FDOT TRANSPORTATION SYMPOSIUM 2019

# Safe System Approach to Intersection Planning and Design

Mark Doctor – FHWA Resource Center

# Safe System Approach to Intersection Planning and Design

- What is the “Safe System” approach?
- How does it relate to Vision Zero / Road To Zero / Toward Zero Deaths?
- How does it effect the way we should be designing intersections?

# What do you think?

The Road To Zero (RTZ) coalition seeks to eliminate traffic fatalities in the U.S. by 2050, an aim that aligns with a growing number of Vision Zero goals and efforts.

# Paradigm Shift

**It's not about eliminating crashes, but eliminating fatal and serious injuries.**

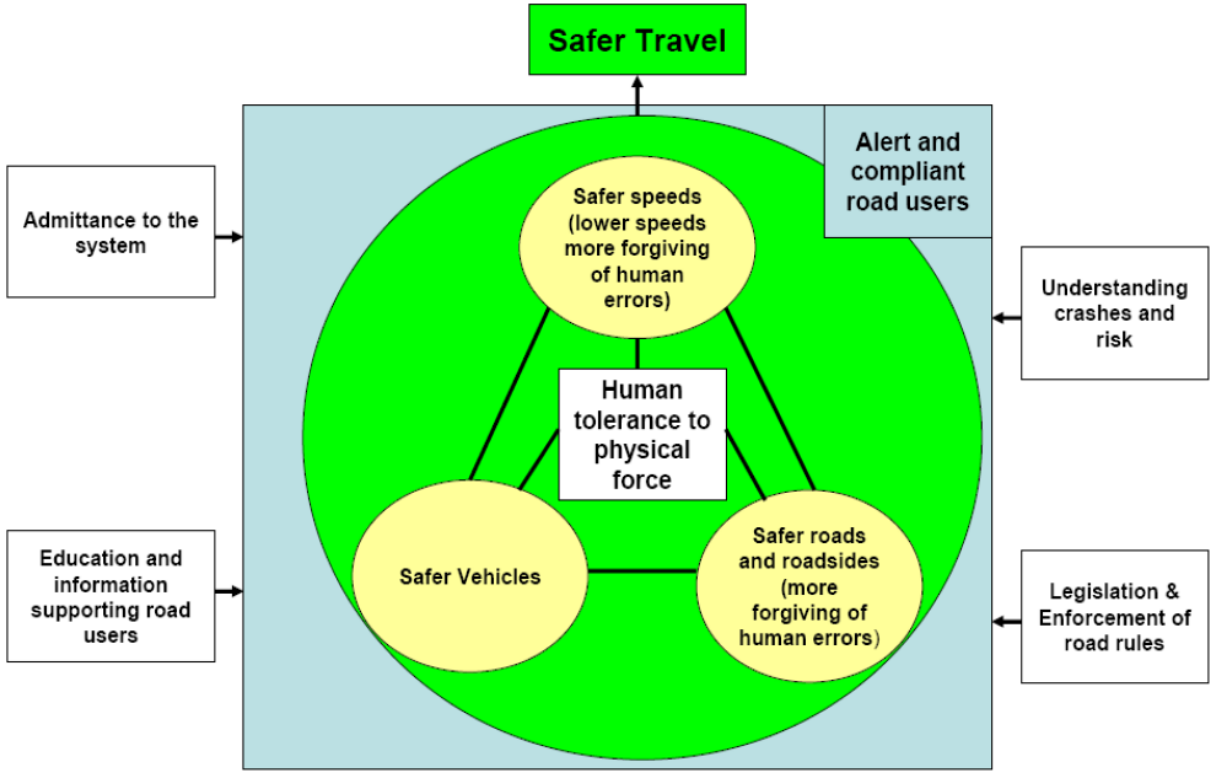
What determines whether a crash is a fatal/severe injury or minor injury (or better yet "Property Damage Only") crash?

# “Safe System” Approach

## Kinetic energy transfer kills road users

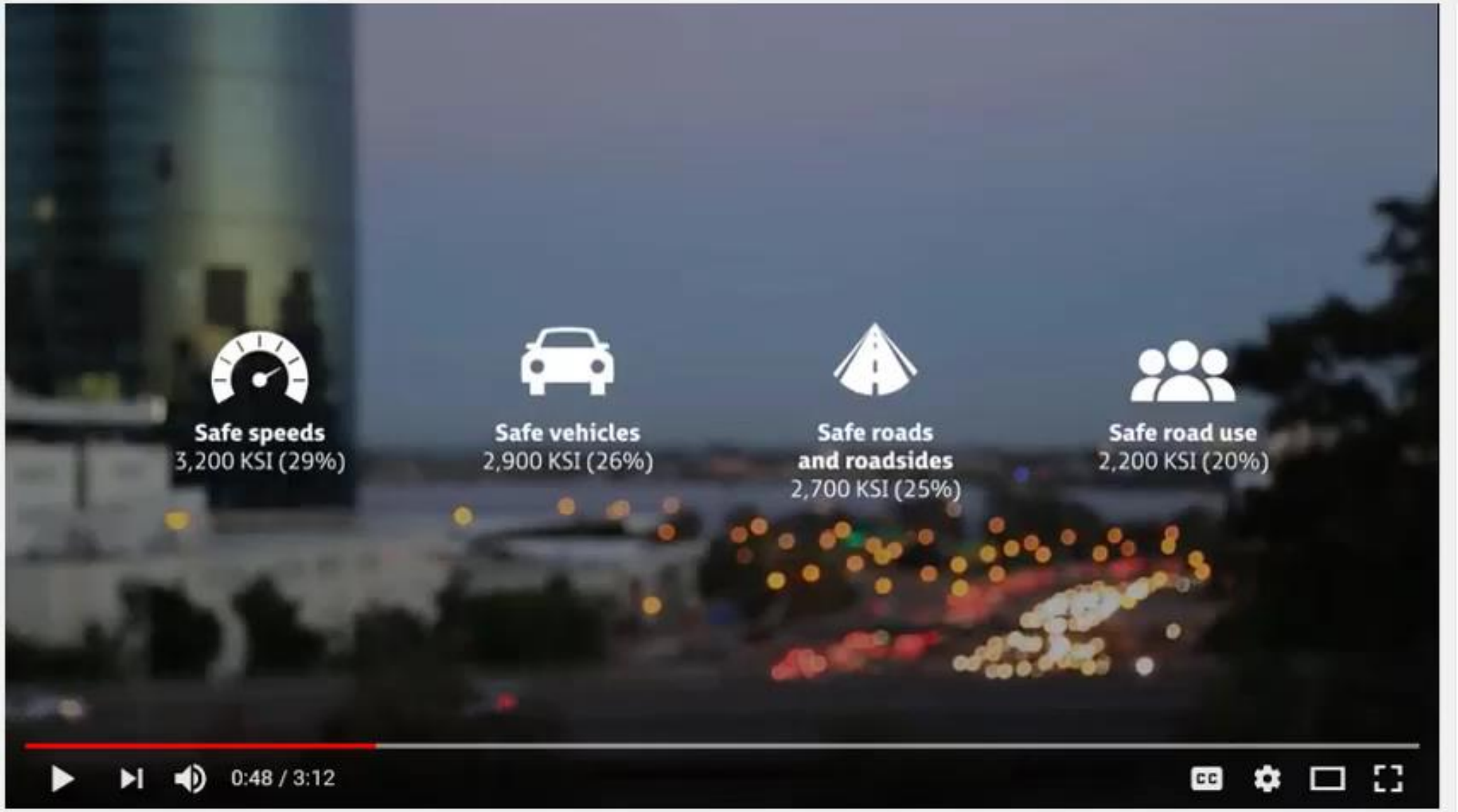
**The Safe System approach acknowledges that users make mistakes. The goal is to ensure redundancy in the system so that in the event of a crash, the impact forces released are within the boundaries of human tolerance and that no fatalities should occur and serious injuries are reduced.**

Source: Roads and Traffic Authority of New South Wales




Source – Australian Transport Council

## Australian Road Safety Commissioner Iain Cameron explains the 'Safe System' approach

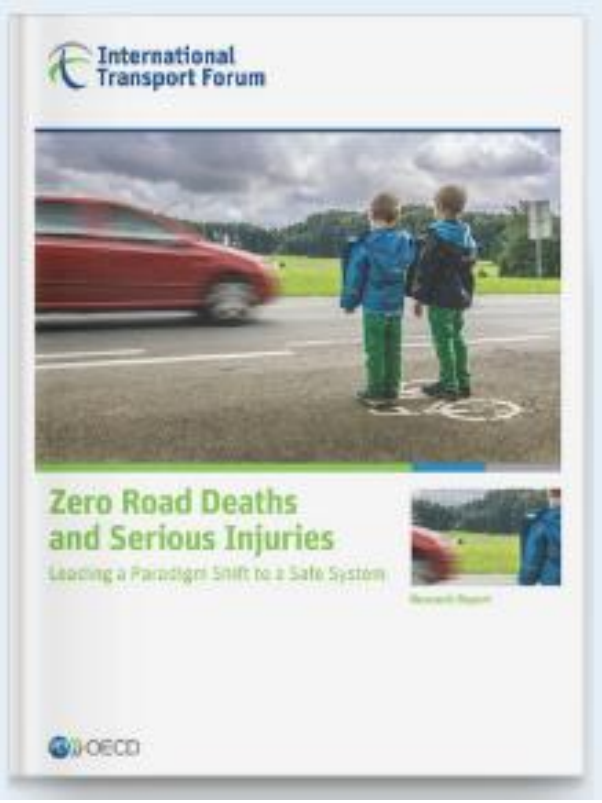



https://www.youtube.com/watch?v=MigxAs0KjBw

# Safe System Approach

Four Guiding Principles:

1. People make mistakes that lead to road crashes
2. The human body has a physical tolerance to crash forces before harm occurs
3. Shared responsibilities among users and those who design, build and maintain vehicles and roads
4. Strengthen all parts of the system so users are protected if one part fails




Source: Zero Road Deaths and Serious Injuries: Leading a Paradigm Shift to a Safe System; OECD

http://www.oecd.org/publications/zero-road-deaths-and-serious-injuries-9789282108055-en.htm

# Paradigm Shift

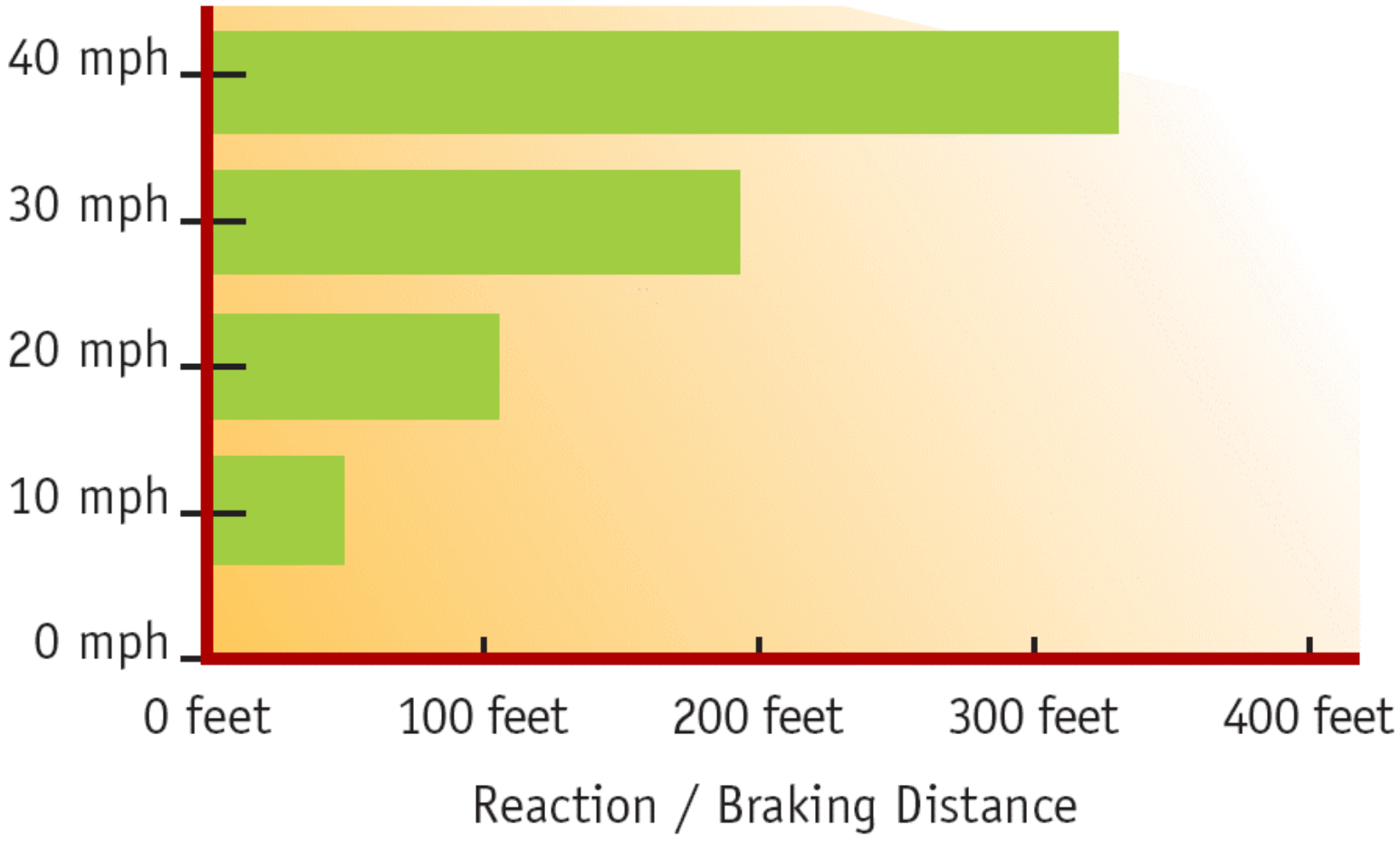
**Designing Safer Roads is an Exercise of Managing Kinetic Energy.**

What determines the level of transferable kinetic energy in a crash?

$$K = \frac{1}{2}mv^2$$

# Speed and Braking Distance

Higher speeds equate to greater reaction and stopping distance

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# Speed and Impact severity

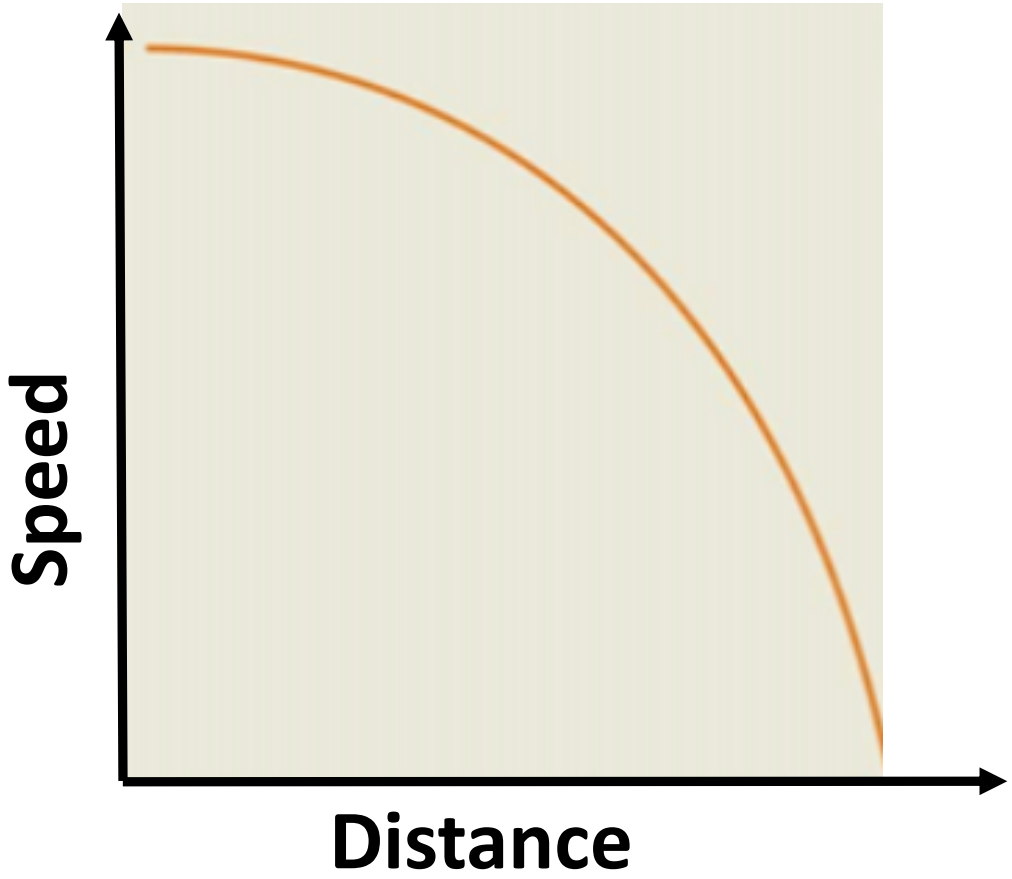
**Australian PSA**

60 kph (37 mph)

vs.

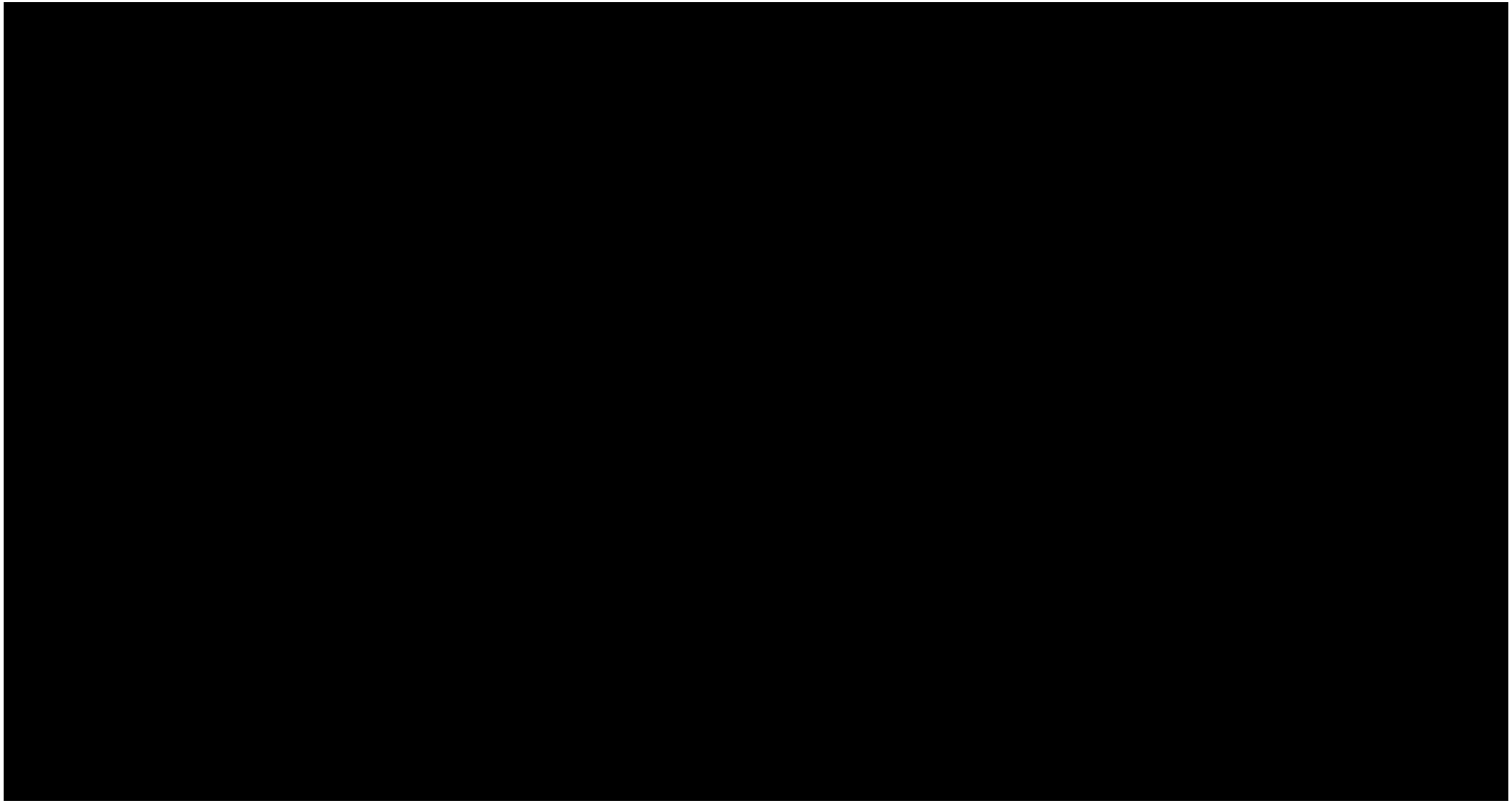
65 kph (40 mph)

# Speed and Impact Severity



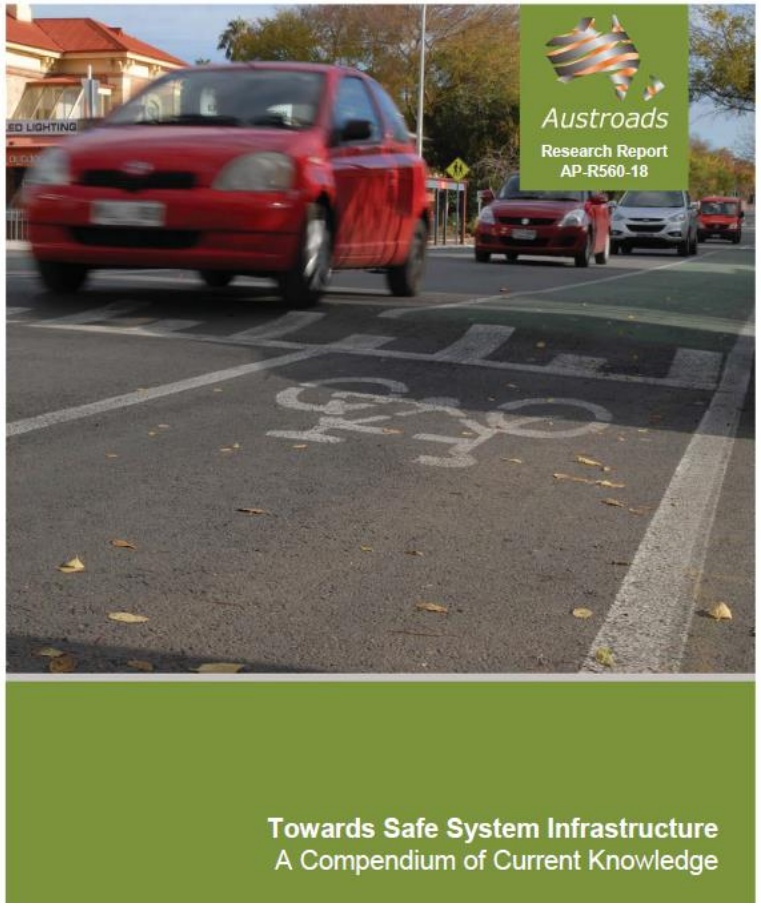

*"We wipe off most our speed during the last moments of braking"*

# For pedestrians …
# Speed Matters – A Lot!!!



# What is the Safe System Approach?

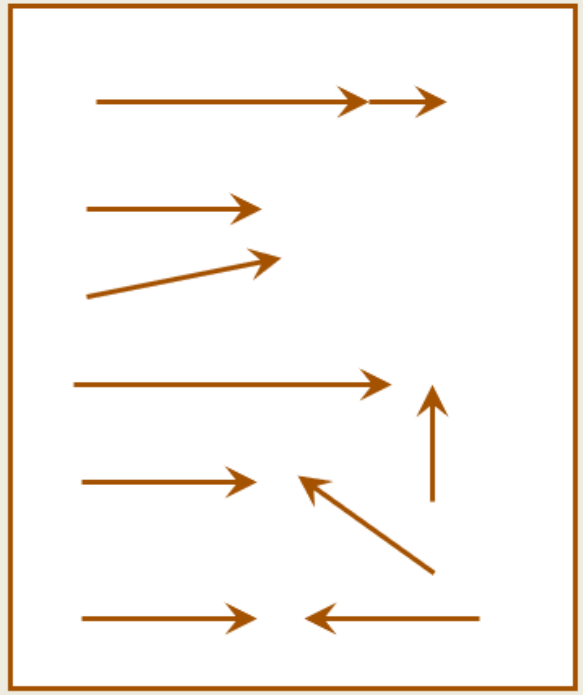
*"Safe System is the management and design of the road system such that impact energy on the human body is <u>firstly avoided</u> or <u>secondly managed at tolerable levels</u> by manipulating speed, mass and crash angles to reduce crash injury severity."*




Reference: Austroads Report AP-R560-18 Towards Safe System Infrastructure: A Compendium of Current Knowledge

# Velocity is a Vector
# Collision Angle is also Important

Intersection crash severity is highly influenced by SPEED and ANGLE of IMPACT



| | |
|---|---|
| Rear-end | Least severe |
| Sideswipe | |
| Angle | |
| Angle | |
| Head-on | Most severe |

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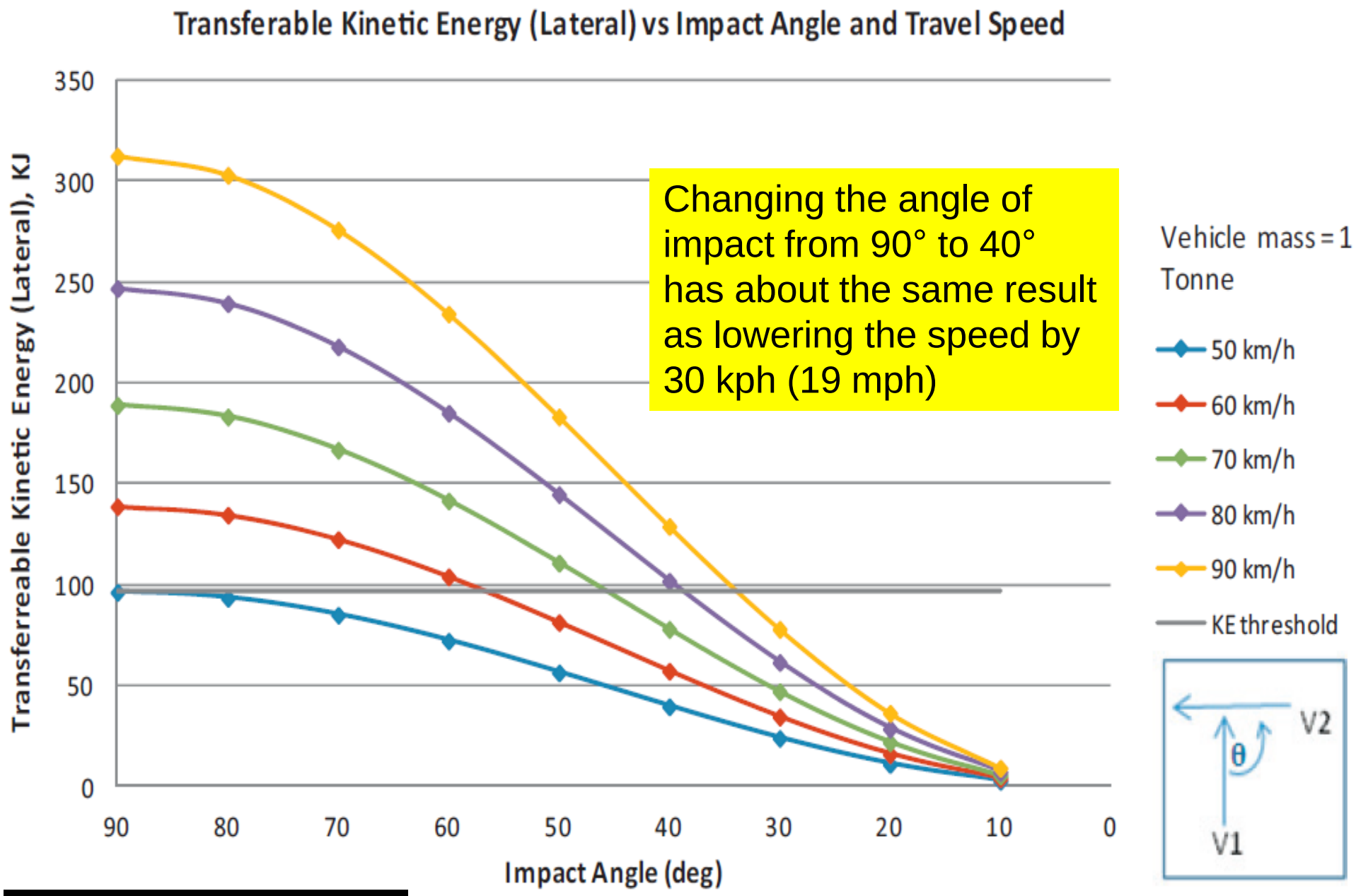



Source: DEVELOPMENT OF THE KINETIC ENERGY MANAGEMENT MODEL AND SAFE INTERSECTION DESIGN PRINCIPLES
MONASH UNIVERSITY (Melbourne, Australia)

Influence of impact angle on transferrable kinetic energy.

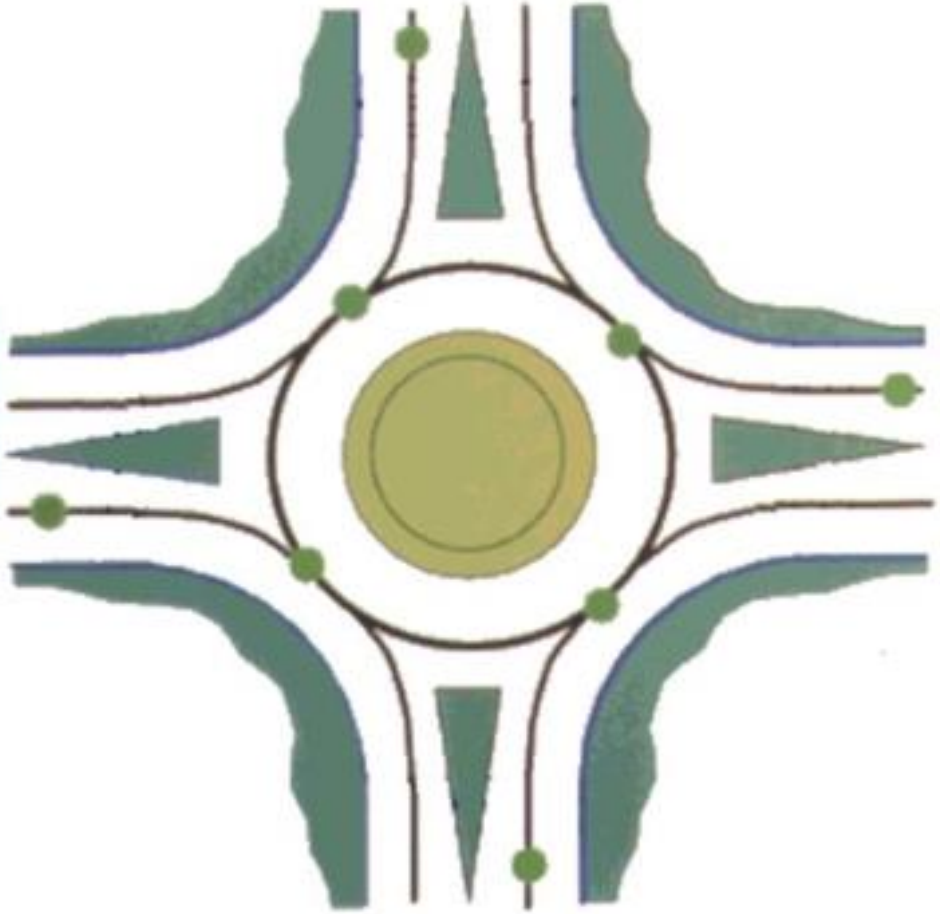
# *Is this why roundabouts are so effective at reducing severe crashes?* - YES !!!

**8**

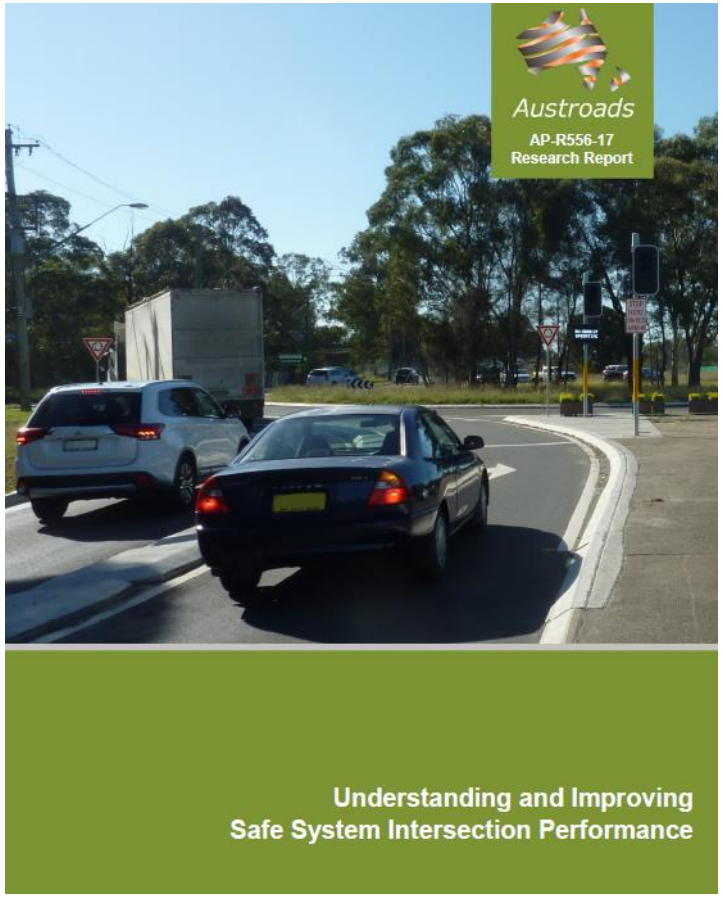
**conflict points**

**75% reduction in Motor Vehicle conflicts**

- ➔ ***Low*** **speed impacts**
- ➔ ***Low*** **angle impacts**



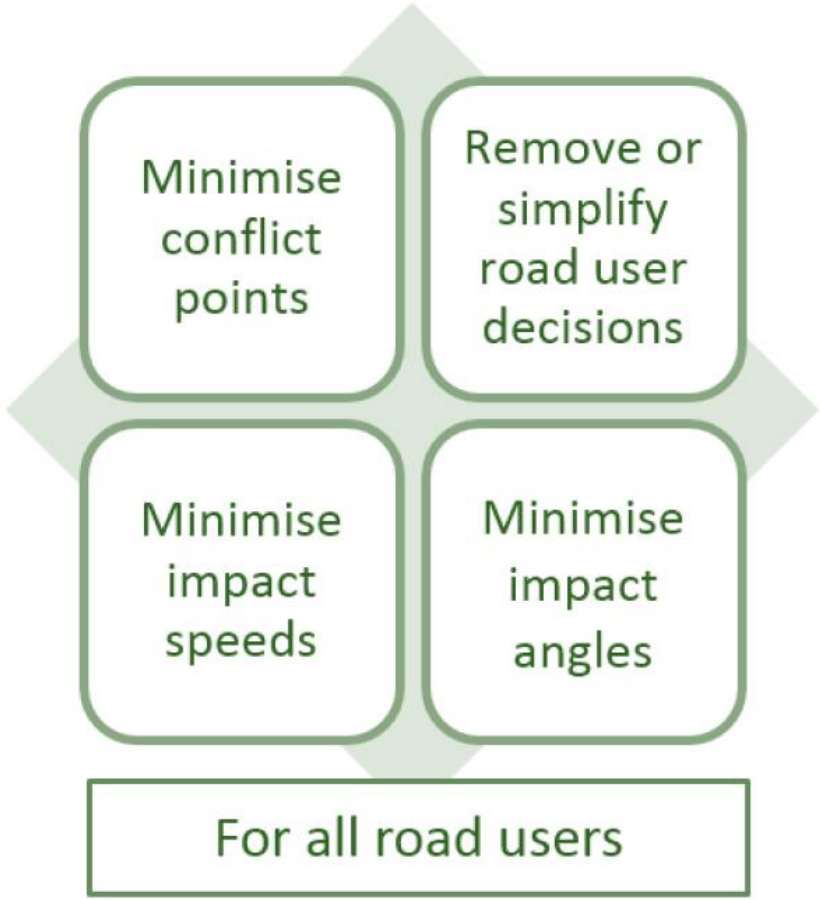
# Safe System for Intersections




Intersection design principles for a Safe System:

- Simplify (or remove) road user decisions
- Reduce the number of <u>crossing</u> conflict points
- Reduce collision impact angles
- Minimize impact speeds

# Safe System Intersection Design Principles




Source: Understanding and Improving Safe System Intersection Performance, Austroads Research Report AP-R556-17

# How many "S's" are in Safety?

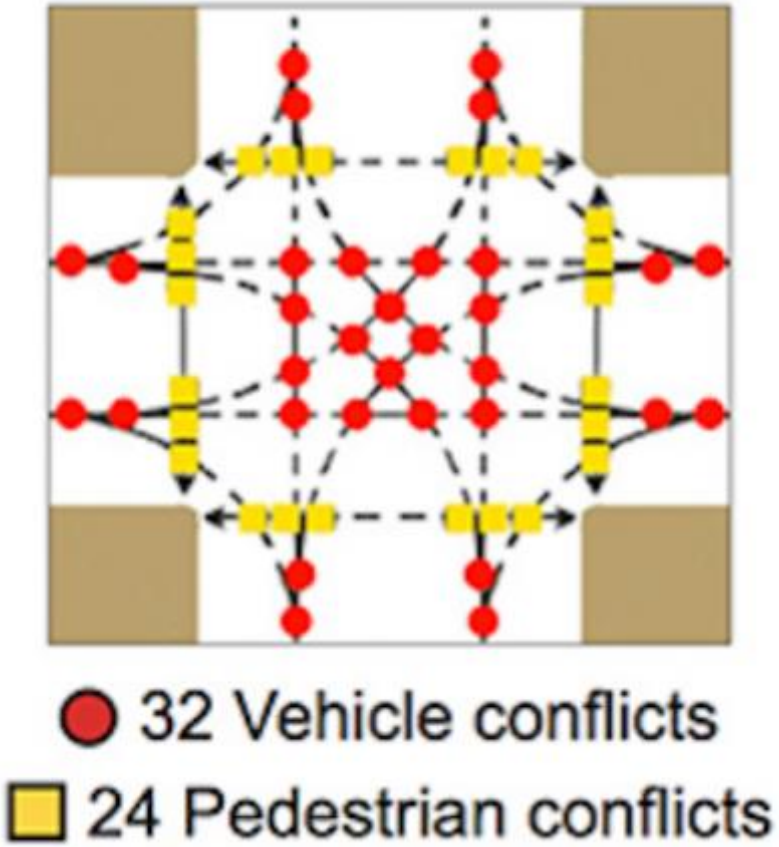
## Simplify – Slow - Separate

In addition to making East Boulevard in Charlotte, N.C., more attractive, a road diet reduced travel speeds, bicycle and pedestrian injury rates and the number of rear-end and left-turn collisions. Photo courtesy city of Charlotte

# SIMPLIFY

# Intersection Conflict Points

"Conventional" Intersection




**Conflict Points may be thought of as "Collision Potential"**

If a person commits an error (poor judgement or traffic control violation)

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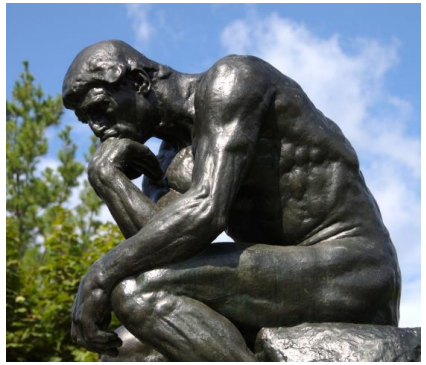
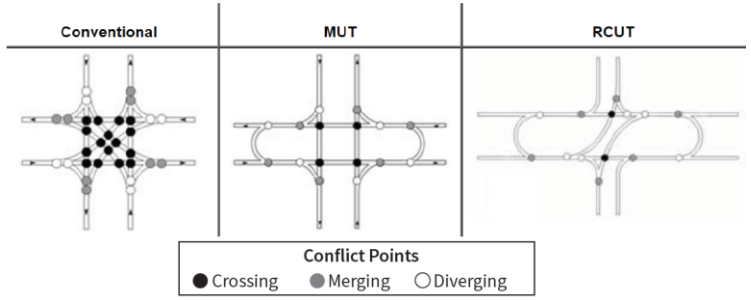
# Doctor's Postulate on Intersection Safety



"If you give people the *opportunity* to make a mistake, eventually they will."

## Reduced Left Turn Conflict Intersections

*MUT and RCUT Can Reduce Conflict Points by 50%*



PROVEN SAFETY COUNTERMEASURES

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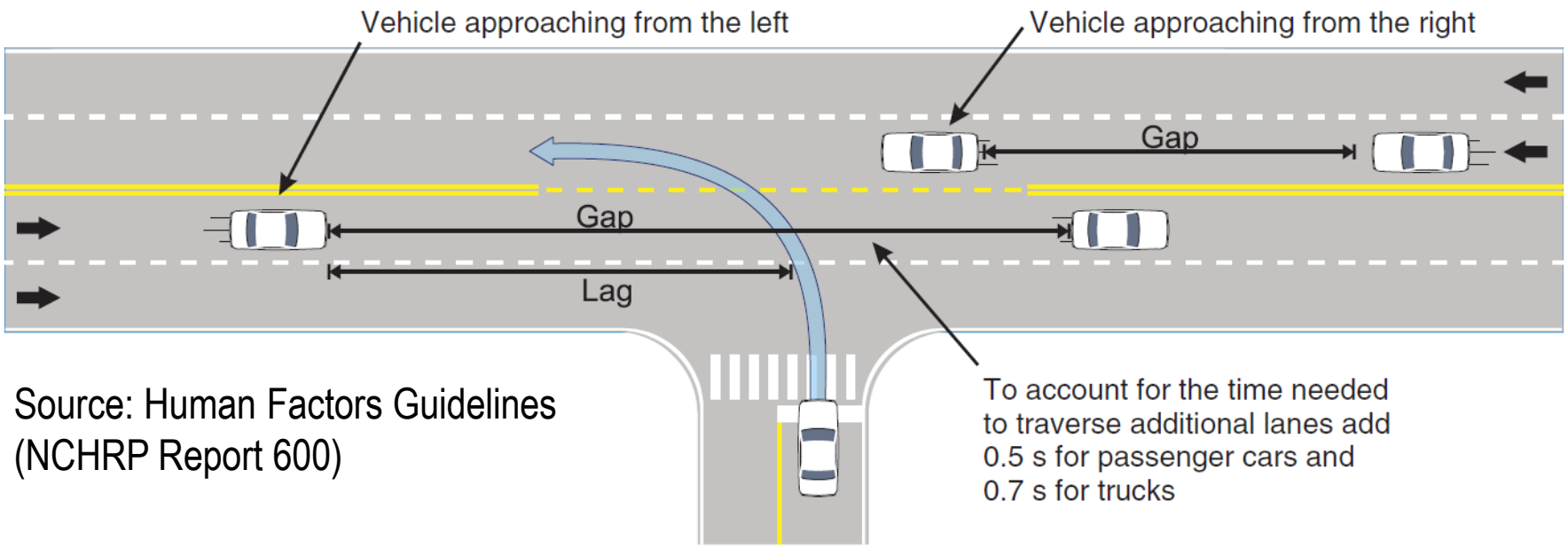
# Fewer Conflict Points = Safer Intersections

The RCUT has fewer total conflict points, fewer crossing conflicts and eliminates far side angle collisions

# Simplify

Making judgments about vehicle speeds and arrival time (gaps) is challenging. Research indicates most drivers tend to underestimate gaps by 20% to 40%.

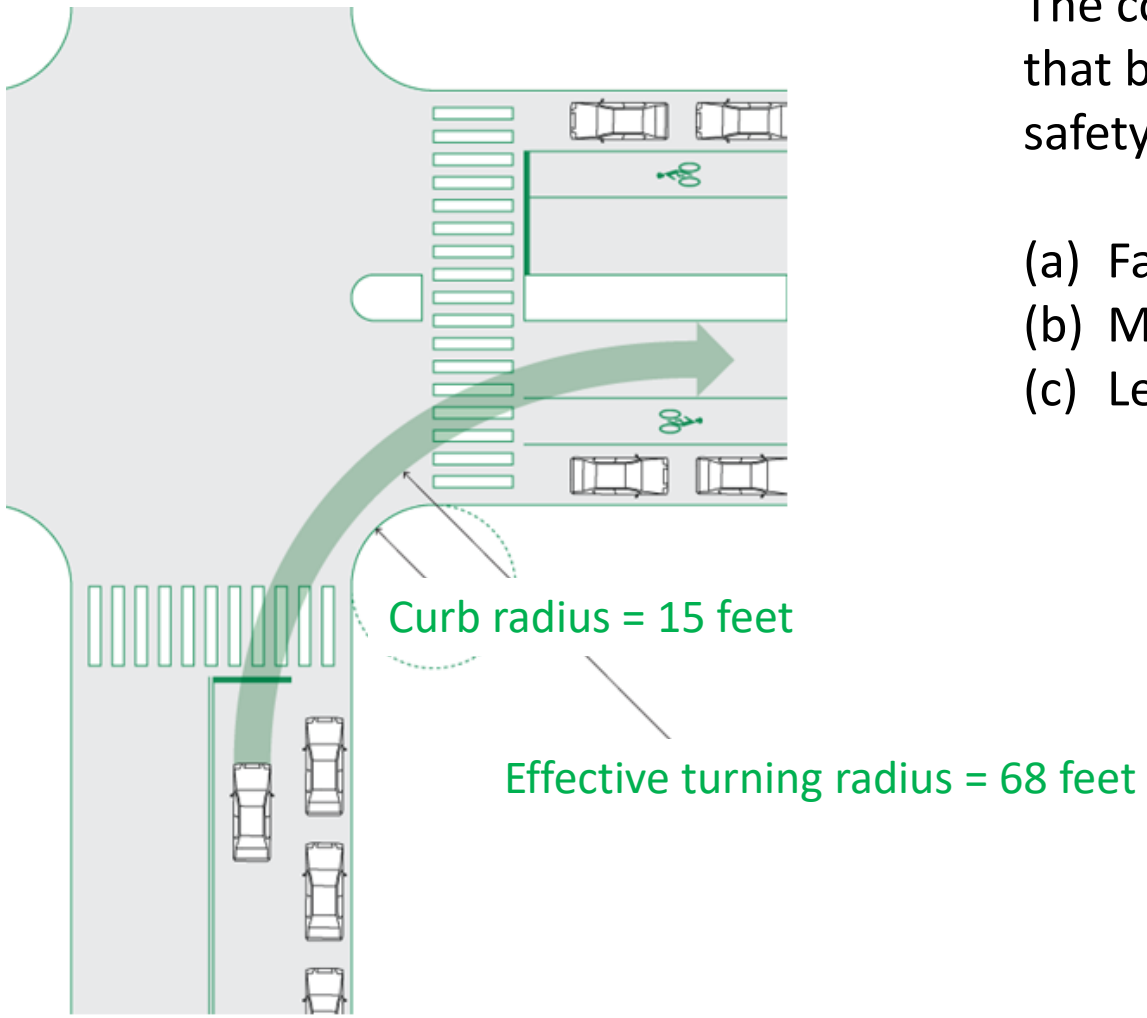



Source: Human Factors Guidelines (NCHRP Report 600)

- Gaps are defined as the time interval between two successive vehicles (measured from the rear of a lead vehicle to the front of the following vehicle)
- Lags are defined as the time interval from the point of the observer to the arrival of the front of the next approaching vehicle

# SLOW

# Intersection Turning Speeds



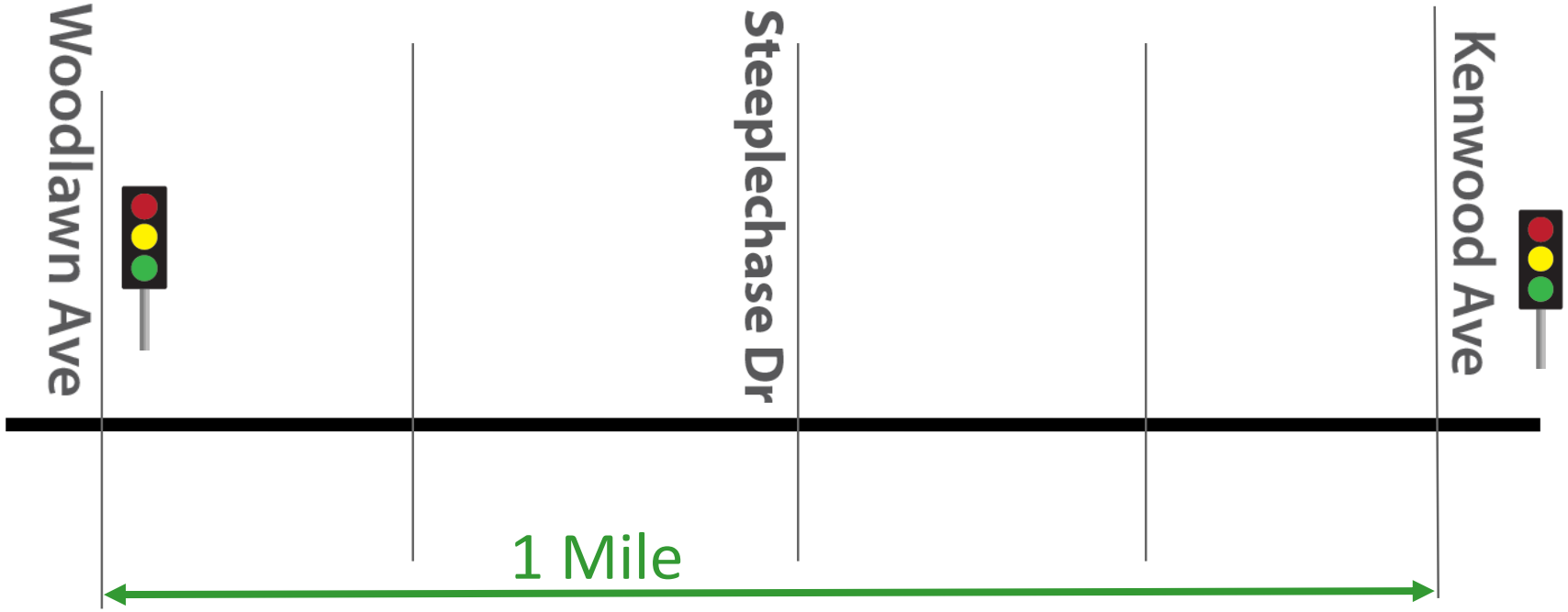

The corner curb radii at intersections is a “trade-off” that balances vehicle operational needs with pedestrian safety. The curb radius directly impacts:

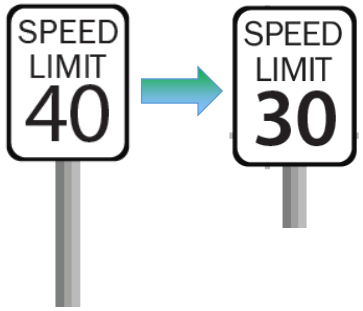
(a) Facilitating large vehicle turning movements,
(b) Moderating the speed of turning vehicles, and
(c) Length of pedestrian crossing distances

Consider the “Effective” turning radius

- Parking and bike lanes can increase the effective turning radius without the need to increase the “curb” radius

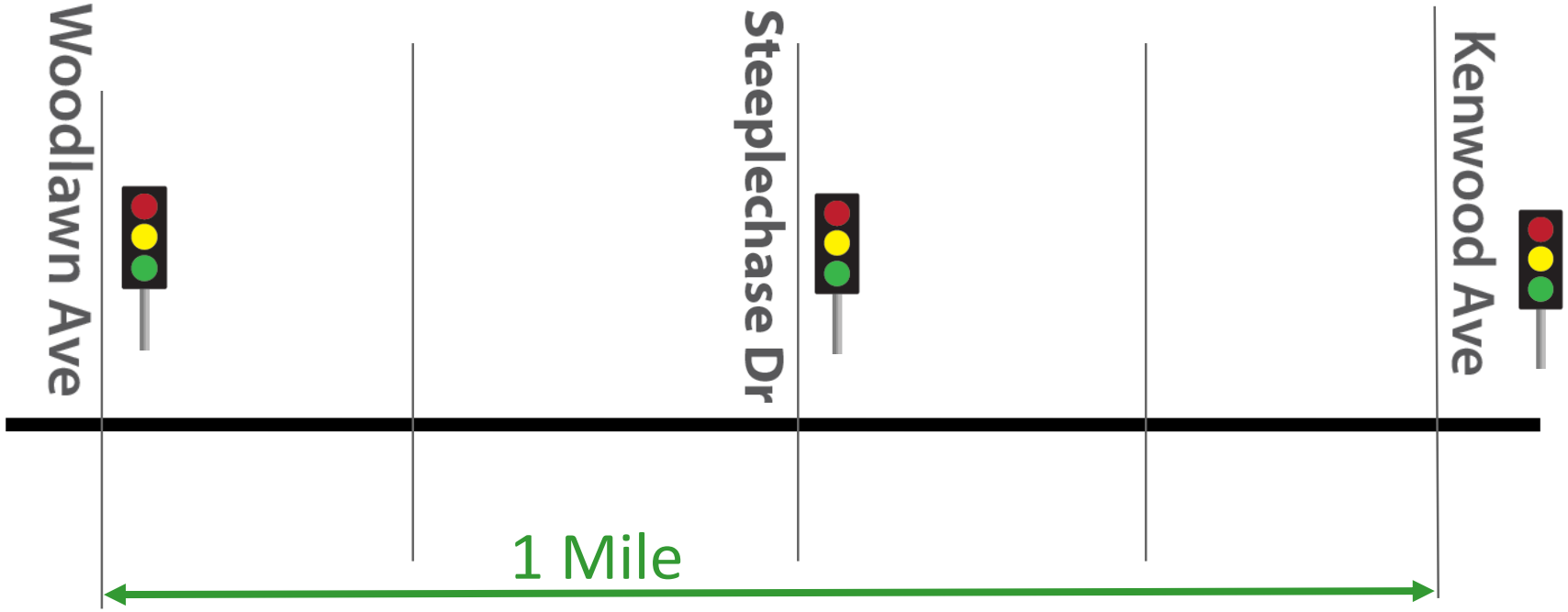
# What are the effects of reducing speed?




Lowering travel speeds from 40 MPH to 30 MPH adds 30 seconds of additional journey time per mile segment

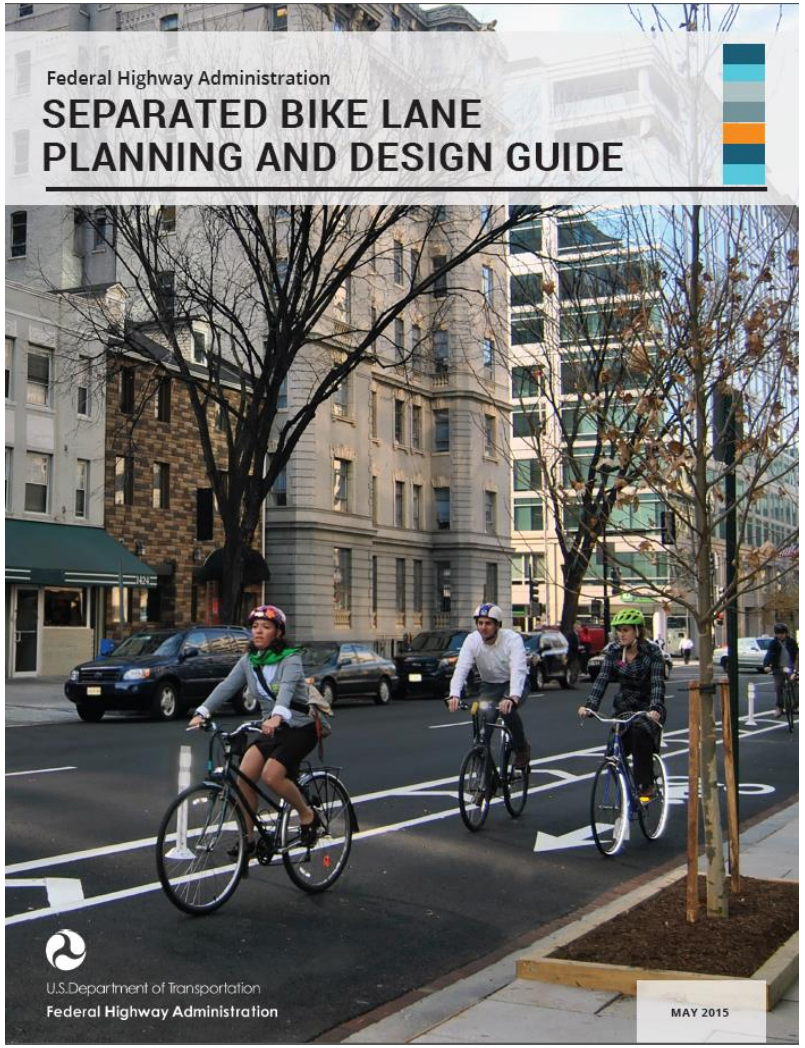
# What are the effects of reducing speed?



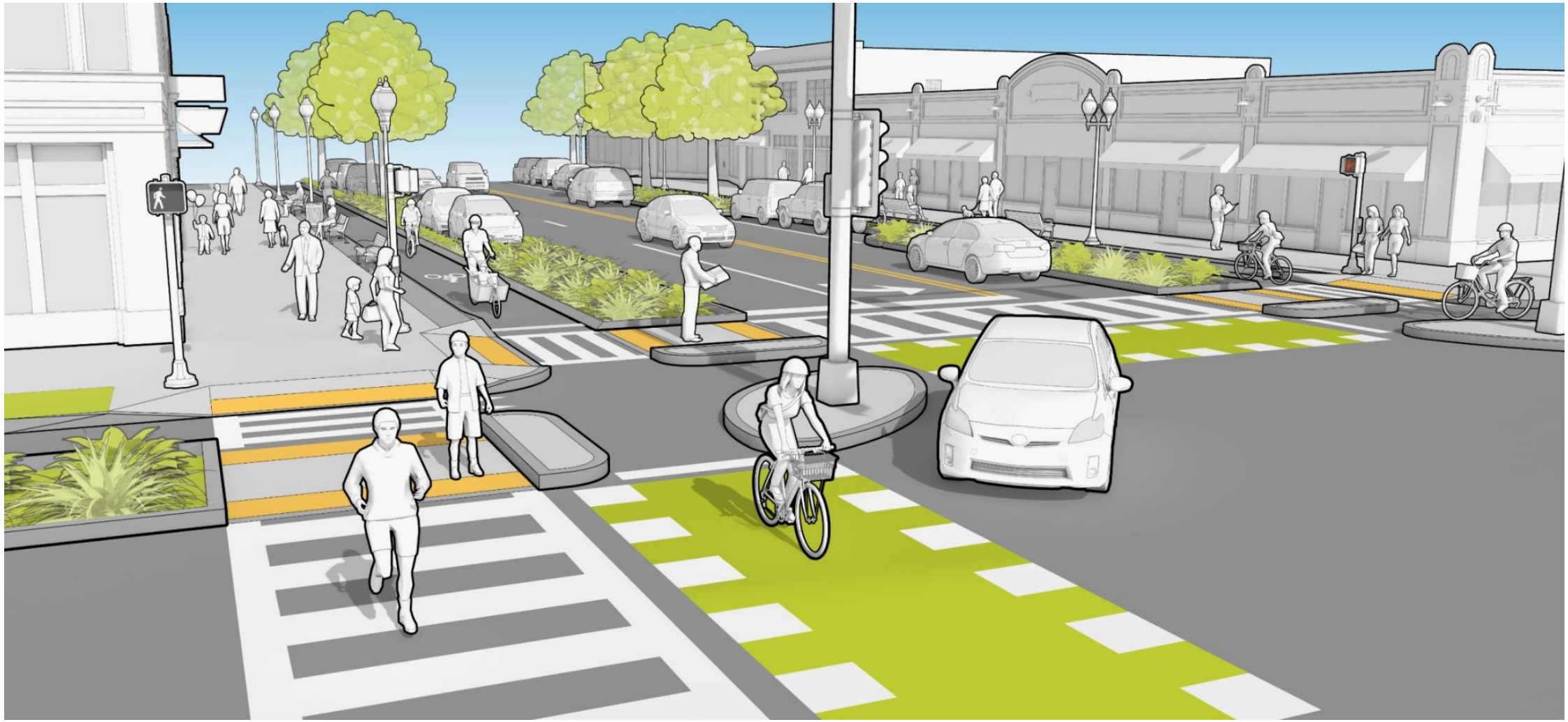

If a new signal was installed how much additional journey time would that create?

# SEPARATE

# Separated Bike Lanes



# ‘Protected’ Intersections



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The application of Safe System approaches to infrastructure planning, design, and operations would represent a fundamental shift in how transportation agencies consider, analyze, and make decisions during project development and offer mechanisms to advance safety across the U.S.

A Safe System approach to intersection planning, design, and operations would build upon other ongoing initiatives, such as:

- Intersection Control Evaluation (ICE)
- Innovative Intersection Implementation
- Complete Streets
- Speed Management Strategies
- Systemic Safety Improvements
- Transportation System Performance

• Intersection Control Evaluation (ICE) Policies and Procedures – Safe System approaches could offer objective analyses and performance measures (e.g., conflict types, conflict speeds, conflict severities) through which to determine applicable intersection types.

• Innovative Intersection Implementation – The geometrics of some innovative intersection designs encourage lower operating speeds at conflict points and reduce or remove severe conflicts associated with certain left-turn movements.

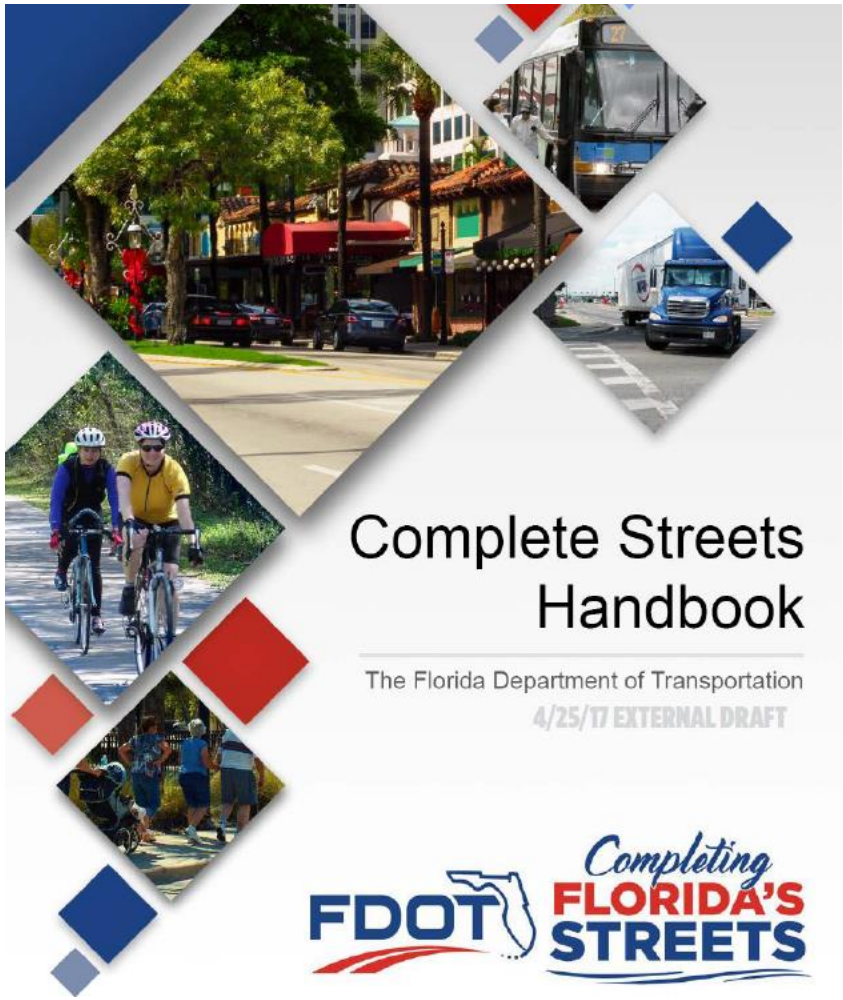
• Crosscutting Speed Management Strategies – Managing operating speeds through intersections and on intersection approaches to levels less than the maximum survivable impact speeds for conflict types that are present is a critical aspect of Safe System approaches.

• Pedestrian and Bicyclist Integration – With a focus on significantly reducing risk of fatalities or serious injuries, Safe System approaches prioritize needs of vulnerable users (pedestrians, bicyclists, motorcyclists).

# Safe System and Complete Streets

***"Complete streets are designed and operated to enable safe access for all users. Pedestrians, bicyclists, motorists and transit riders of all ages and abilities must be able to safely move along and across a complete street."***

Defined by the National Complete Streets Coalition



# Safe System Intersection Design Guidance

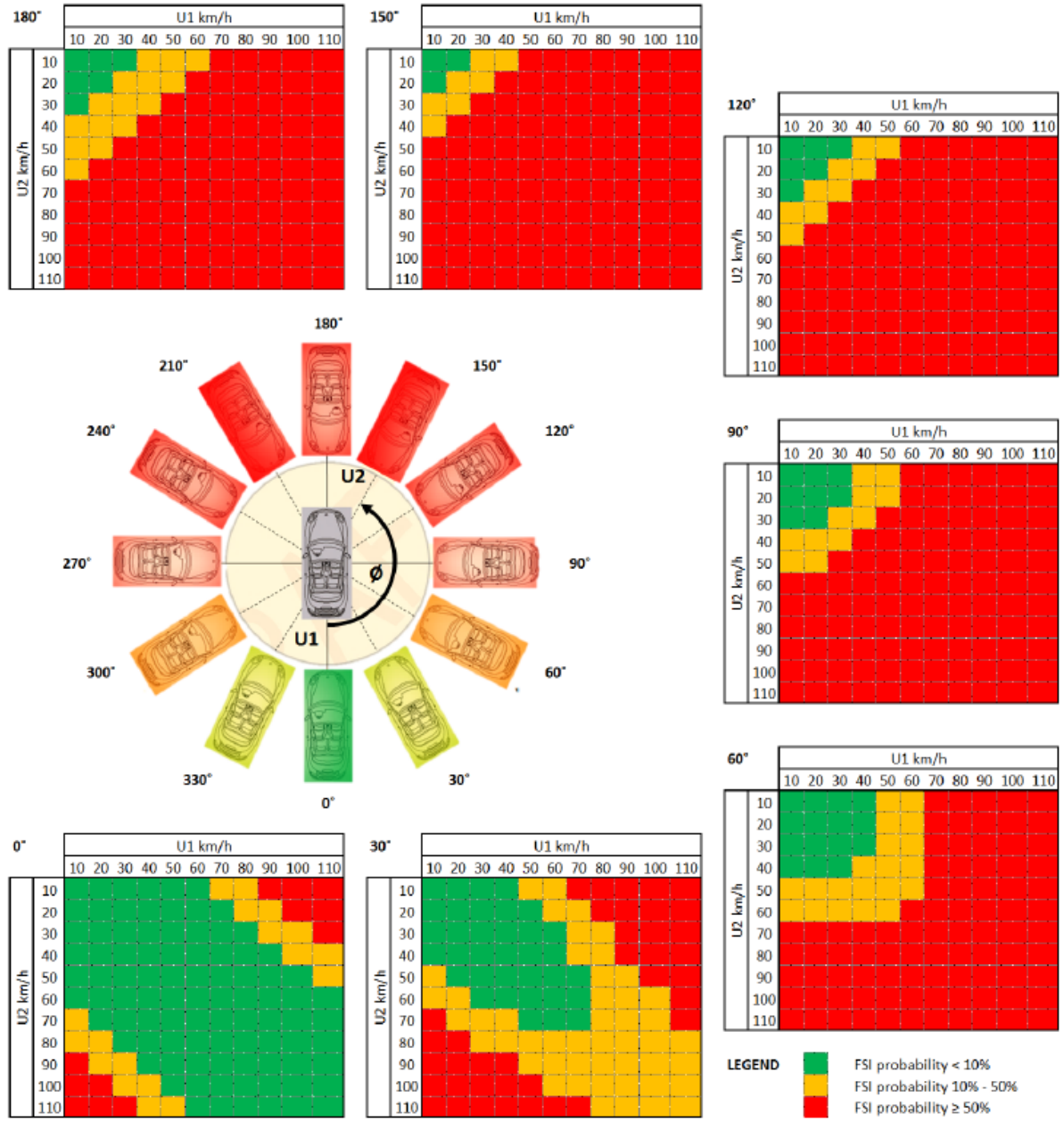
Minimize likelihood of a crash for each user (human error) by:

- Minimize the number of conflict points, e.g. ban turns or separate vertically (e.g. overpass)
- Can some road user groups be redirected to a safer facility, or separated (e.g. pedestrian overpass, a tunnel)?
- Apply strict movement control separated in time (e.g. signalized protected left-turn movements)
- Give road users more time to make decisions by reducing approach speeds
- Simplify road user decisions: provide clear and logical traffic control, route guidance, channelization and delineation

Safe System Intersection Design Guidance

If crash occurs, minimize probability of fatal and severe injury outcome (minimize kinetic energy and its transfer to road users)

- Minimize intersection approach and potential impact speeds (low speed limits, traffic calming, intersection geometry)
- Minimize impact angles
- Consider separating incompatible vehicles (mass difference, e.g. cyclists from motor vehicles)
- Redesign roadside environment to remove infrangible poles, posts and trees
- Provide for effective emergency response
- Build-in system redundancies and synergies from multiple supporting solutions to multiply the safety effect (e.g. lighting and retroreflective delineation)




Source: ARRB Group.

# *Extended Kinetic Energy Management Model for Intersections (X-KEMM-X)*

Source: Jurewicz, Chris, Amir Sobhani, Phuong Chau, Jeremy Woolley, and Colin Brodie. *Understanding and Improving Safe System Intersection Performance*. No. AP-R556-17. 2017.

# Speed and angle combinations that produce safe system compatible levels of kinetic energy

The relationship between conflict angle and travel speed (impact speed) to avoid intersection designs with a probability of death in a vehicle to vehicle collision that remains below about 10%

| Maximum impact speed (km/h) | Maximum acceptable conflict angle |
|---|---|
| 40 and below | All OK |
| 50 | 90° |
| 60 | 52°/128° (from KEMM-X) |
| 70 | 0°/180° |
| 80 and above | None feasible |

NOTE: 0° and 180° in the above table indicate a head-on and rear-end collision respectively.

Source: Candappa, N., Logan, D., Van Nes, N. and Corben, B., 2015. An exploration of alternative intersection designs in the context of Safe System. *Accident Analysis & Prevention*, *74*, pp.314-323.

# A Safe Systems Approach to Intersection Planning & Design in the United States

The SSI framework will provide a technical basis by which practitioners can apply Safe Systems principles to inform intersection planning and design decisions.

U.S. Department of Transportation

Federal Highway Administration

vhb®

THE UNIVERSITY OF NORTH CAROLINA HIGHWAY SAFETY RESEARCH CENTER

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# Preliminary Framework for the SSI Methodology

- Encompasses following elements
  - Combinations of intersection geometric characteristics and controls.
  - Exposure and conflict frequency (considering temporal variations in volumes).
  - Speed and conflict severity.
  - Modal and user vulnerability (considering higher-risk or non-motorized users).
  - Critical thresholds of collision kinetic energy (considering collision angles/types).
  - Other intersection collision risk factors.

Methodology Currently in Development
Scheduled Completion December 2019

| Type of Collision | Maximum Survivable Impact Speeds |
|---|---|
| Car/car (side impact) | 50 km/hr |
| Car/car (head-on) | 70 km/hr |
| Car/tree or pole | 40 km/hr |
| Car/pedestrian | 30 km/hr |
| Car/motorcyclist | 30 km/hr |
| Source: Australian National Road Safety Strategy (2011-2020) | |

# Produce SSI Methodology Resources

- Informational Guide and Tech Brief
- Current thinking on “guiding principles” of Guide
  - Augments and supports design policy
  - Ties to ICE policies/procedures
  - Aids in application of SSI method, while recognizing that other performance assessments will occur
  - Ties to project planning and geometric design decisions
  - Discloses relevant SSI method development background and limitations
  - Uses examples/case studies/graphics

Informational Guide and Webinars
Summer 2020

# QUESTIONS

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