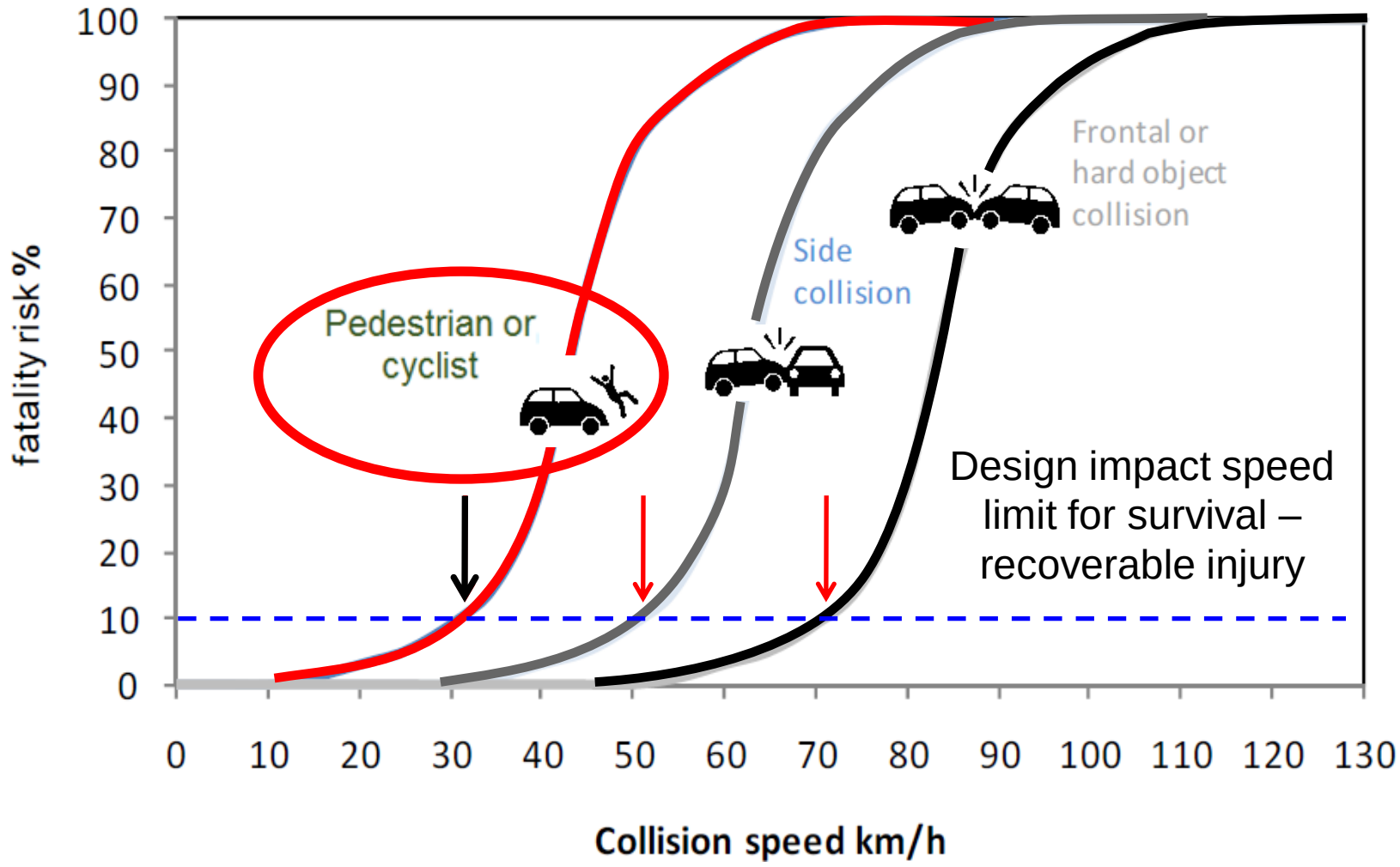
**TOWARDS ZERO - Ambitious Road Safety Targets and the Safe System Approach (Sept 2008)**

***Eric Howard,*** *Implementing a "Safe System" approach to road safety in Victoria, Proc. Road Safety Research, Policing and Education Conference, 2004.*

# *Safe System* principles *(adopted in 2004)*

- Important to recognise humans make errors
- Assess consequences of those errors
- Propose countermeasures: roads more forgiving of errors
- Countermeasures reduces crash severity to survivable limits and/or eliminate or compensates for the human error
- shift responsibility from emphasis on road users being responsible for behaviour on the road to a greater responsibility for road system designers and managers to build safe guards into the system to prevent injury-causing crashes
- No more trading off lives for benefit of mobility and cost efficiency – more humanistic ethical approach

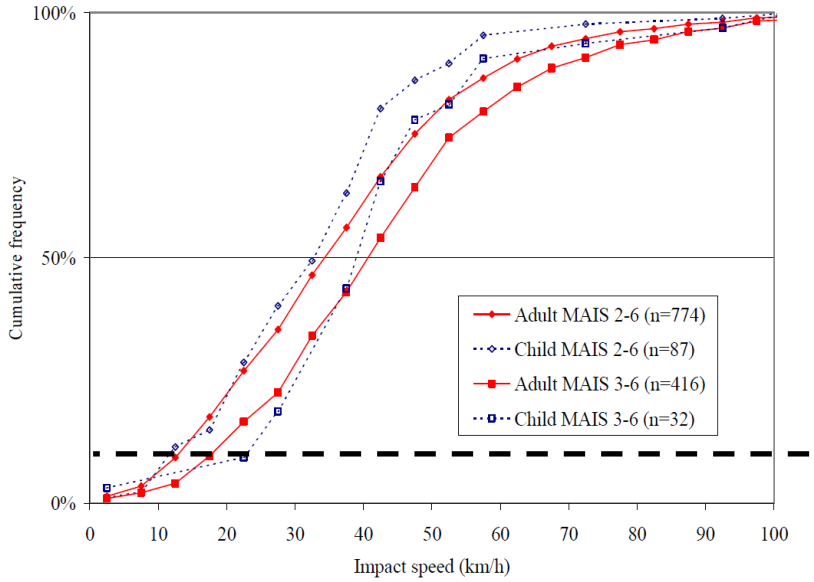
# *Making crashes survivable* – *Safe System Approach*



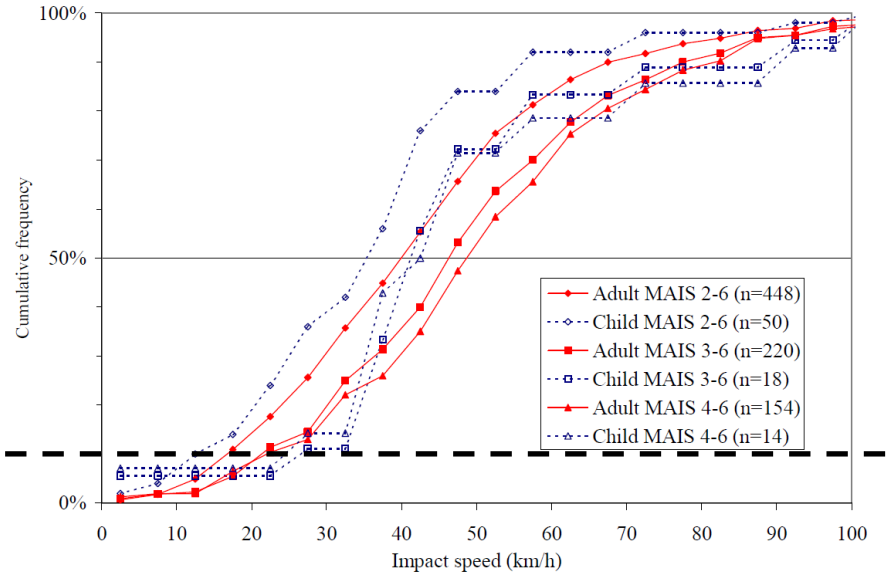

*Source: Wramborg, P. (2005). A New Approach to a Safe and Sustainable Road Structure and Street Design for Urban Areas.* Paper presented at Road Safety on Four Continents Conference, Warsaw Poland.
http://www.internationaltransportforum.org/jtrc/safety/targets/08TargetsSummary.pdf

# Pedestrian Impact Velocity by MAIS

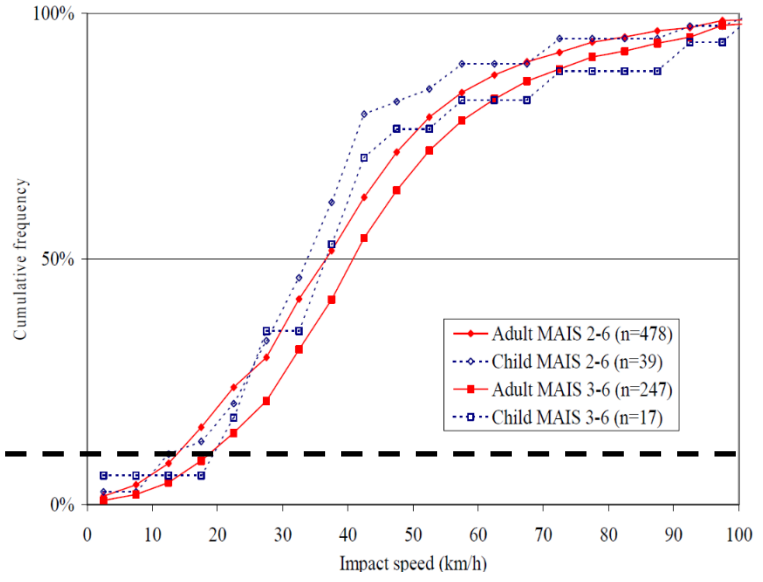
**MAIS** = Maximum Abbreviated Injury Scale




**All body regions**




**Head Injuries**

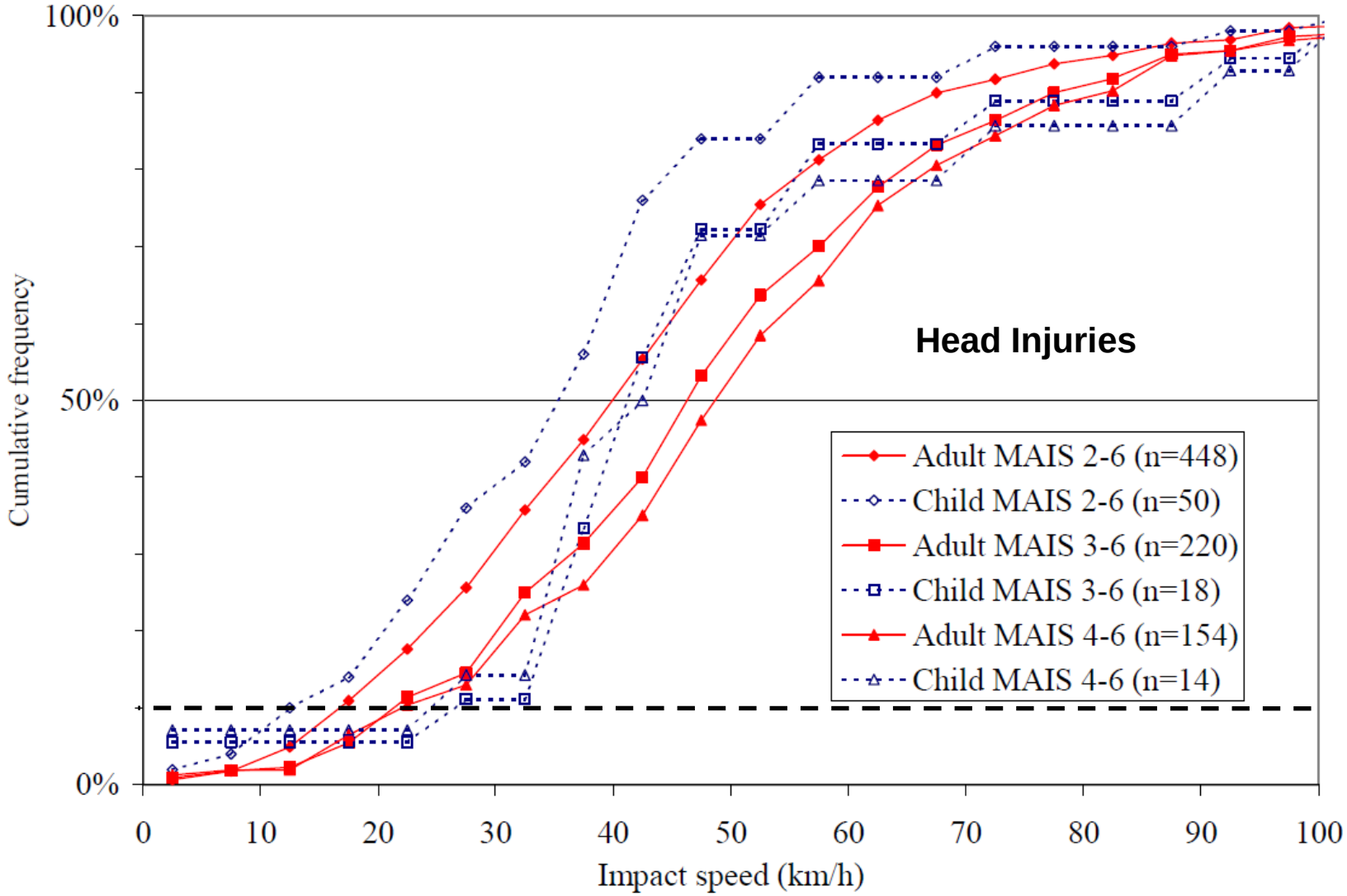



**Leg Injuries**

***Mizuno, Y. 2005.*** *Summary of IHRA pedestrian safety WG activities (2005) – proposed test methods to evaluate pedestrian protection afforded by passenger cars, in 19th International Technical Conference on the Enhanced Safety of Vehicles (ESV), 6–9 June 2005, Washington, DC, US, 1–15.*

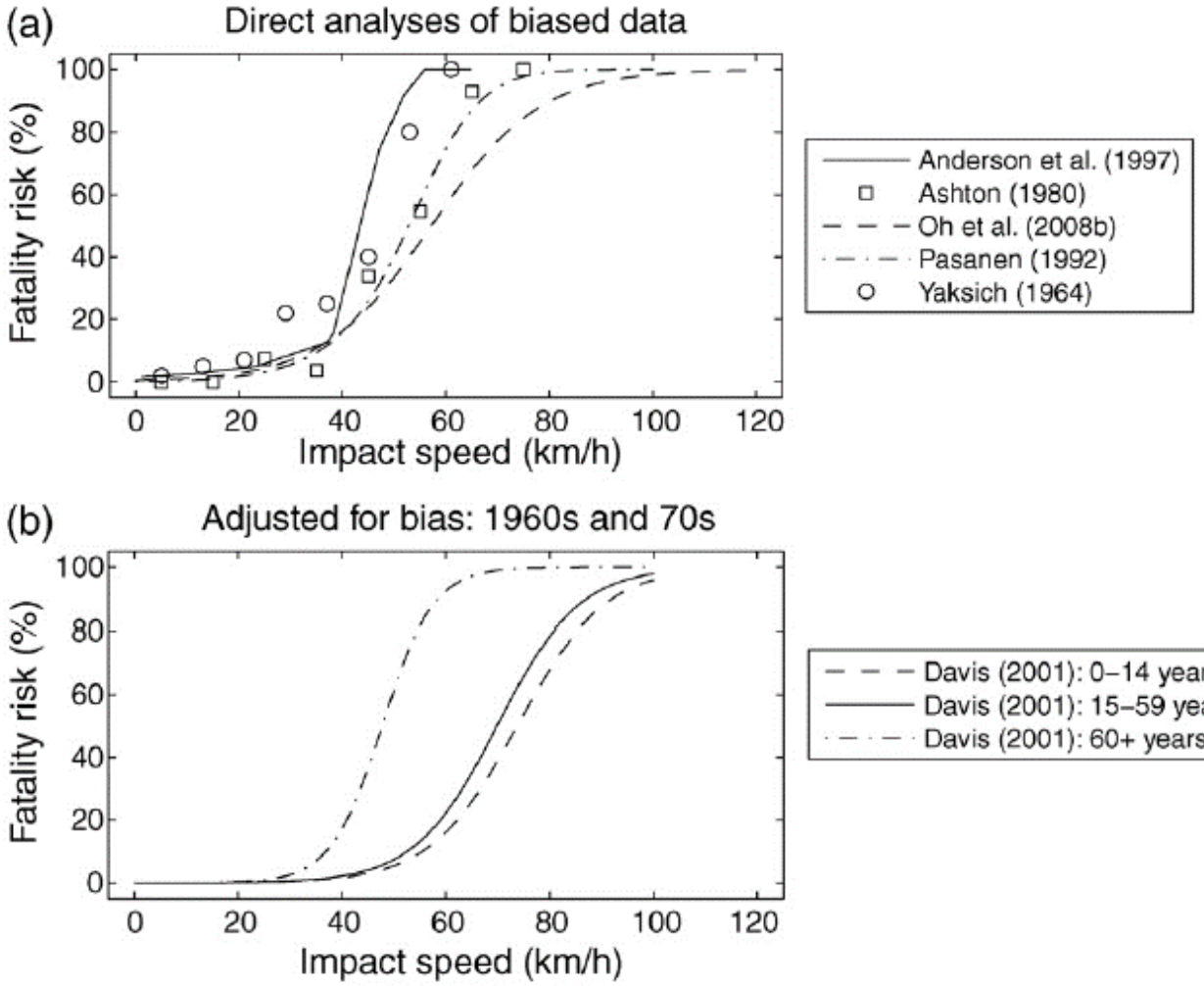
# Pedestrian Impact Velocity by MAIS

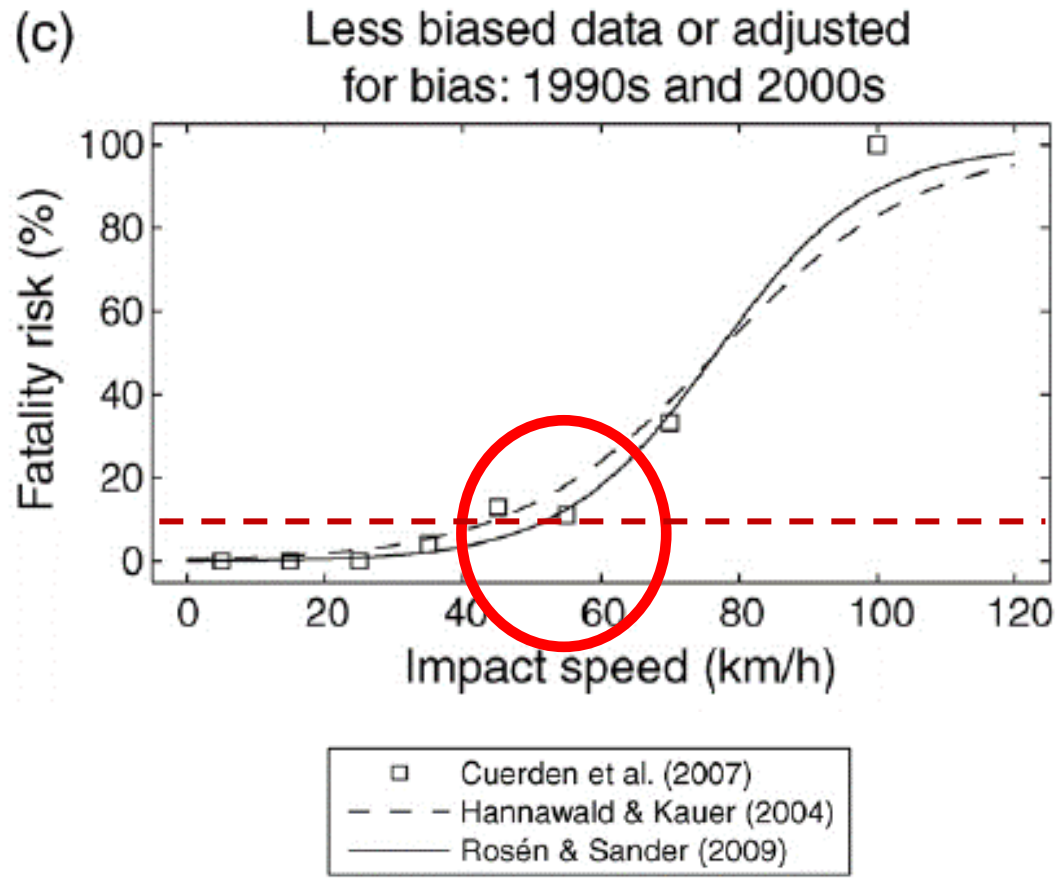
**MAIS** = Maximum Abbreviated Injury Scale



# European Citizen´s Initiative "30kmh – making streets liveable!"

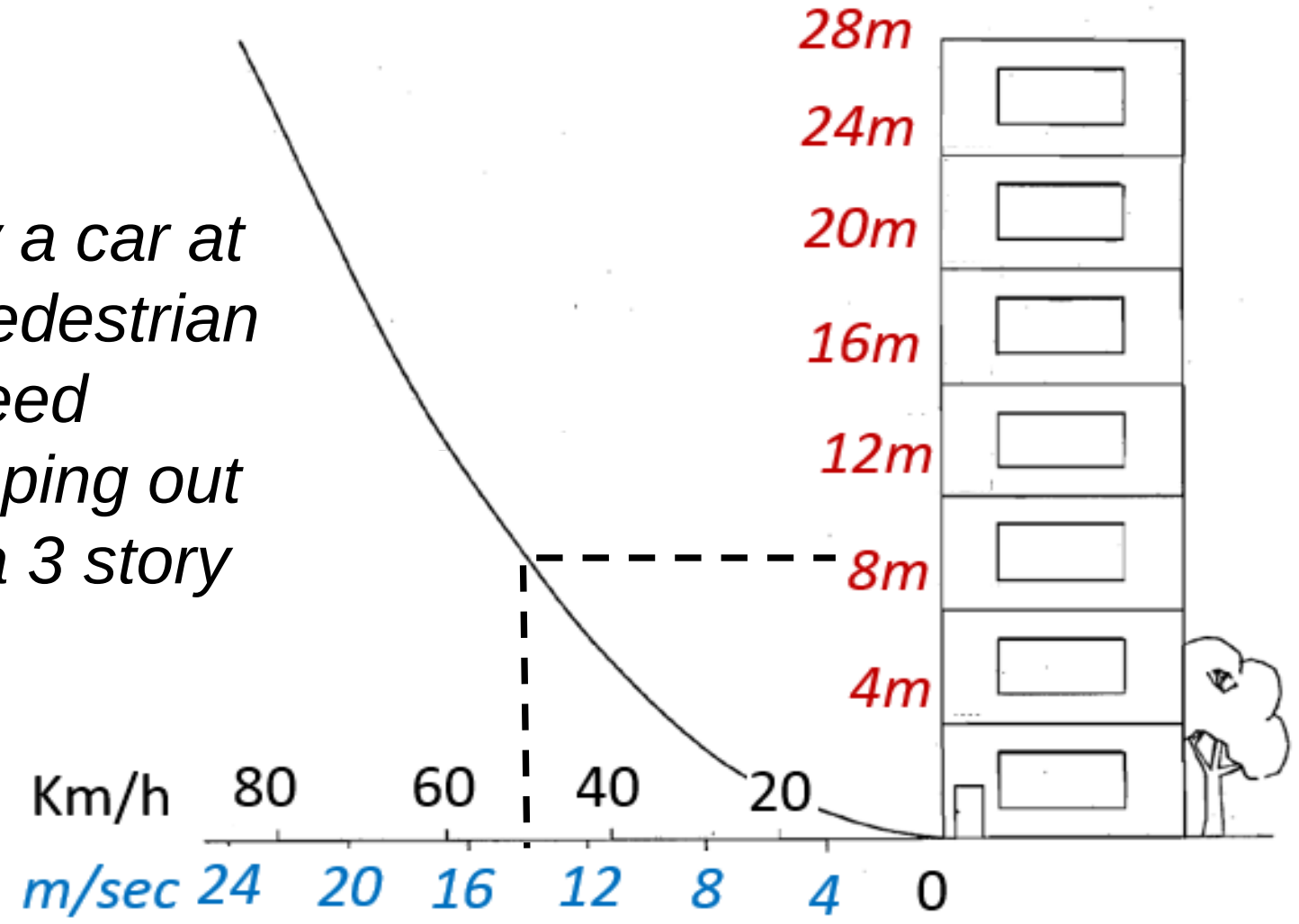



(a)
Direct analyses of biased data
Fatality risk (%)
Impact speed (km/h)
Anderson et al. (1997)
Ashton (1980)
Oh et al. (2008b)
Pasanen (1992)
Yaksich (1964)
(b)
Adjusted for bias: 1960s and 70s
Fatality risk (%)
Impact speed (km/h)
Davis (2001): 0–14 years
Davis (2001): 15–59 years
Davis (2001): 60+ years


(c)
Less biased data or adjusted for bias: 1990s and 2000s
Fatality risk (%)
Impact speed (km/h)
Cuerden et al. (2007)
Hannawald & Kauer (2004)
Rosén & Sander (2009)

# What is a survivable impact?

*Being struck by a car at 50 km/h as a pedestrian is the same speed reached by jumping out the window of a 3 story window*




Murray N.W., When it Comes to the Crunch, The mechanics of Car Collisions, World Scientific, Singapore, 1994

Accident Analysis and Prevention 129 (2019) 241–249

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journal homepage: www.elsevier.com/locate/aap

# The relationship between impact speed and the probability of pedestrian fatality during a vehicle-pedestrian crash: A systematic review and meta-analysis

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[b] Uhasselt, Transportation Research Institute (IMOB), Agoralaan, 3590, Diepenbeek, Belgium
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[d] Transport and Road Safety (TARS) Research Centre, UNSW, 1st Floor West Wing, Old Main Building (K15), Sydney, NSW, 2052, Australia

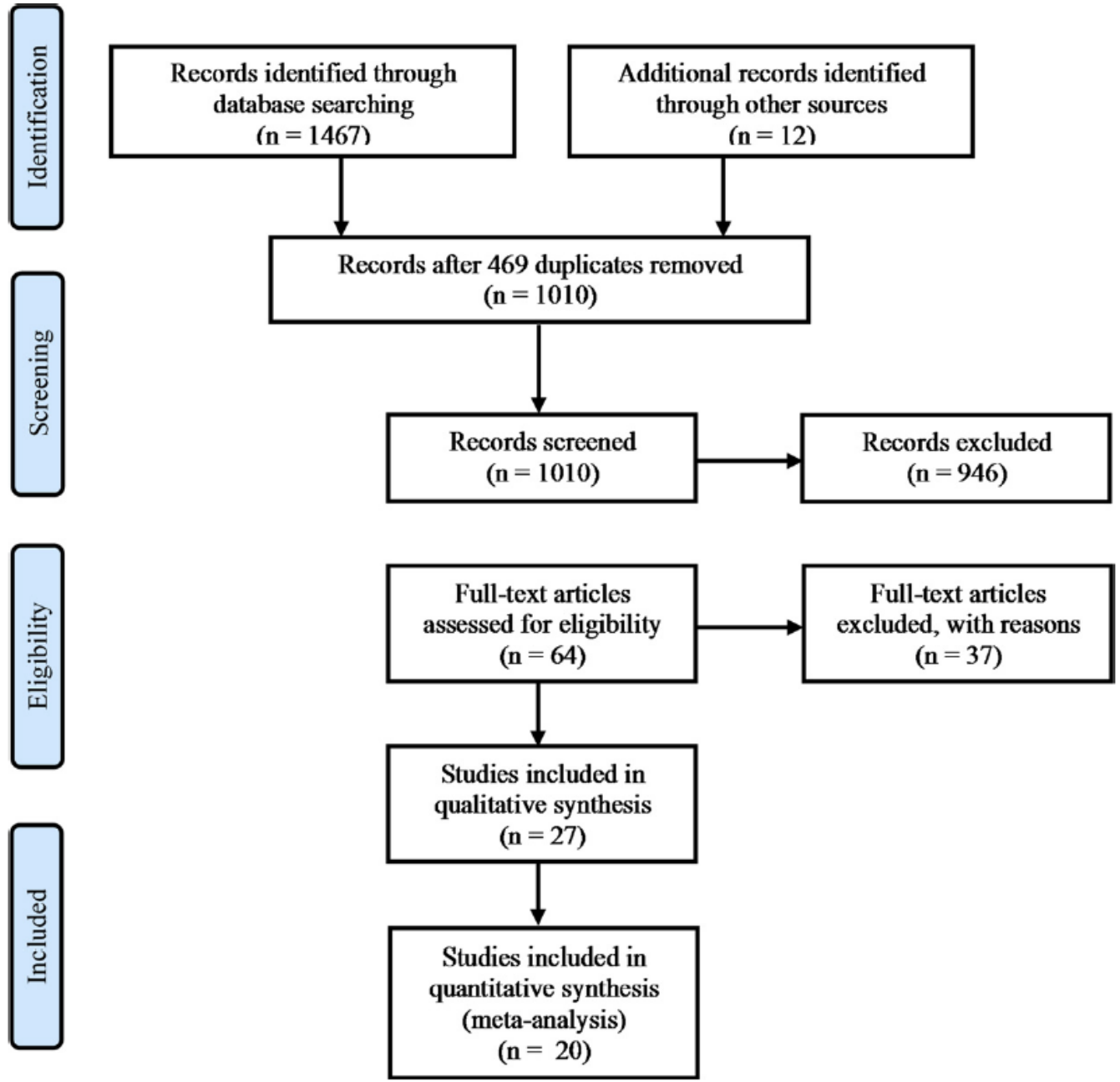
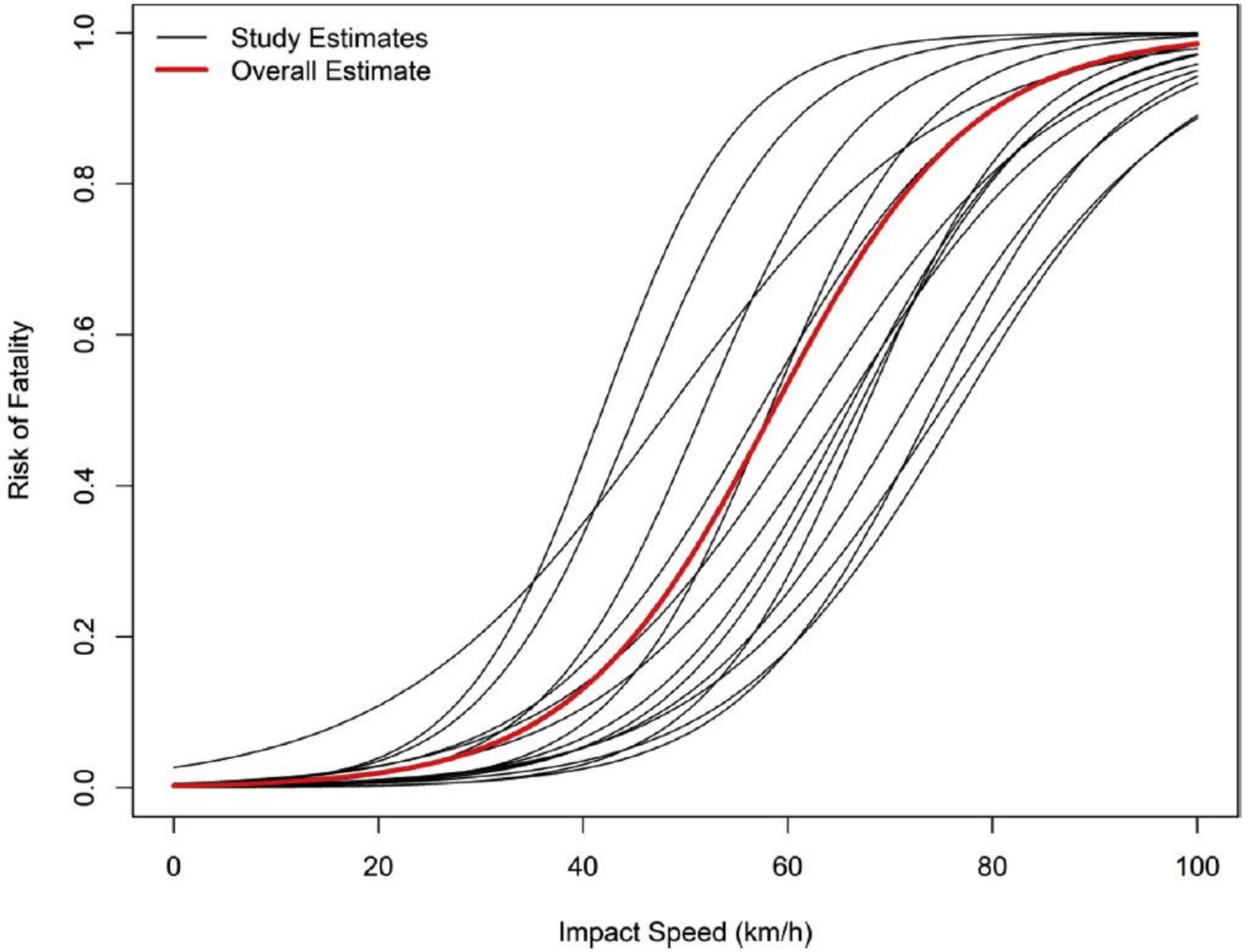



**Fig. 1.** PRISMA flow diagram of included studies.




Results suggest an impact speed of **30 km/h** has on average a **risk of a fatality** of **around 5%**. The risk increases to **13% for an impact speed of 40 km/h** and **29% at 50 km/h**.

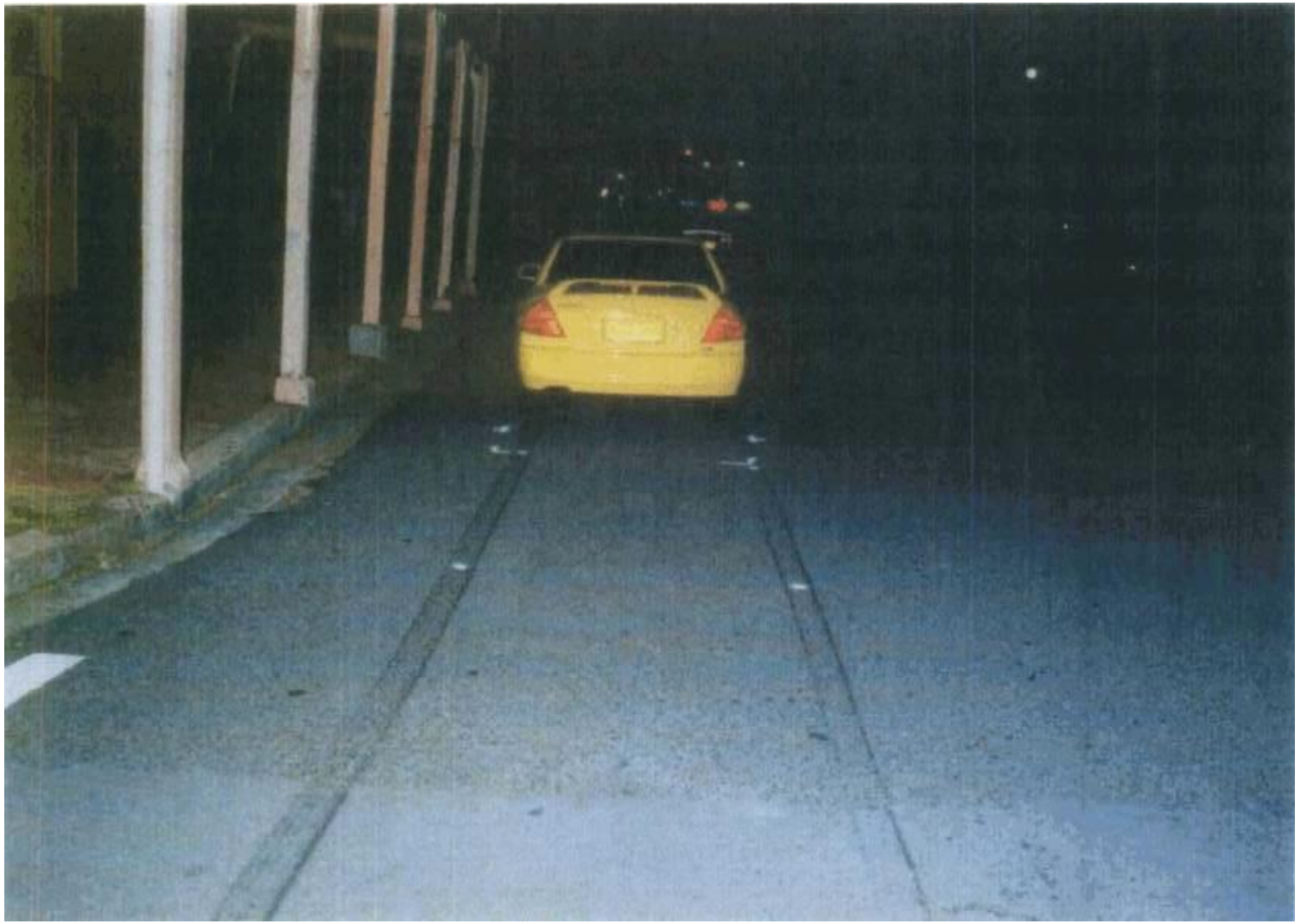
# SAFE SYSTEM APPROACH - human factors

## Pedestrian impact at night

Glancing blow – head strike where glass star pattern observed & mirror is broken

# SAFE SYSTEM APPROACH - human factors

## Pedestrian impact at night

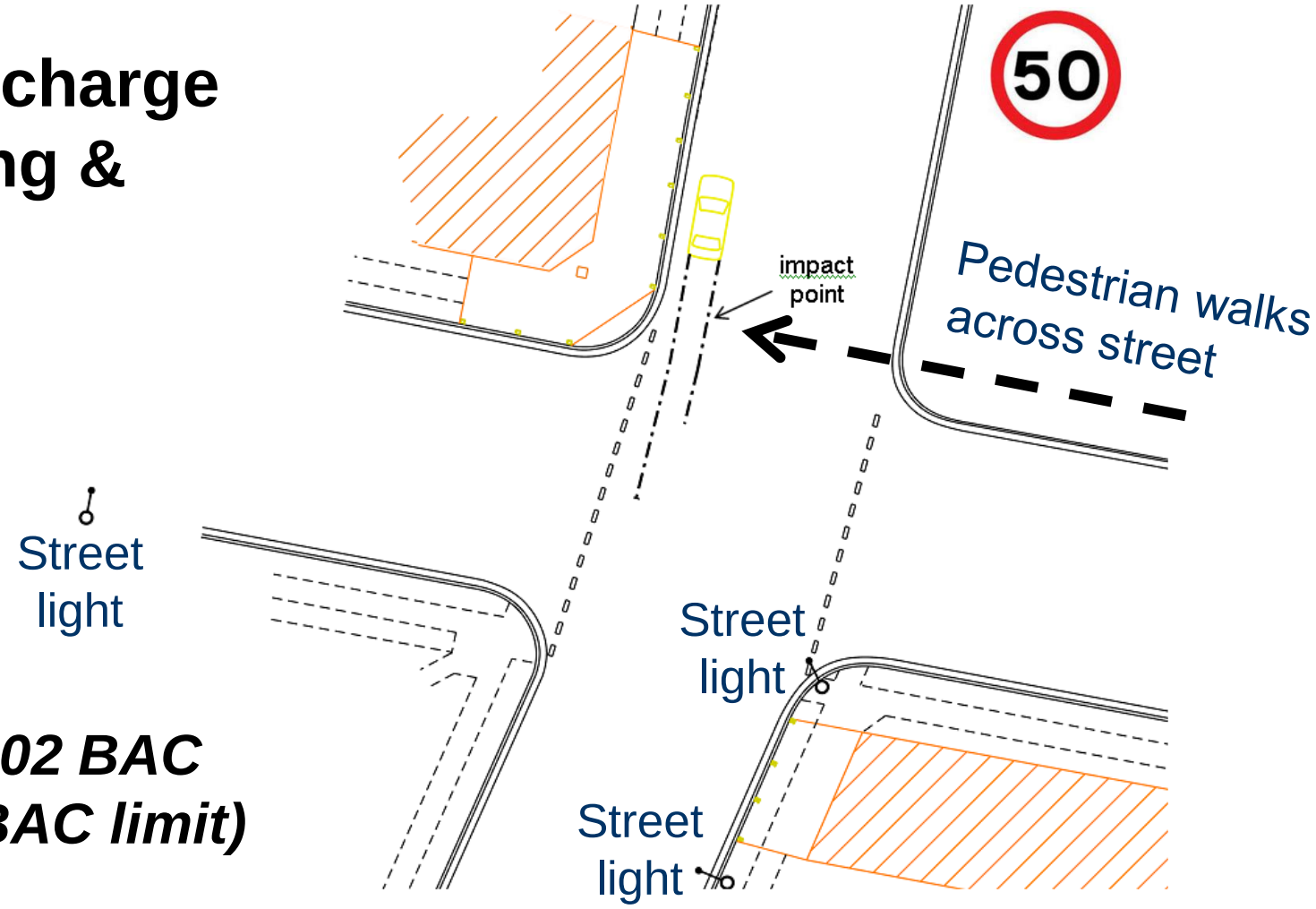


Skid marks left.

Possible to determine impact speed using ‘Speed from Skid’ equation and adopting commonly accepted perception reaction time of driver

# Pedestrian impact at night

**Police wanted to charge driver for speeding & reckless driving**




***Driver was 0.02 BAC (below 0.05 BAC limit)***

**Was it the driver's fault?**

# Visibility and lighting

## Car headlights on low beam

# Speed from skid equation

$$V^2 = 2ad$$

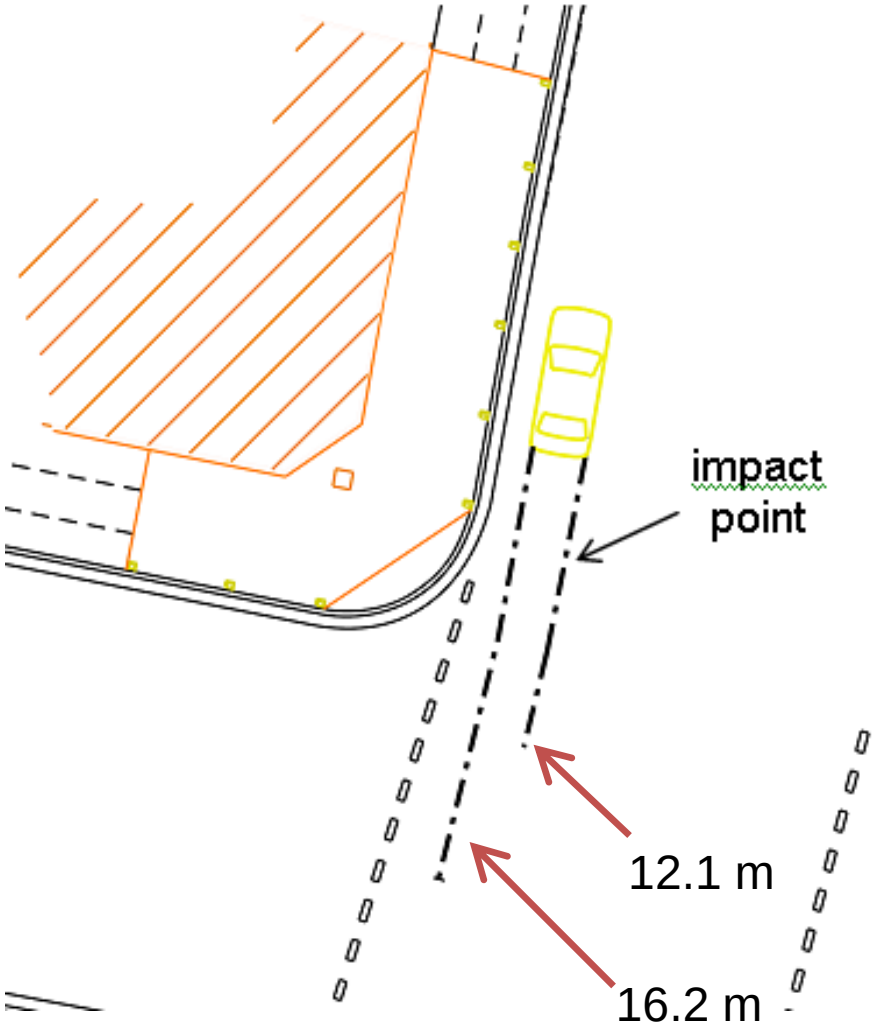
*V = vehicle velocity*

$a$ = *deceleration*

$d$ = *length of skid*

# Crash reconstruction

## Speed from skid




assumed $\mu = 0.6$

$$V^2 = 2ad$$

$$V = \sqrt{2\mu g \times 16.2}$$

$$= \sqrt{2 \times 0.6 \times 9.81 \times 16.2}$$

$$= \sqrt{190.7}$$

$$= 13.8 \text{ m/sec}^2$$

$$= 50\ km/h$$

# Crash reconstruction

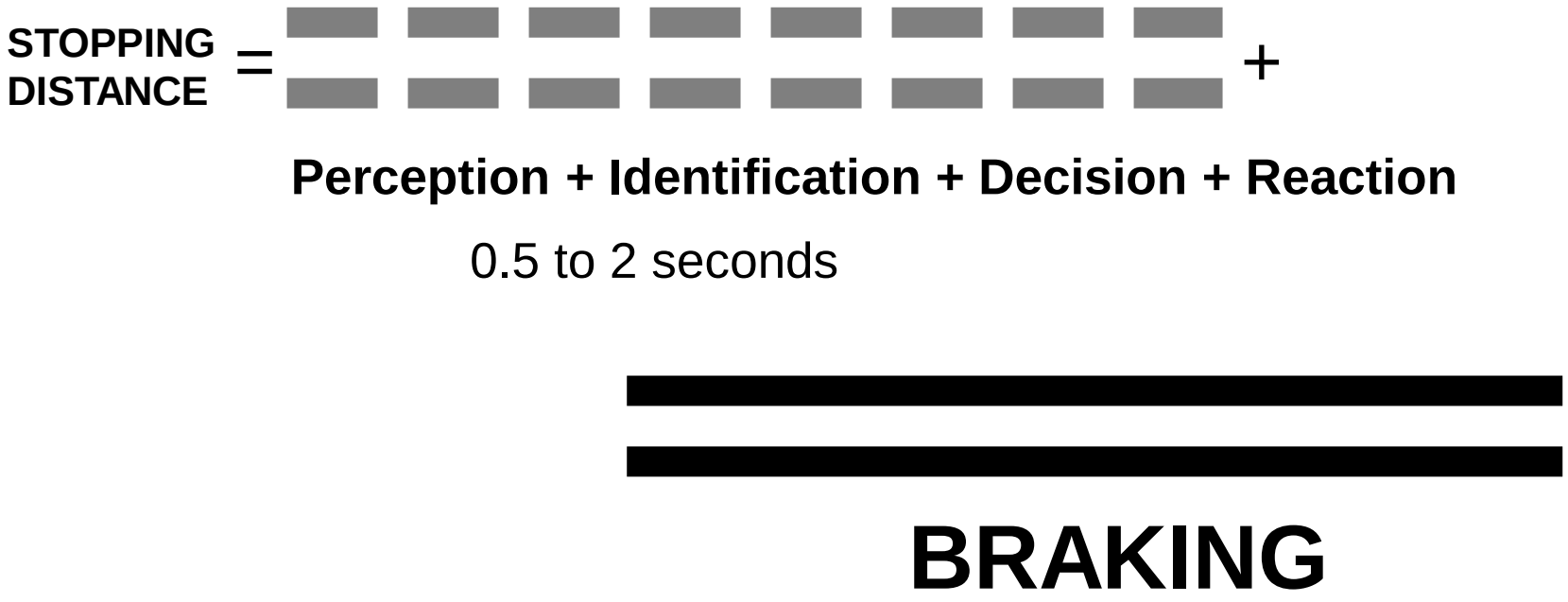
## Perception reaction time

From around 1.0 second to up to 2.5 seconds depending on the experience and alertness of the driver but commonly adopt 1.5 seconds

- detect the presence of the pedestrian
- identify that the pedestrian represents a hazard
- decide action to be taken
- react or respond by taking action (e.g. apply brakes)

# Crash reconstruction

## Perception + Reaction + Braking



# Visibility and lighting


At **36 meters** away from crossing pedestrian using **low beam lights**

# Visibility and lighting


At **36 meters** away from crossing pedestrian using **high beam lights**

# Visibility and lighting


At **20 meters** away from crossing pedestrian using **low beam lights**

# Visibility and lighting


At **14 meters** away from crossing pedestrian using **low beam lights**

# Crash reconstruction

## Is it possible to brake in time?

Assuming 1.5 seconds PRT and speed of 50 km/h

Car traveling at around 14 m/sec
In 1.5 seconds travels around 21 metres
**Not possible to perceive and react in time!**

**IMPACT AT 50 km/h = Jumping out top window of 3 story building**

(Assuming 1 second P-R - impact speed is around 40 km/h)
**Jumping out top floor window of 2 story house**

# Crash reconstruction

## Is it possible to brake in time?

Assuming 1.5 seconds P-R and speed of **40 km/h**

Car traveling at around 11 m/sec

In 1.5 seconds travels around 17 metres (at 20 m visible)

Car will brake for 3 metres (needs around 10 metres to stop)
and will strike pedestrian at around 33 km/h

**IMPACT AT 33 km/h = Jumping off a house roof**

(Assuming 1 second P-R  - impact speed is 17 km/h)

# Crash reconstruction

## Is it possible to brake in time?

Assuming 1.5 seconds P-R and speed of **30 km/h**

Car traveling at around 8.3 m/sec

In 1.5 seconds travels around 12.5 metres (at 20 m visible)

Car needs around 6 metres to stop

# NO IMPACT!

# Summarising

Do we blame the pedestrian?

The driver was likely travelling at the speed limit.

The driver did exceptionally well perceiving and reacting to the pedestrian within 1 second despite being 0.02 BAC.

Do we blame the pedestrian?

Not really as the pedestrian was mentally handicapped.

INFRASTRUCTURE - POOR LIGHTING

SPEED LIMIT IS TOO HIGH FOR ROAD CONDITIONS

**SAFE SYSTEM APPROACH = 30 km/h (40 km/h maybe acceptable)**

Safe System thinking essential to reduce trauma

Pedestrians must be visible at night if you want to maintain 50 km/h speed limit
Otherwise set to 30 km/h (or 40 km/h)

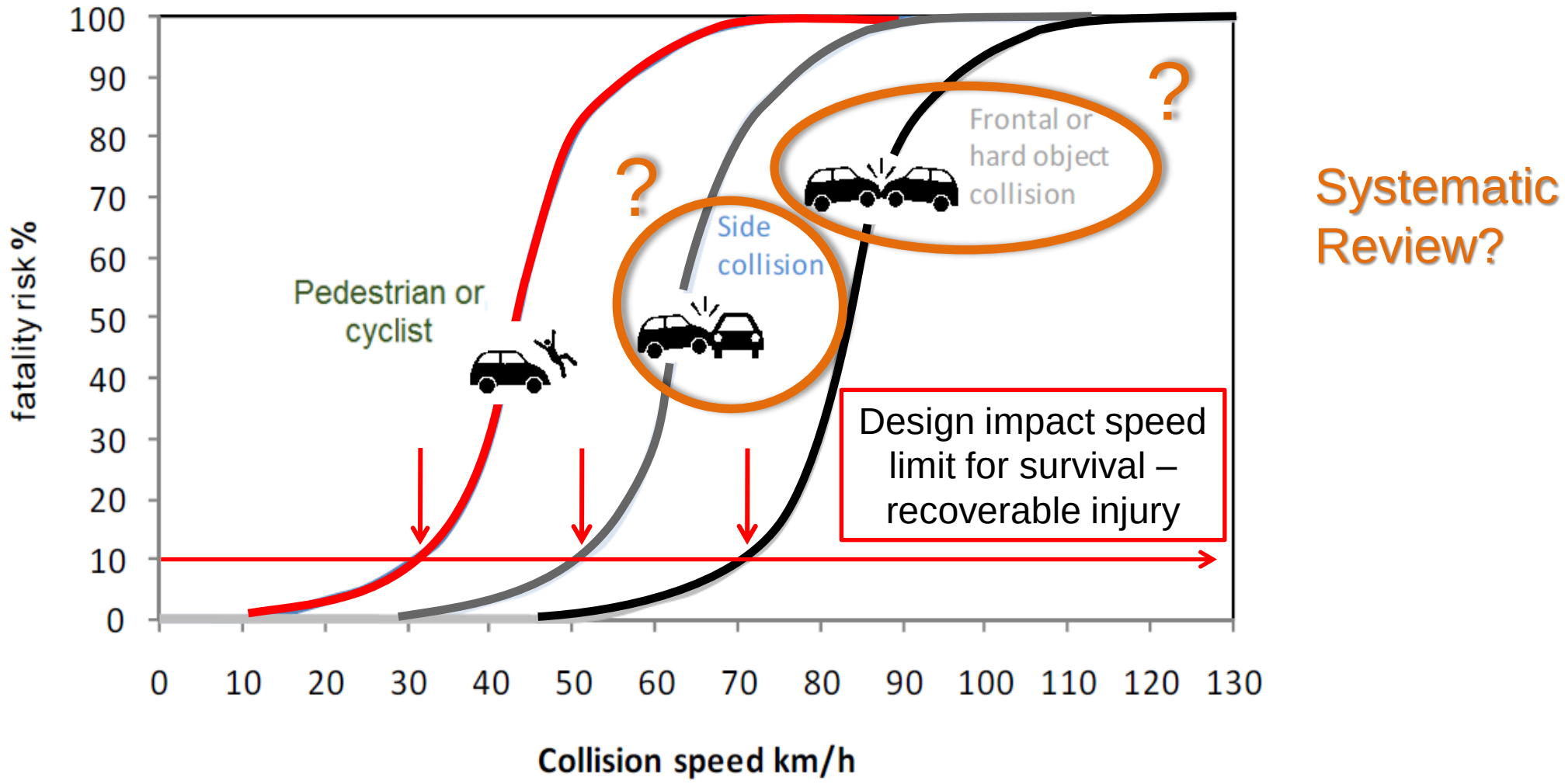
# Latvia's default speed limit for a Safe System to reduce pedestrian trauma



*Default*


*Selected places*

# *Making crashes survivable* – *Safe System Approach*

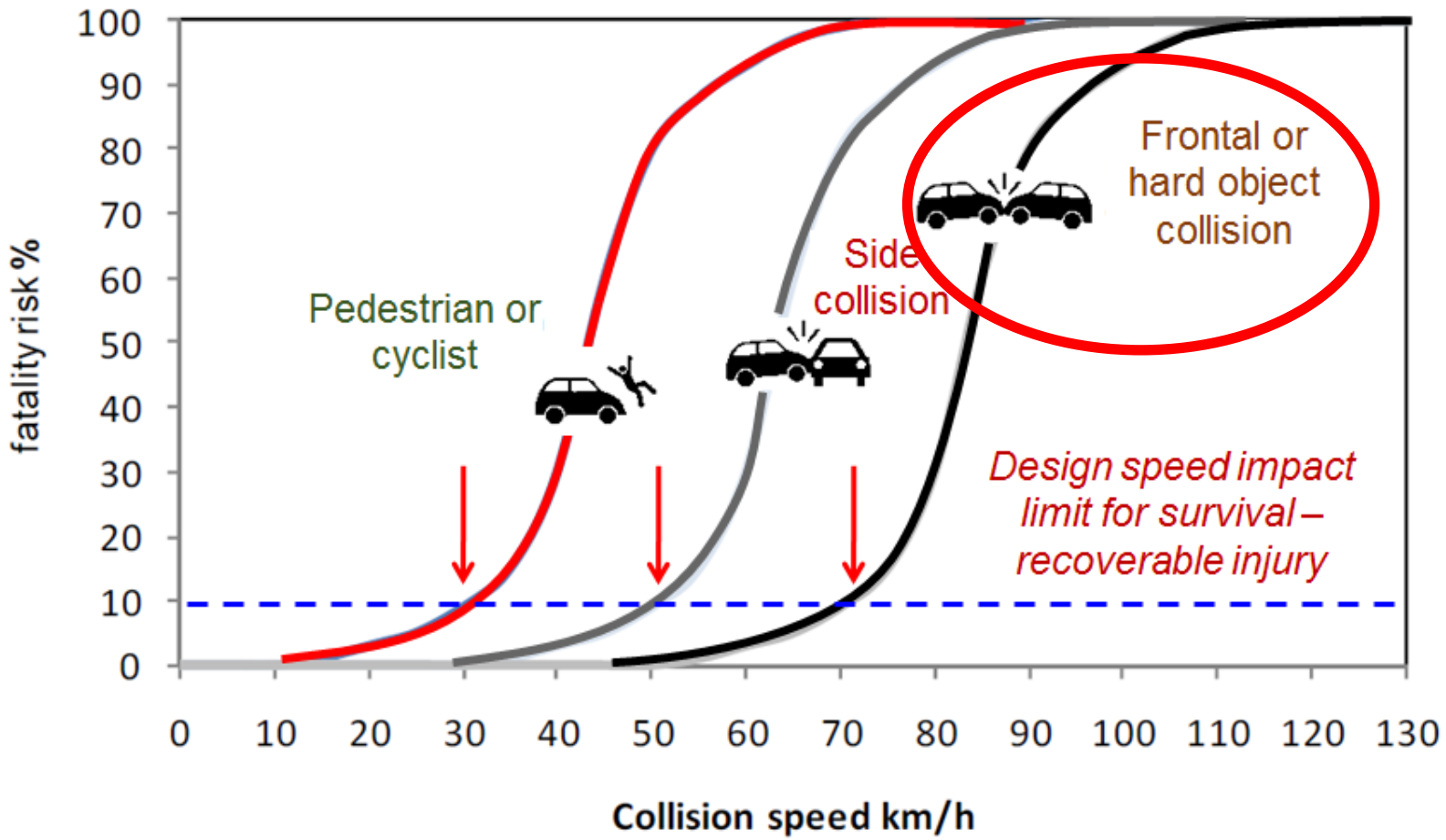



Systematic Review?

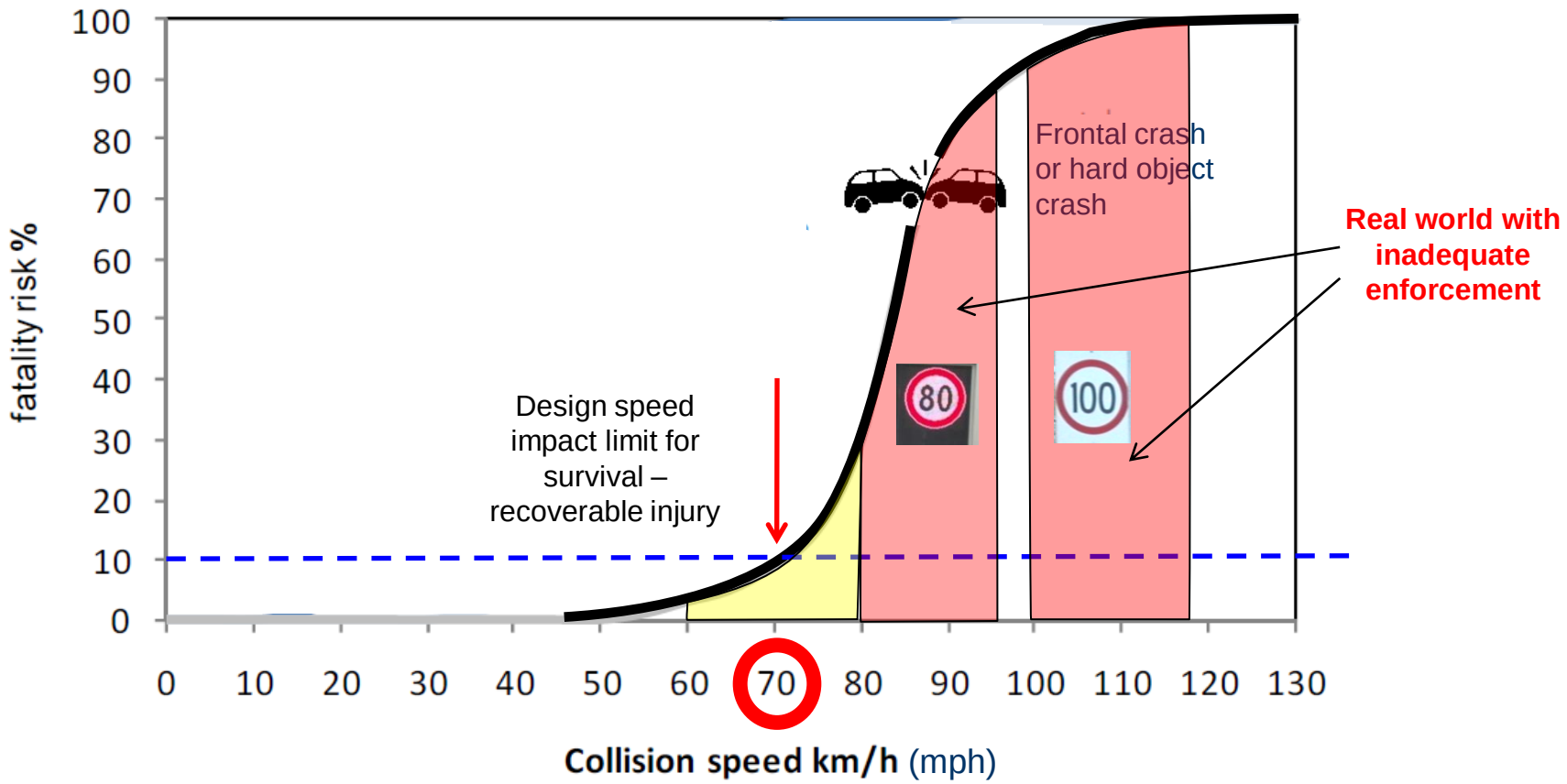
*Source: Wramborg, P. (2005). A New Approach to a Safe and Sustainable Road Structure and Street Design for Urban Areas.* Paper presented at Road Safety on Four Continents Conference, Warsaw Poland.
http://www.internationaltransportforum.org/jtrc/safety/targets/08TargetsSummary.pdf

# What is a survivable crash?

## *Make crashes survivable – intrinsic safety*



# Frontal Crashes – head on + run-off-the road into hard object (tree, pole, abutment)



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# What is a survivable impact?

## Motor vehicles

At 60 km/h, driving off roof of 3 story building

At 80 km/h, driving off roof of 6 story building

At 100 km/h, driving off roof of 10 storey building

**High risk of fatality at speeds > 80 km/h**

# What is a survivable impact?

## Motor vehicles – 60 km/h vs 100 km/h

# Princess Diana crash 31 August 1997

*No barrier*

*Impact into column!*

*At the absolute limits of survivability!*

Around

85-90 km/h

# Australia - Speed limit ~~100~~ km/h

**Should be 80 km/h**

**Crash into tree not survivable at this speed**

# Australia - Speed limit ~~100~~ km/h

**Head-on crashes not survivable at this speed**

## Should be 80 km/h

# Wire-rope median barrier

# Wire-rope barrier installation

- NZ Centenial Highway
  - 1996 to 2000:  8 fatalities, 2 serious injury and 7 minor
  - 2001 to 2004 removed passing lanes & wide yellow double tactile lines & reflectors & signs: 4 fatalities 2 serious injuries 2 minor injuries
  - 2005 to 2009 installed wire-rope median barriers and dropped speed limit to 80 km/h: **No fatalities, No serious injuries**, 3 minor injuries.

Source: Marsh F. and Pilgrim M., (2010) Performance of Narrow Median Wire Rope Barrier Installation on Centennial Highway, New Zealand, accepted for publication Journal of the Australasian College of Road Safety, May.

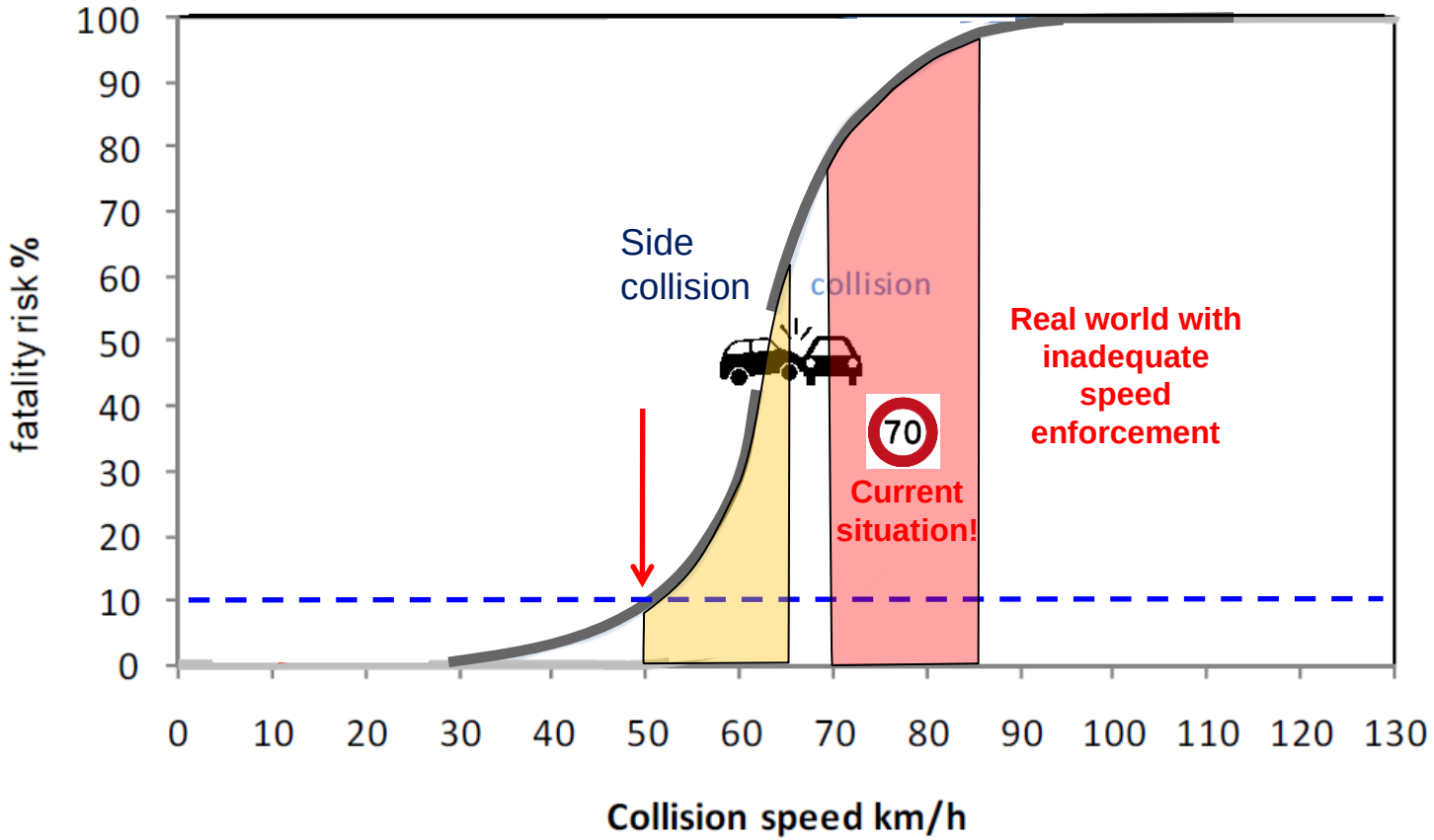
# New Zealand

## Centennial Highway – actual incident


Source: Fabian Marsh, New Zealand Transport Agency, Wellington

# What is a survivable impact?

## Intersection crashes



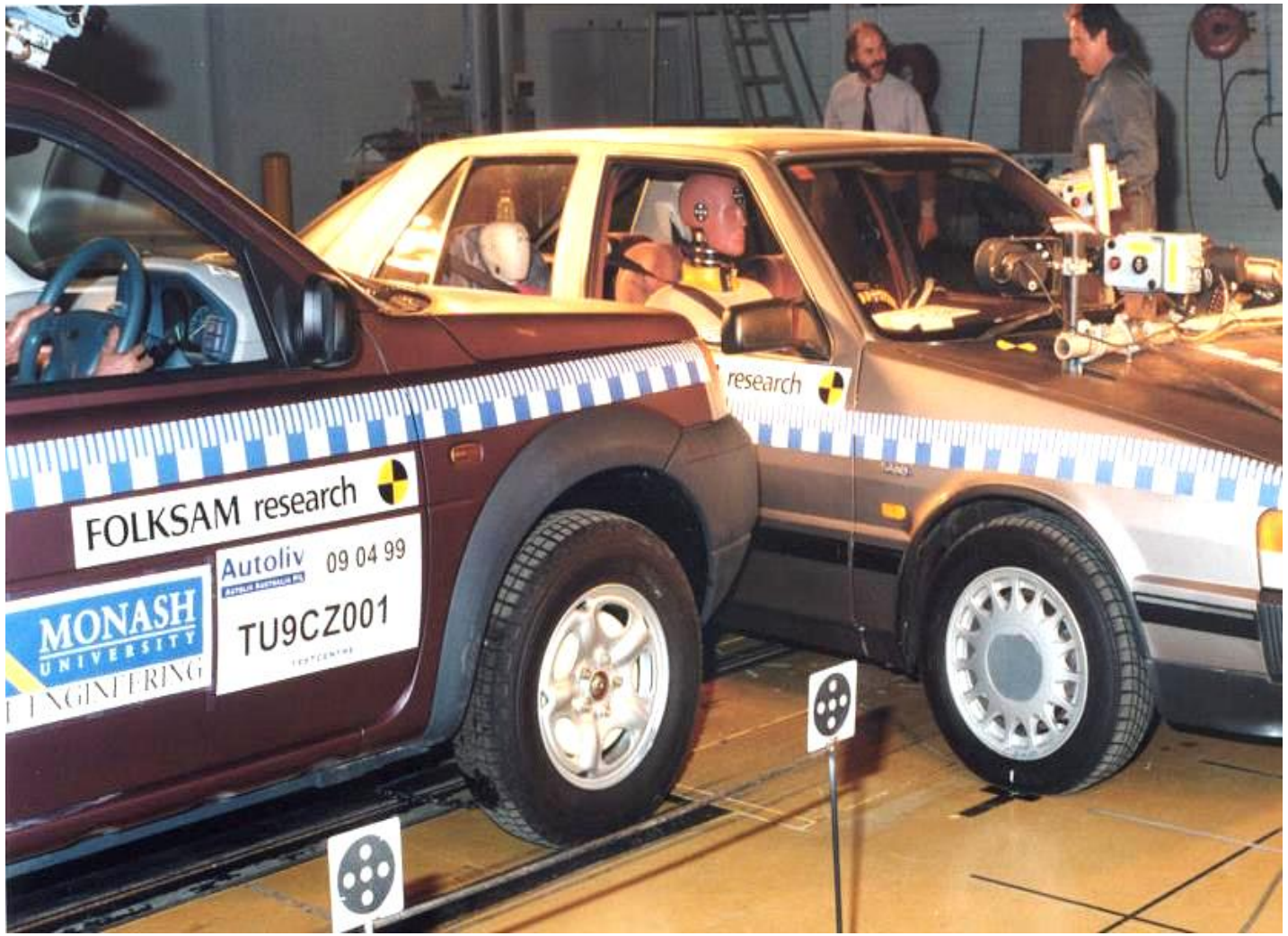
# What is a survivable impact?

## Intersection crashes

4 fatalities and
3 serious injuries
over a three-year
period.

Approach speed is 70 km/h from both directions – much too high

# *Crash types: Side impact crash*



# *Crash types: Side impact crash*

## Post crash damage

*Head strike* →



# *Common T bone intersection crash*

US deformable barrier Test = **50 km/h**

Euro NCAP deformable barrier Test less severe (lower barrier height & lower impact speed & perpendicular) = 32 km/h

US Insurance Institute for Highway Safety

# *Common T bone intersection crash*

US deformable barrier Test = **50 km/h**

Euro NCAP deformable barrier Test less severe (lower barrier height & lower impact speed & perpendicular) = 32 km/h

US Insurance Institute for Highway Safety

# How head injuries occur in crashes

## Side Impact pole crash – with side airbag

Euro NCAP
Pole Test
**= 32 km/h**

# How head injuries occur in crashes

## Side Impact pole crash – with side airbag

Euro NCAP
Pole Test
**= 32 km/h**

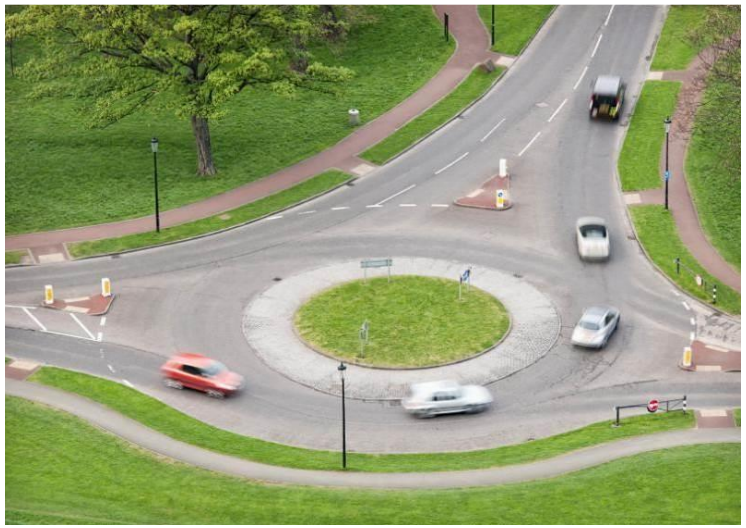
# How head injuries occur in crashes

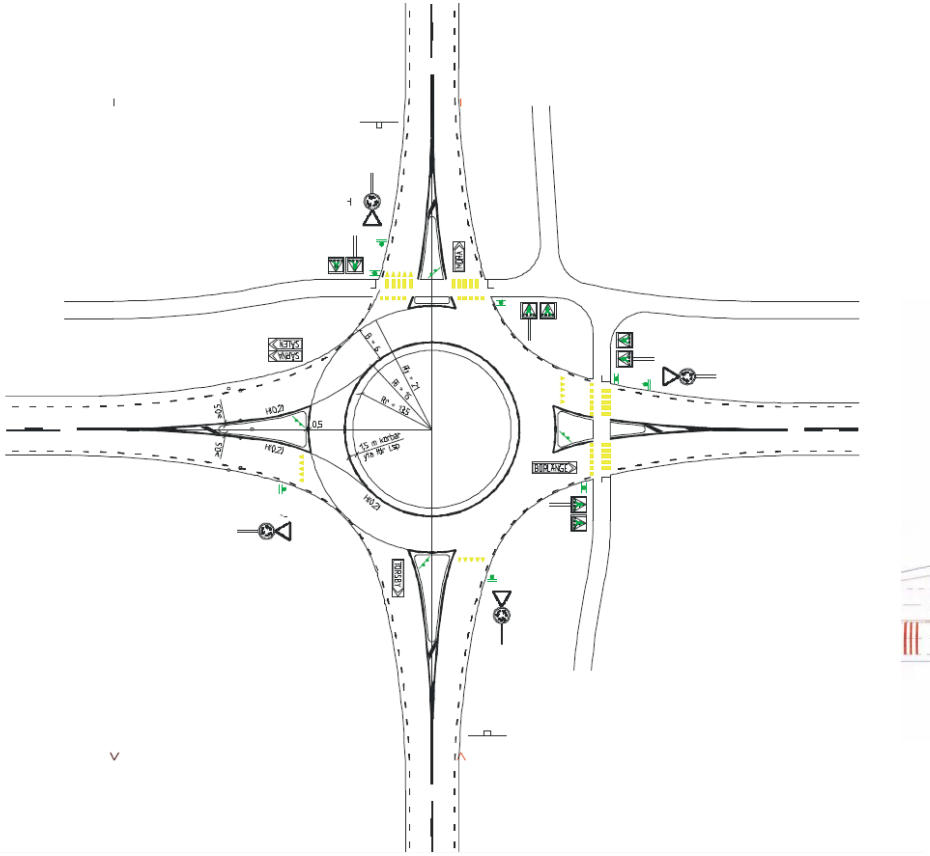
## Side Impact pole crash – with side airbag

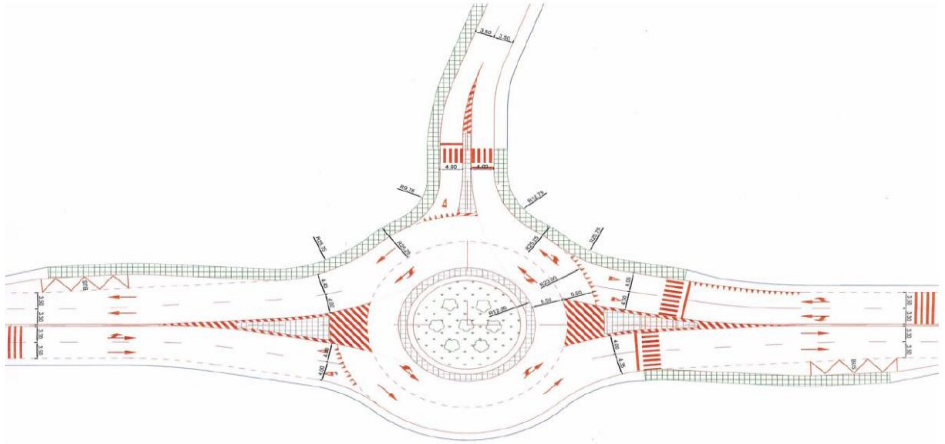
Euro NCAP
Pole Test
**= 32 km/h**

# Roundabout – naturally controls speed and directional impact forces at intersections reducing T-bone impact severity (Aus)

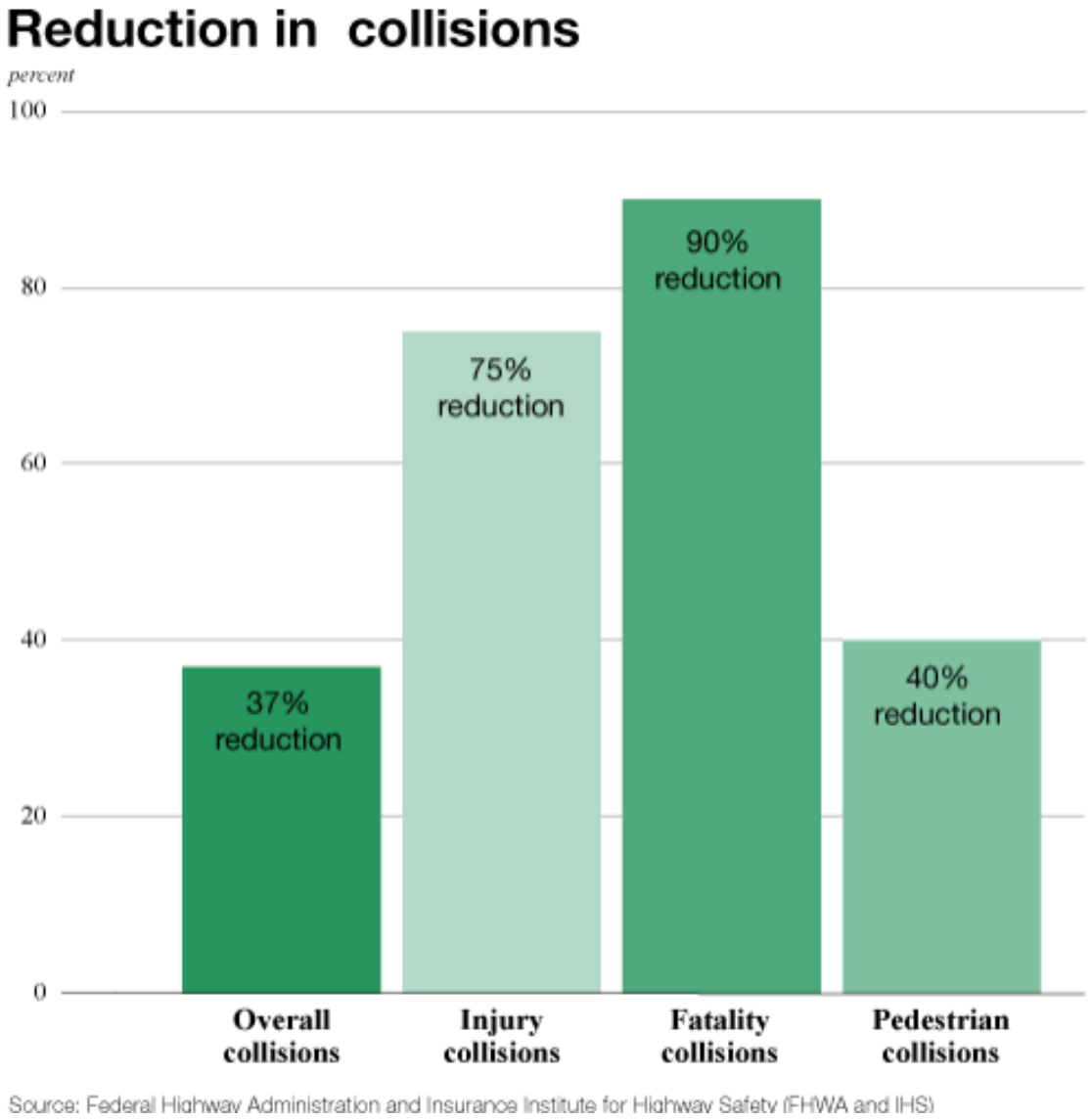
# Roundabout – forces drivers to reduce their speed to around 50 km/h safe system impact speed







# Roundabout coutermeasure



# Questions?