THE SAFE SYSTEM APPROACH: WHAT IS IT AND WHY IS IT GETTING SO MUCH ATTENTION?

March 28, 2022

THE SAFE SYSTEM APPROACH

Zero is our goal. A Safe System is how we get there.

U.S.Department of Transportation
Federal Highway Administration

Mark Doctor, P.E.
Senior Safety & Design Engineer / Team Leader
Federal Highway Administration Resource Center
Phone: (404) 895-6210
mark.doctor@dot.gov

ZERO IS OUR GOAL
A SAFE SYSTEM IS HOW WE GET THERE

1

THE SAFE SYSTEM APPROACH

What is it?

Who is involved?

Why is it different?

How can my agency/organization contribute to implement a Safe System?

2

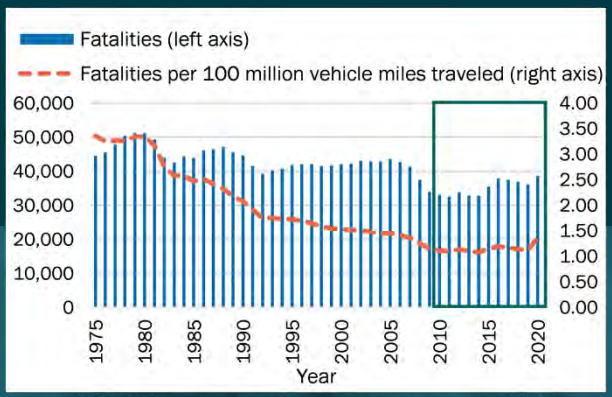
TOP 3 TAKEAWAYS

- The Safe System Approach is “Principles Based”
- Achieving a Safe System requires all five elements to be strengthened
- Safe Roads is a continuum, not an absolute

3

We have a National Roadway Safety Problem

Roadway fatalities and the fatality rate was on the decline for 30 years…



…but progress has stalled over the last decade…

Source: Fatality Analysis Reporting System

4

4

We have a National Roadway Safety Problem

Oregon Transportation Fatalities (2000-2018)

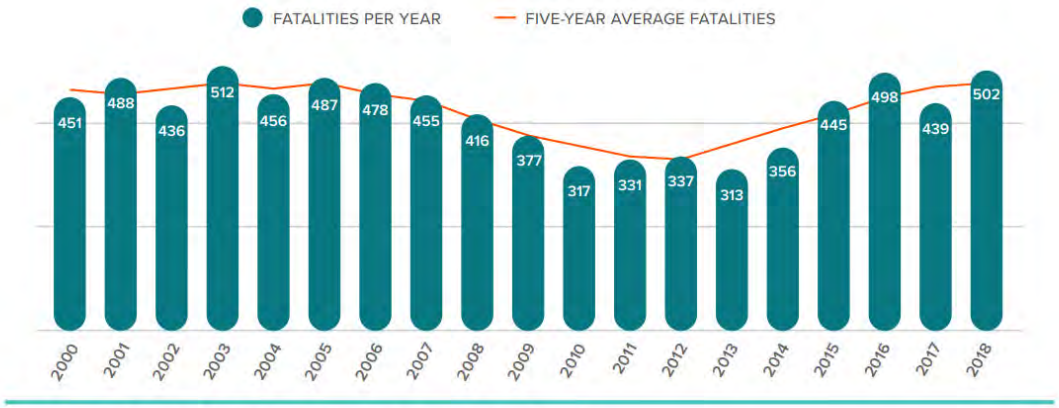
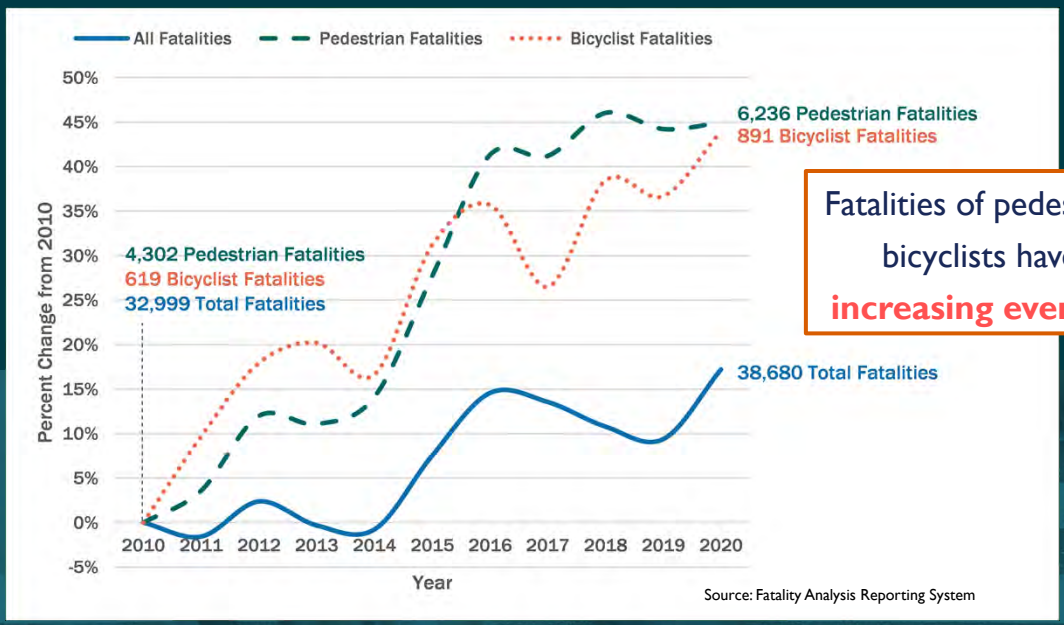


FIGURE ES.1 OREGON TRANSPORTATION FATALITIES (2000-2018)

5

We have a National Roadway Safety Problem



Fatalities of pedestrians and bicyclists have been **increasing even greater**

6

6

U.S. Department of Transportation

National Roadway Safety Strategy

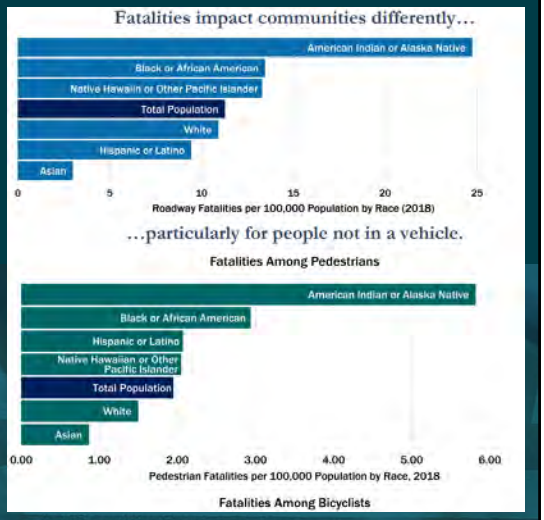
United States Department of Transportation | January 2022

Opportunities to Simultaneously Address Safety, Equity, and Climate

Safety is and will always be the Department's top priority. Roadway safety is also a foundational pre-requisite to our success in addressing two other major priorities: equity and climate.

"The Department will advance equity as an instrumental component of transportation safety and convene key stakeholders – government at all levels, law enforcement, advocacy, community organizations, and the general public – to develop both a better understanding of the intersection of equity and roadway safety, and a comprehensive approach to incorporating equity into all of the Department's efforts to achieve zero roadway fatalities and serious injuries."

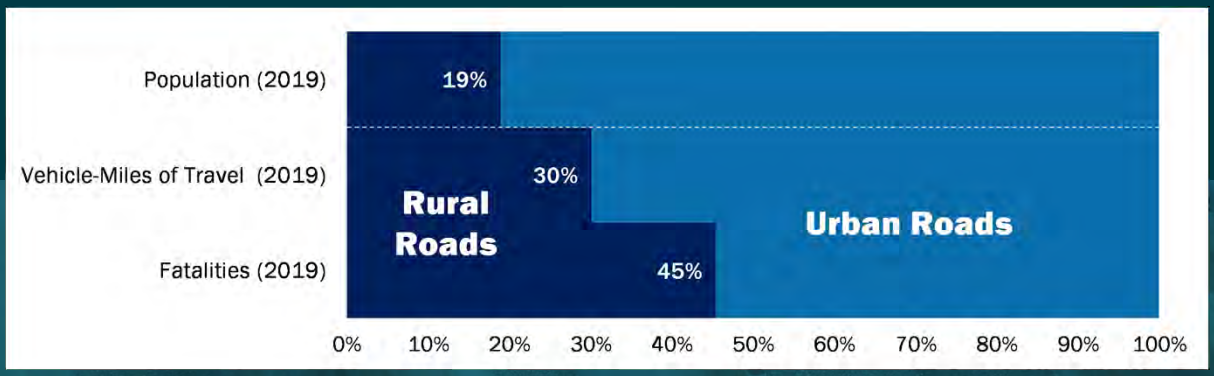
https://www.transportation.gov/sites/dot.gov/files/2022-02/USDOT-National-Roadway-Safety-Strategy.pdf



7

We have a National Roadway Safety Problem

Rural Roads: Fatalities and fatal crashes occur disproportionately - by both population and vehicle travel.



8

Why are people killed and seriously injured on the roads?

IMPAIRED DRIVING

SPEEDING AND AGGRESSIVE DRIVING

DISTRACTED DRIVING

OCCUPANT PROTECTION

PEDESTRIANS AND BICYCLISTS

MOTORCYCLISTS AND MOTOR SCOOTER RIDERS

COMMERCIAL MOTOR VEHICLE OPERATORS

TEEN DRIVERS

AGING ROAD USERS

People are killed and seriously injured on the roads when the collision forces transferred onto the human body exceed tolerable thresholds.

9

PARADIGM SHIFT

NEW PARADIGM AHEAD

" In road injury epidemiology, kinetic energy is the pathogen "

Robertson LS. *Injury epidemiology*. Oxford: Oxford University Press, 1992

10

WHAT IS THE SAFE SYSTEM APPROACH?

A different way of thinking about the road safety problem …

Accommodating human mistakes

Keeping impacts on the human body at tolerable levels

11

SUCCESSFUL SAFE SYSTEM ADOPTERS




Sweden	Netherlands	Australia	New Zealand
Vision Zero	Sustainable Safety	Safe System	Safer Journeys
60-70% Reduction in fatalities 1994-2015	**50-60%** Reduction in fatalities 1994-2015	**50-60%** Reduction in fatalities 1994-2015	**50-60%** Reduction in fatalities 1994-2015

Source: World Resources Institute

12

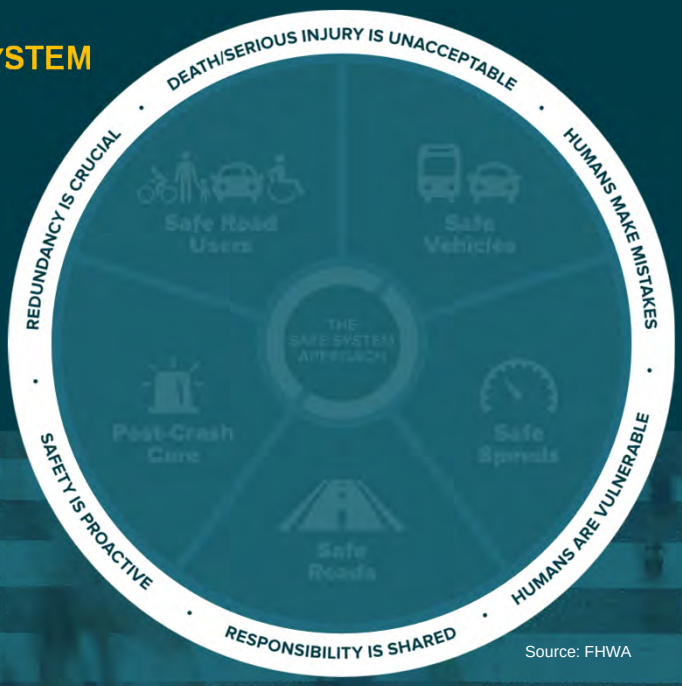
THE SAFE SYSTEM APPROACH

Source: FHWA

13

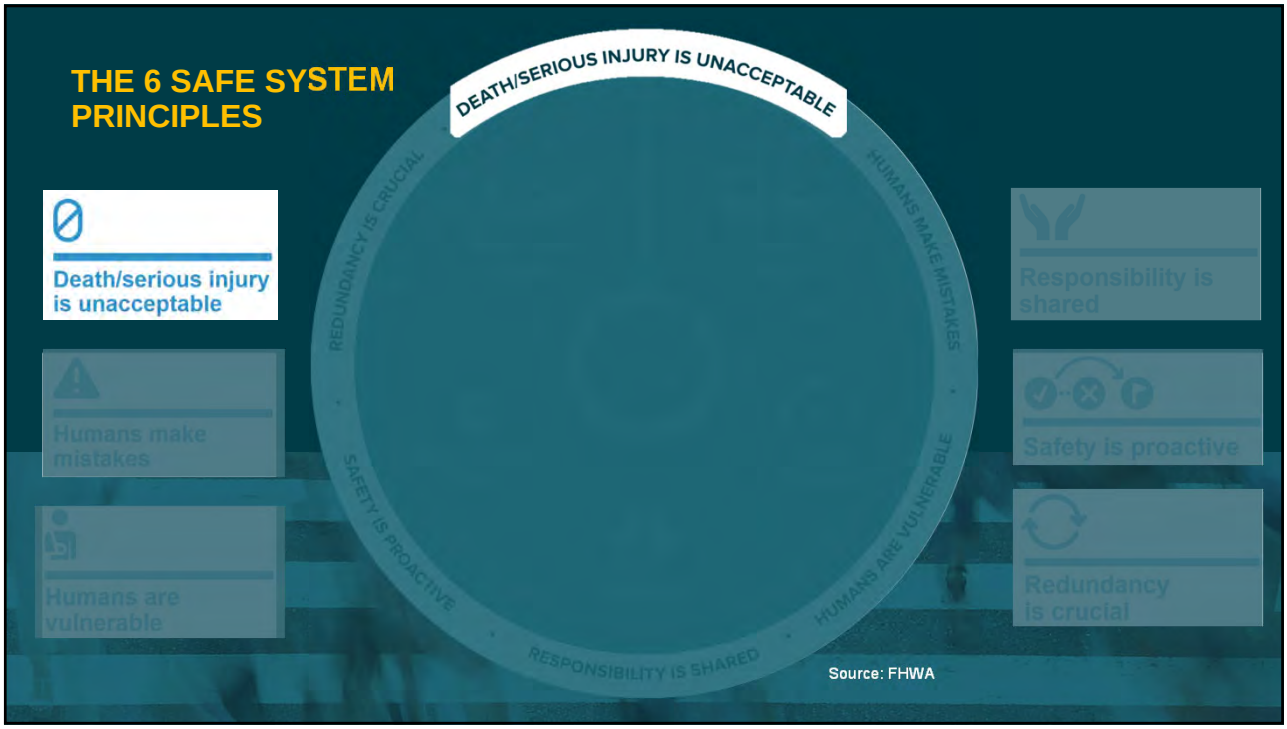
THE 6 SAFE SYSTEM PRINCIPLES

- Death/serious injury is unacceptable
- Humans make mistakes
- Humans are vulnerable
- Responsibility is shared
- Safety is proactive
- Redundancy is crucial

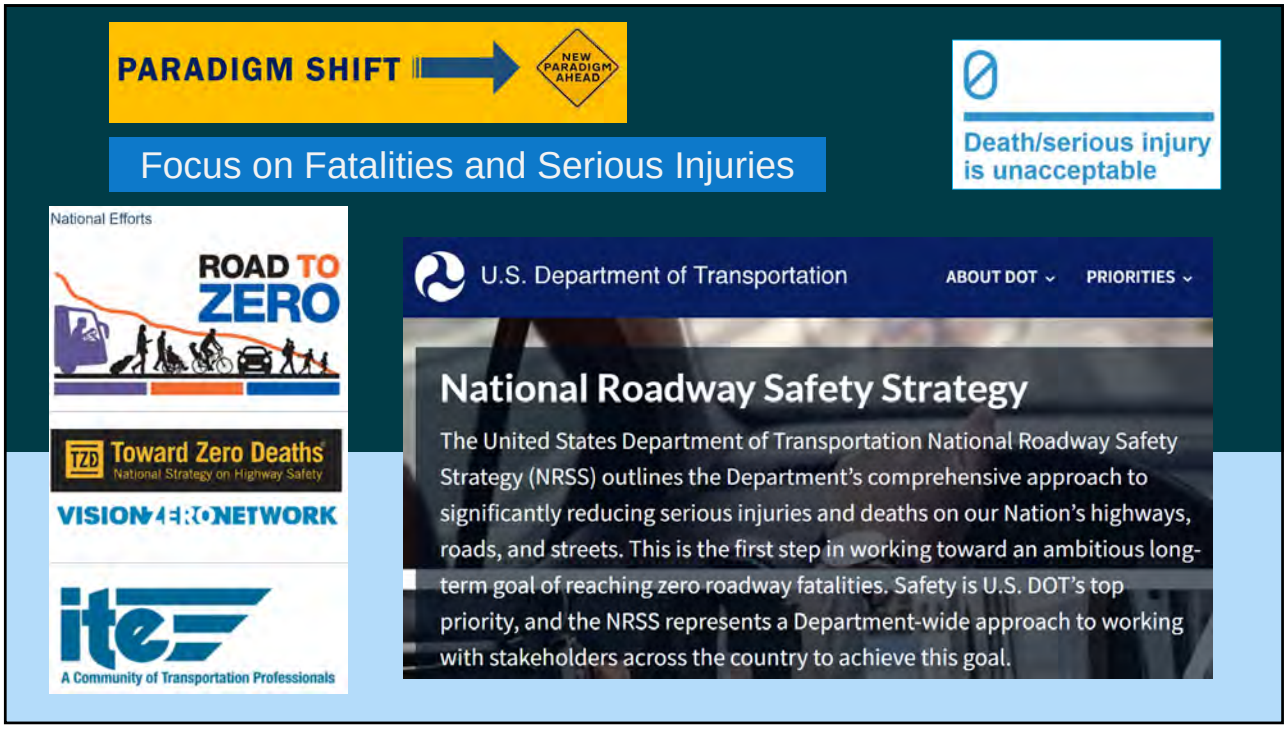


Source: FHWA

14


THE 6 SAFE SYSTEM PRINCIPLES
DEATH/SERIOUS INJURY IS UNACCEPTABLE
HUMANS MAKE MISTAKES
HUMANS ARE VULNERABLE
RESPONSIBILITY IS SHARED
SAFETY IS PROACTIVE
REDUNDANCY IS CRUCIAL
Death/serious injury is unacceptable
Humans make mistakes
Humans are vulnerable
Responsibility is shared
Safety is proactive
Redundancy is crucial
Source: FHWA

15


PARADIGM SHIFT
NEW PARADIGM AHEAD
Focus on Fatalities and Serious Injuries
Death/serious injury is unacceptable
National Efforts
ROAD TO ZERO
Toward Zero Deaths
National Strategy on Highway Safety
VISION ZERO NETWORK
ite
A Community of Transportation Professionals
U.S. Department of Transportation
ABOUT DOT
PRIORITIES
National Roadway Safety Strategy
The United States Department of Transportation National Roadway Safety Strategy (NRSS) outlines the Department's comprehensive approach to significantly reducing serious injuries and deaths on our Nation's highways, roads, and streets. This is the first step in working toward an ambitious long-term goal of reaching zero roadway fatalities. Safety is U.S. DOT's top priority, and the NRSS represents a Department-wide approach to working with stakeholders across the country to achieve this goal.

16

What would you do?

PARADIGM SHIFT

If you had the opportunity to implement a feature that would reduce the number of fatalities and serious injuries by 50%,but would double the total number of minor crashes …

Number of minor crashes: UP 2X

Number of fatal and severe crashes: DOWN 50%

Would you do it? Yes or No

17

Would you trade 540 minor crashes for 1 Fatal Crash?

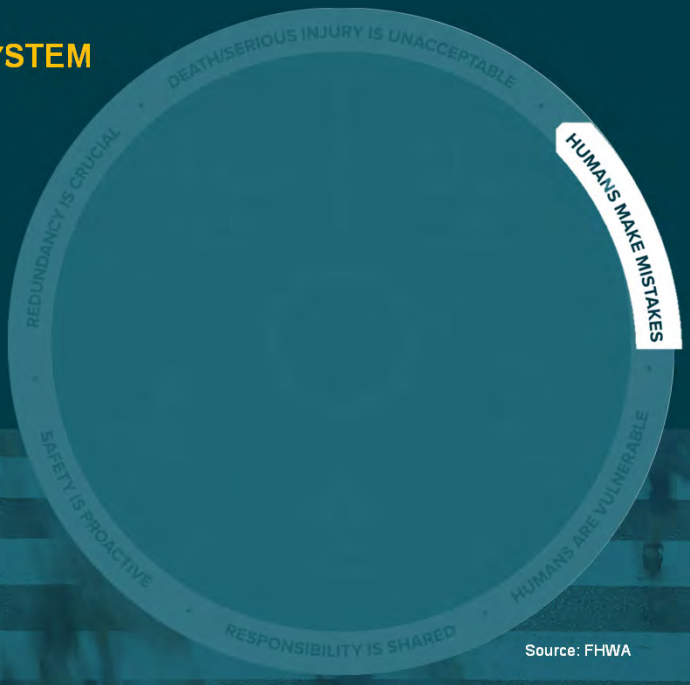
Table 4-7. Societal Crash Cost Assumptions

Severity	Comprehensive Crash Cost (2001 Dollars)
Fatal (K)	$4,008,900
Injury Crashes (A/B/C)	$82,600
PDO (O)	$7,400

Source: *Crash Cost Estimates by Maximum Police-Reported Injury Severity within Selected Crash Geometries*, FHWA-HRT-05-051, October 2005

18

THE 6 SAFE SYSTEM PRINCIPLES



Death/serious injury is unacceptable

Humans make mistakes

Humans are vulnerable

Responsibility is shared

Safety is proactive

Redundancy is crucial

Source: FHWA

19

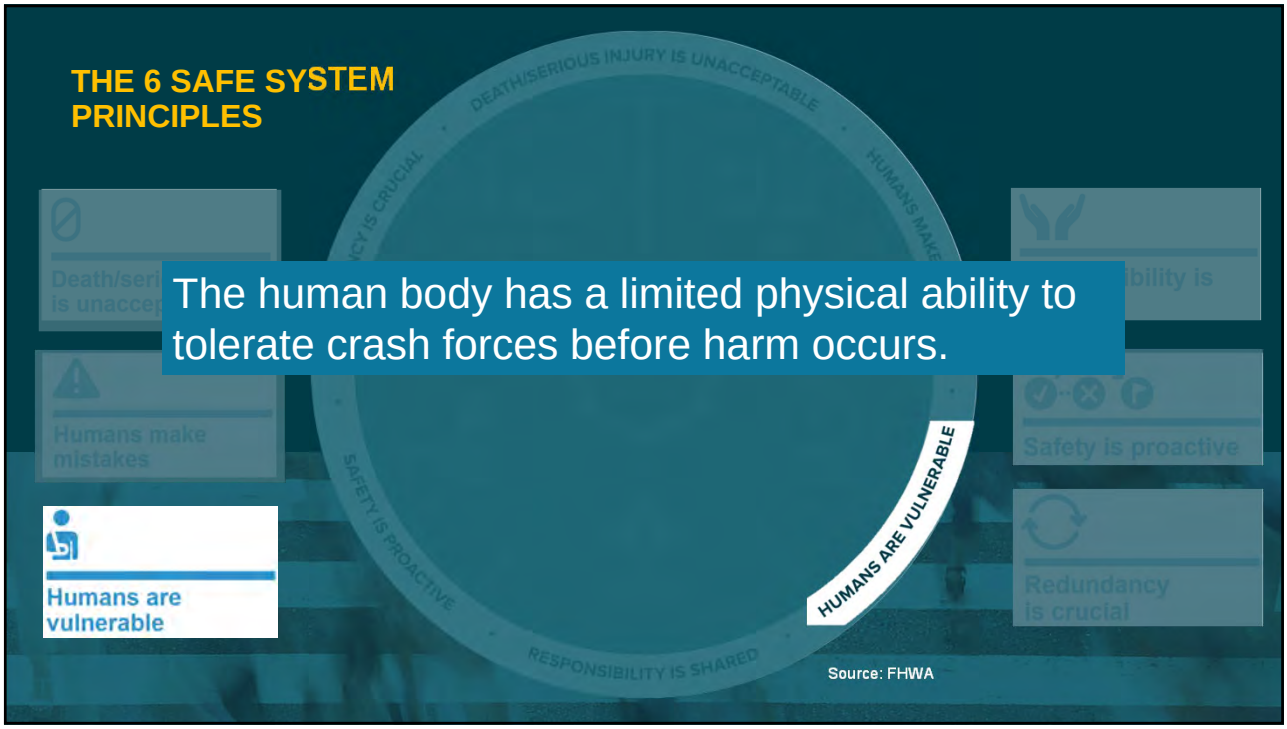
PARADIGM SHIFT

NEW PARADIGM AHEAD

Humans make mistakes

As road users, people will inevitably make mistakes and those mistakes may lead to crashes

In a Safe System approach, owners and operators of the system strive to make it easy for humans to *not* make mistakes by designing roads and vehicles to be in tune with human competences.


THE 6 SAFE SYSTEM PRINCIPLES
The human body has a limited physical ability to tolerate crash forces before harm occurs.
Humans are vulnerable
Humans make mistakes
Safety is proactive
Redundancy is crucial
HUMANS ARE VULNERABLE
Source: FHWA

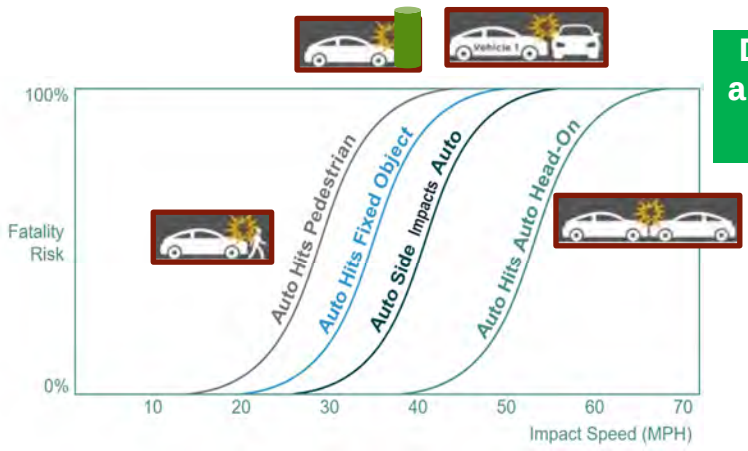
21


Under the Safe System approach, the roadway operating conditions are managed to prevent those large forces.
Humans are vulnerable
Image: https://www.ocregister.com/2015/05/15/wheeler-dealer-bumper-cars/

22

HUMANS ARE VULNERABLE

Humans are vulnerable



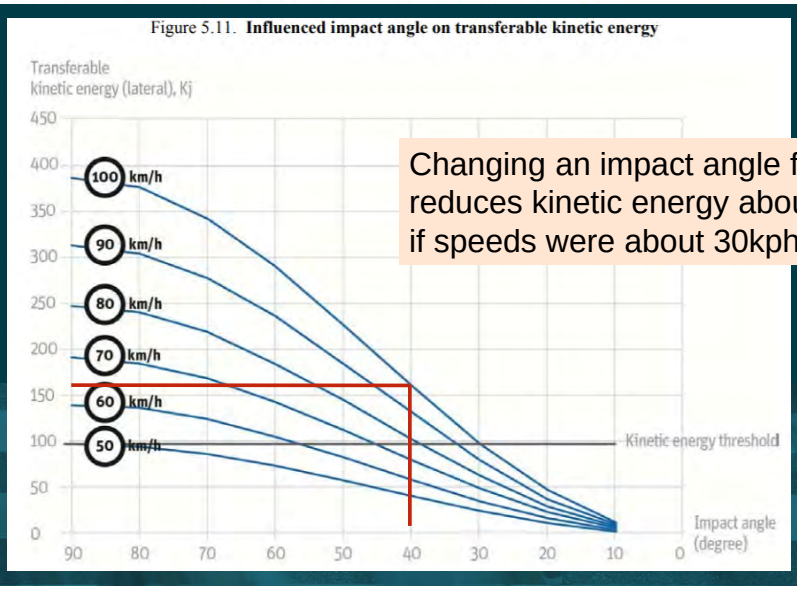
Designing safer roads is an exercise of managing kinetic energy

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

Velocity is a vector
- Speed
- Direction (angle of impact)

Source: FHWA

Transferable Kinetic Energy (Lateral) vs Impact Angle and Travel Speed



Changing an impact angle from 90° to 40° reduces kinetic energy about the same as if speeds were about 30kph (20 mph) less

Source: Zero Road Deaths and Serious Injuries, Leading a Paradigm Shift to a Safe System, ITF, 2016
https://www.itf-oecd.org/sites/default/files/docs/zero-road-deaths.pdf

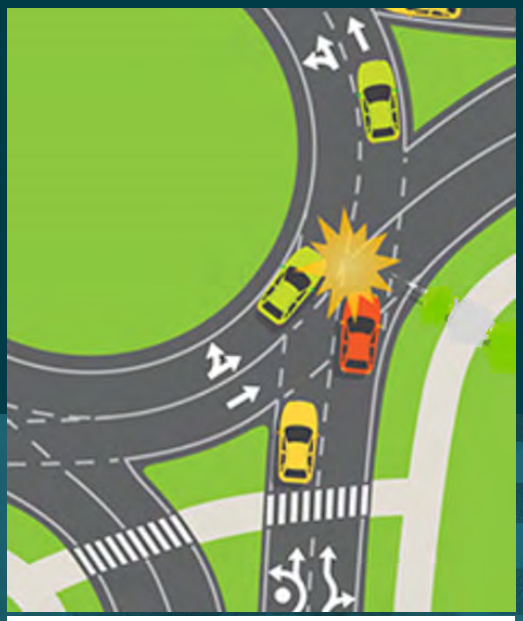


Image derived from: https://dublinohiousa.gov/roundabouts

Example: Roundabouts vs Signalized Intersections

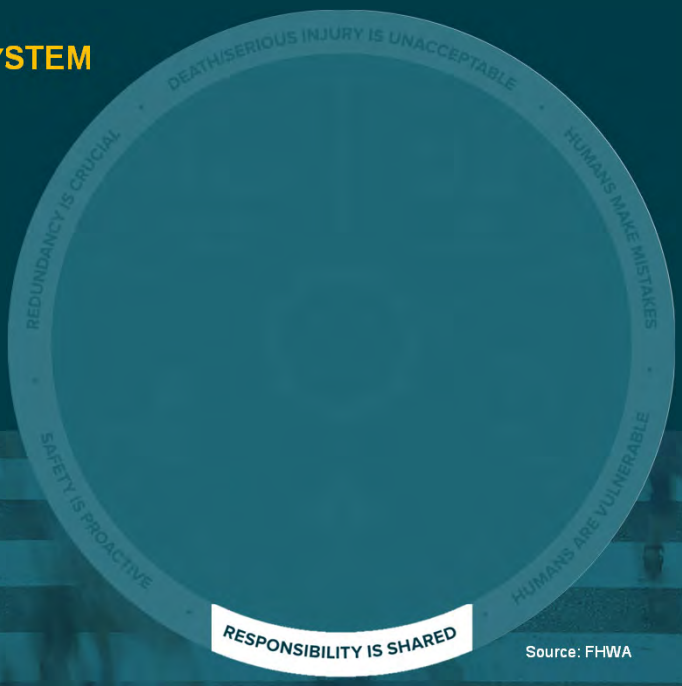
		
Lower Speeds	✓	
Lower Impact Angles	✓	
Fewer Conflict Points	✓	

Is this why roundabouts are so effective at reducing severe crashes?

YES !!!

25

THE 6 SAFE SYSTEM PRINCIPLES



Death/serious injury is unacceptable

Humans make mistakes

Humans are vulnerable

Responsibility is shared

Safety is proactive

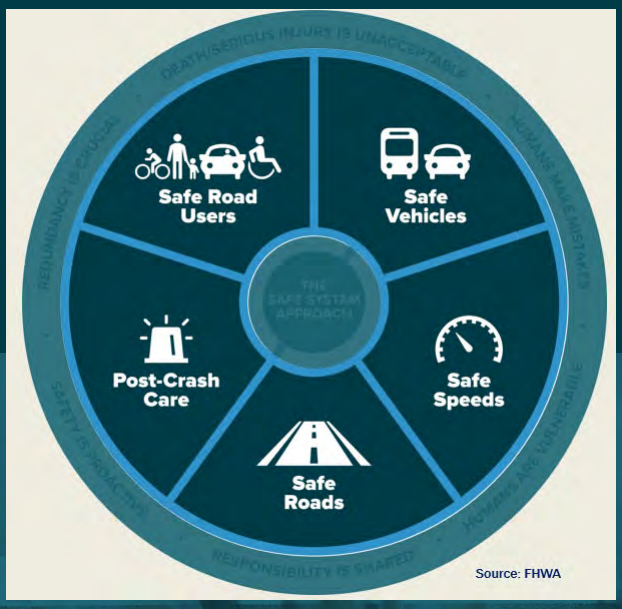
Redundancy is crucial

Source: FHWA

26

26

Five Safe System Elements



Responsibility is shared

Implementing the Safe System approach is a shared responsibility

It cannot be achieved by engineering alone

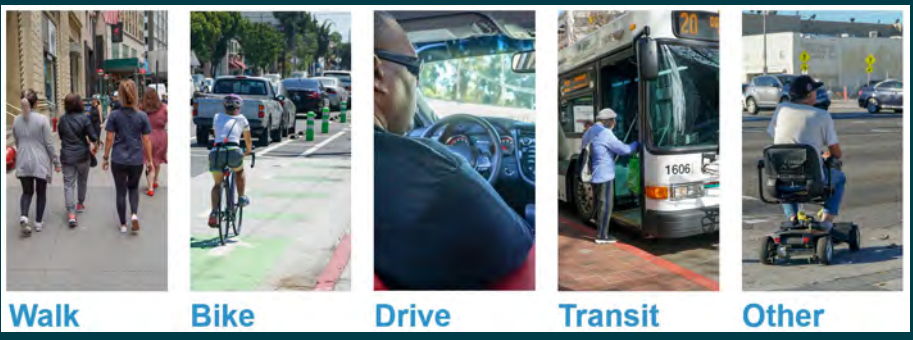
27

THE 5 SAFE SYSTEM ELEMENTS

Source: FHWA

28

Safe Road Users



Source for all images: Fehr & Peers

Not distracted or impaired

Follow rules

Act within the limits of the road design

29

GHSA Governors Highway Safety Association
The States' Voice on Highway Safety

https://www.ghsa.org/resources/GHSA/Safe-System-Report21

Describes the integral role of behavioral safety and road user responsibility in the Safe System approach with actionable recommendations illustrating how organizations and advocates can work together to prevent roadway deaths.

30

THE 5 SAFE SYSTEM ELEMENTS

Source: FHWA

31

Safe Vehicles

Active Safety	Passive Safety
Reduces the chance of a crash occurring	Protective systems for when crashes occur
• Lane departure warnings • Lane keeping assist • Forward collision warnings • Autonomous emergency braking • Pedestrian detection • Backup camera • Antilock brakes • Electronic stability control	• Seatbelts • Airbags • Crumple zones • Collapsible steering column

Leveraging connected and automated vehicle (CAV) technology to improve safety

32

THE 5 SAFE SYSTEM ELEMENTS

Source: FHWA

33

33

SAFE SPEEDS

Safe Speeds

Source: FHWA

Some roads are engineered to accommodate higher speeds …

Source: FHWA

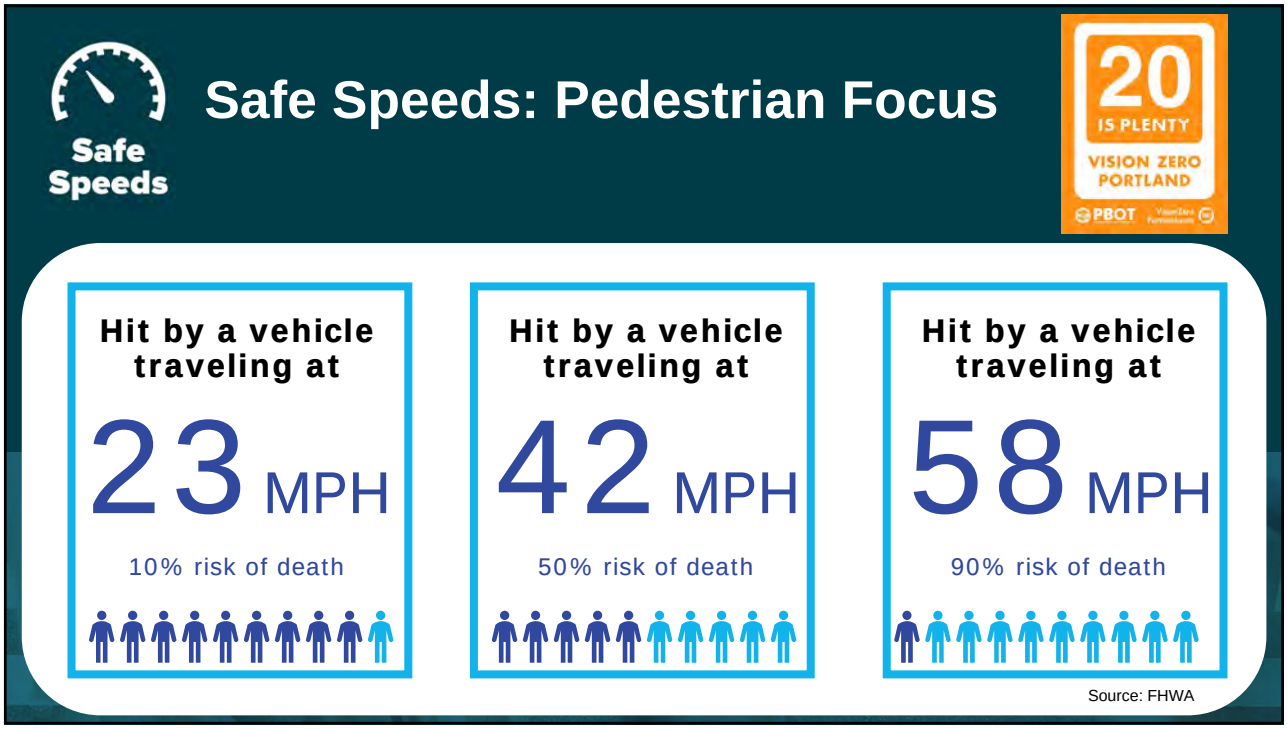
Source: FHWA

… and others not.

The Safe System approach is not about universally reducing speeds. It's about matching speed appropriate to the road conditions that exist.

34

34


Safe Speeds
Safe Speeds: Pedestrian Focus
20 IS PLENTY
VISION ZERO PORTLAND
PBOT
Hit by a vehicle traveling at
23 MPH
10% risk of death
Hit by a vehicle traveling at
42 MPH
50% risk of death
Hit by a vehicle traveling at
58 MPH
90% risk of death
Source: FHWA

35


THE 5 SAFE SYSTEM ELEMENTS
DEATH/SERIOUS INJURY IS UNACCEPTABLE
HUMANS MAKE MISTAKES
HUMANS ARE VULNERABLE
RESPONSIBILITY IS SHARED
SAFETY IS PROACTIVE
REDUNDANCY IS CRUCIAL
Safe Road Users
Safe Vehicles
Post-Crash Care
Safe Speeds
Safe Roads
THE SAFE SYSTEM APPROACH
Source: FHWA

36

Thoughts on the Safe Roads Element

Safe Roads

Think of “Safe Roads” as a continuum – not an absolute

- The aim is to design and operate roads to continuously approach toward creating a Safe System by implementing features appropriate for the intended and actual road use and speed environment
  - Reduce the likelihood of error
  - Reduce the consequences of error

https://safety.fhwa.dot.gov/provencountermeasures/pdf/FHWA-SA-21-071_PSC%20Booklet.pdf

·Grxedn0Grzq¶#rq#zkdw#zrunv#

Safe Roads

Transportation agencies are strongly encouraged to consider widespread implementation of PSCs to accelerate the achievement of local, State, and National safety goals.

Prevention through Design (PtD)

Hierarchy of Control

Eliminate
Physically remove the hazard

Substitute
Replace the hazard with option that lowers severity

Engineering Controls
Operate the system to reduce exposure

Administrative Controls
Education, legislation & policies to change behavior

Personal Protective Equipment
PPE, protective gear

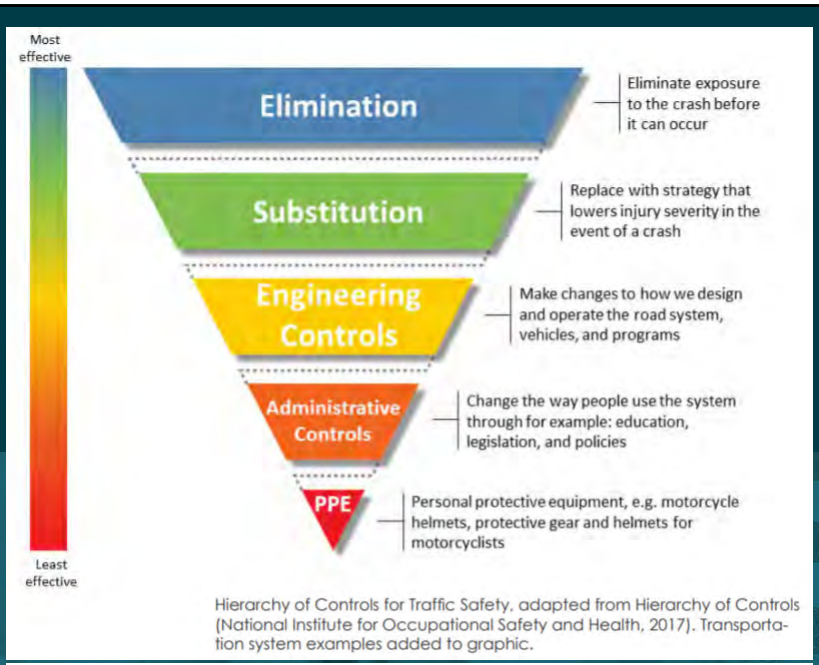
Adapted from National Institute for Occupational Safety and Health - https://www.cdc.gov/niosh/topics/hierarchy/default.html

Prevention through Design

Initiative led by the National Institute for Occupational Safety and Health (NIOSH) to prevent or reduce occupational injuries, illnesses, and fatalities through efforts that anticipate and "design out" hazards to workers.

Hierarchy of controls is a PtD strategy.
https://www.cdc.gov/niosh/topics/ptd/

39



Hierarchy of Controls for Traffic Safety, adapted from Hierarchy of Controls (National Institute for Occupational Safety and Health, 2017). Transportation system examples added to graphic.

http://targetzero.com/wp-content/uploads/2020/03/TargetZero2019_Lo-Res.pdf

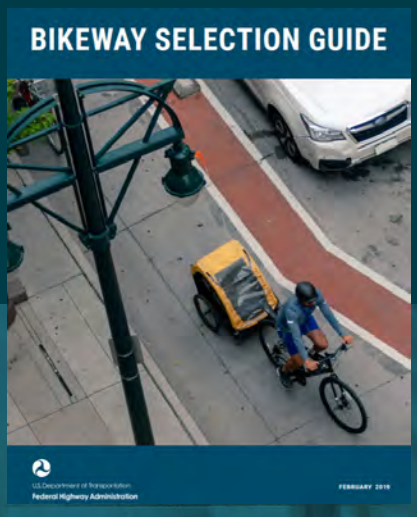
Washington State Strategic Highway Safety Plan:

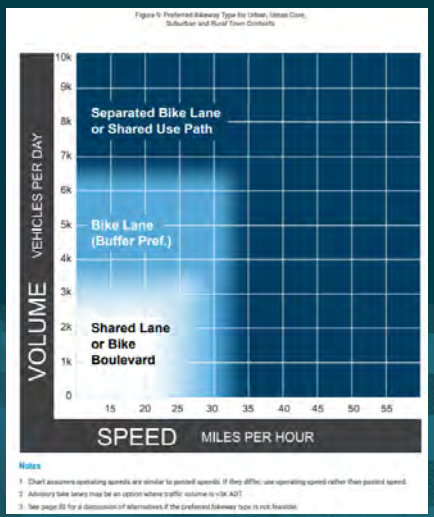
Target Zero 2019

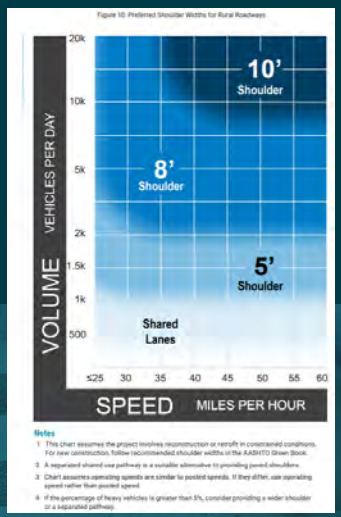
40

41

Separating Users in Space

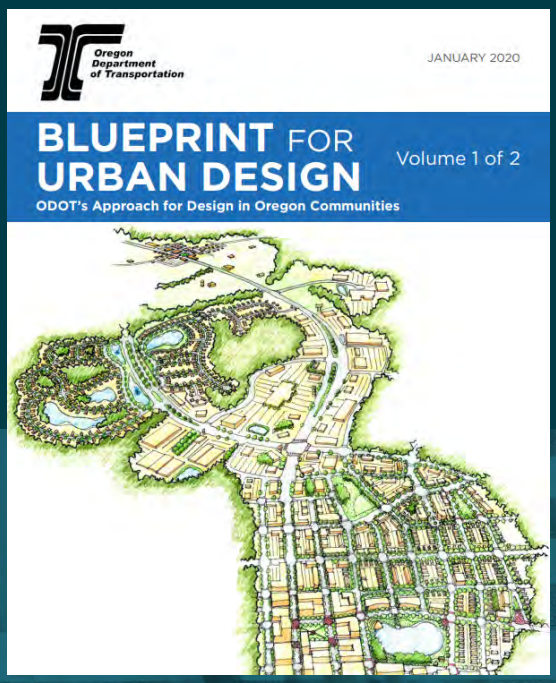


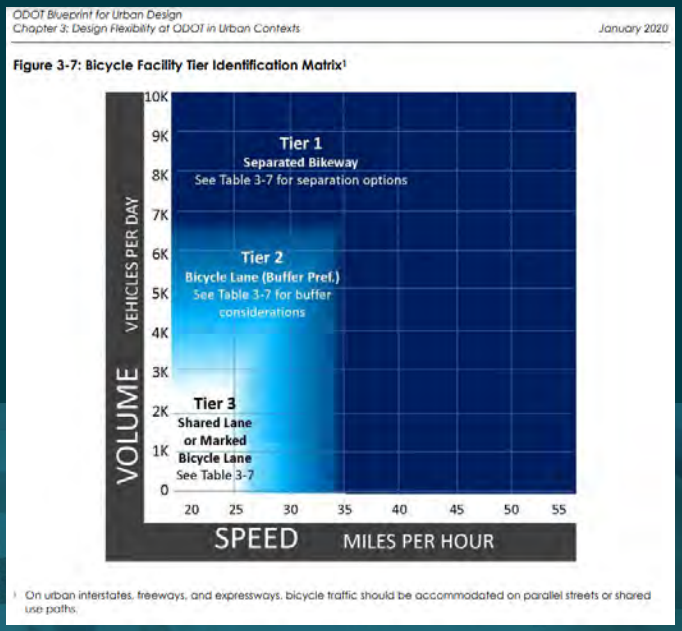




https://safety.fhwa.dot.gov/ped_bike/tools_solve/docs/fhwasa18077.pdf

42





43

Table 14. Recommended Countermeasure Tiers Depending on Traffic Context

Roadway Type (Number of Travel Lanes and Median Type)	Vehicle ADT < 9,000			Vehicle ADT 9,000–12,000			Vehicle ADT 12,000–15,000			Vehicle ADT ≥ 15,000		
	Speed Limit (mph)											
	≤30	35	≥40*	≤30	35	≥40*	≤30	35	≥40*	≤30	35	≥40*
2 Lanes	1	1	2	1	1	2	1	1	3	1	2	3
3 Lanes	1	1	2	1	2	2	2	3	3	2	3	3
4 Lanes with raised median**	1	1	2	1	2	2	2	3	3	3	3	3
4+ Lanes without raised median	1	2	3	2	2	3	3	3	3	3	3	3

Legend:

1 ***Tier 1:*** Traffic context generally supports motorist yielding; countermeasures are generally less expensive and require less process than other two tiers to implement

2 ***Tier 2:*** Traffic context generally requires intervention to induce motorist yielding; countermeasures are generally less expensive and require less process than Tier 3 to implement

3 ***Tier 3:*** Traffic context generally requires intervention to require motorist to stop or to physically separate pedestrians and bicyclists from traffic; often the most expensive and may require extensive public process

* Where the speed limit exceeds 40 mph, Tier 3 should be considered.

** Raised medians must be at least 6 feet wide to serve pedestrians. See the AASHTO *Bicycle Guide* for lengths to serve bicyclists. Where median width is less than these values, review category of 4+ lanes without raised median.

Table adapted from AASHTO *Bicycle Guide* and the FHWA *STEP Guide*

Source: Guidance to Improve Pedestrian and Bicyclist Safety at Intersections (2020); National Cooperative Highway Research Program (NCHRP) Report 926 - http://www.trb.org/Main/Blurbs/180624.aspx

44

Separating Users in Time

Pedestrian Hybrid Beacons

Leading Pedestrian Interval

All Images
Source: FHWA

45

Increasing Users Attentiveness & Awareness

ROADWAY DEPARTURE

- Wider Edge Lines
- Longitudinal Rumble Strips and Stripes on Two-Lane Roads
- Enhanced Delineation for Horizontal Curves

INTERSECTIONS

- Backplates with Retroreflective Borders
- Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections

PEDESTRIANS/BICYCLES

- Rectangular Rapid Flashing Beacons (RRFB)
- Crosswalk Visibility Enhancements

CROSSCUTTING

- Lighting

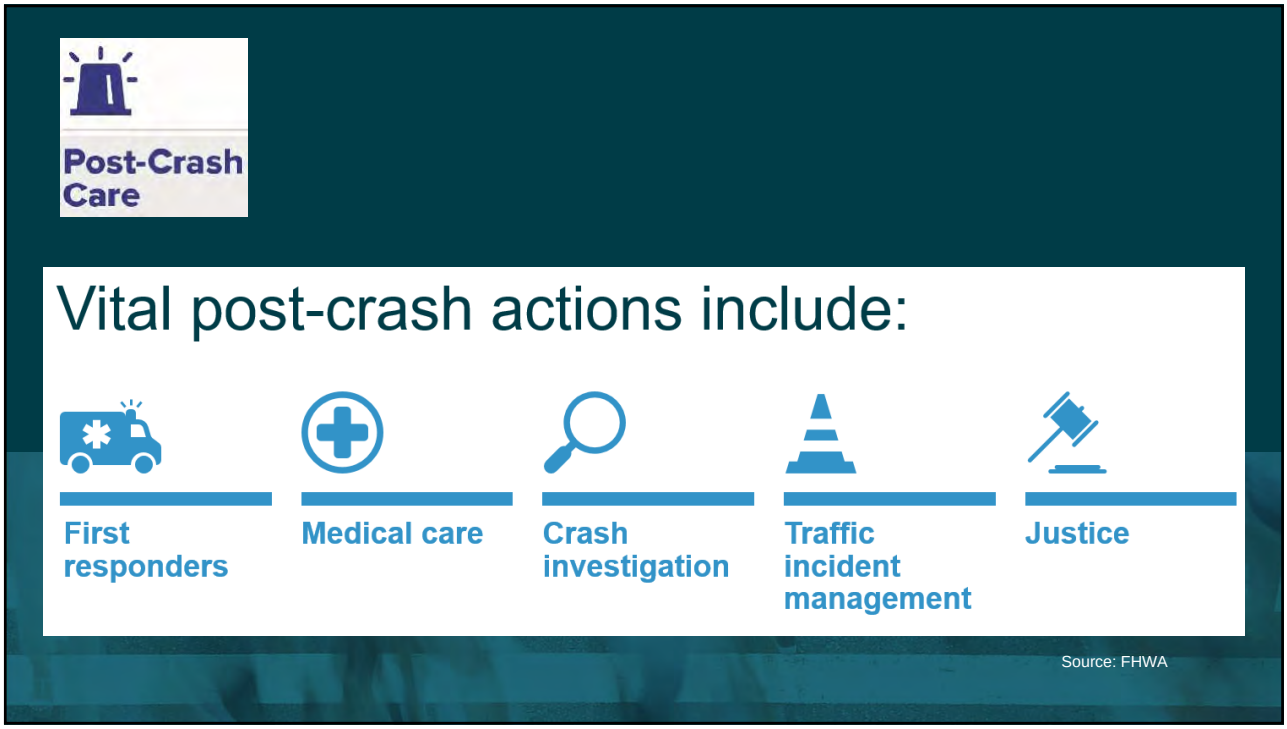
46


TURNING VEHICLES
TO
SEPARATE
SLOW
INCREASE AWARENESS

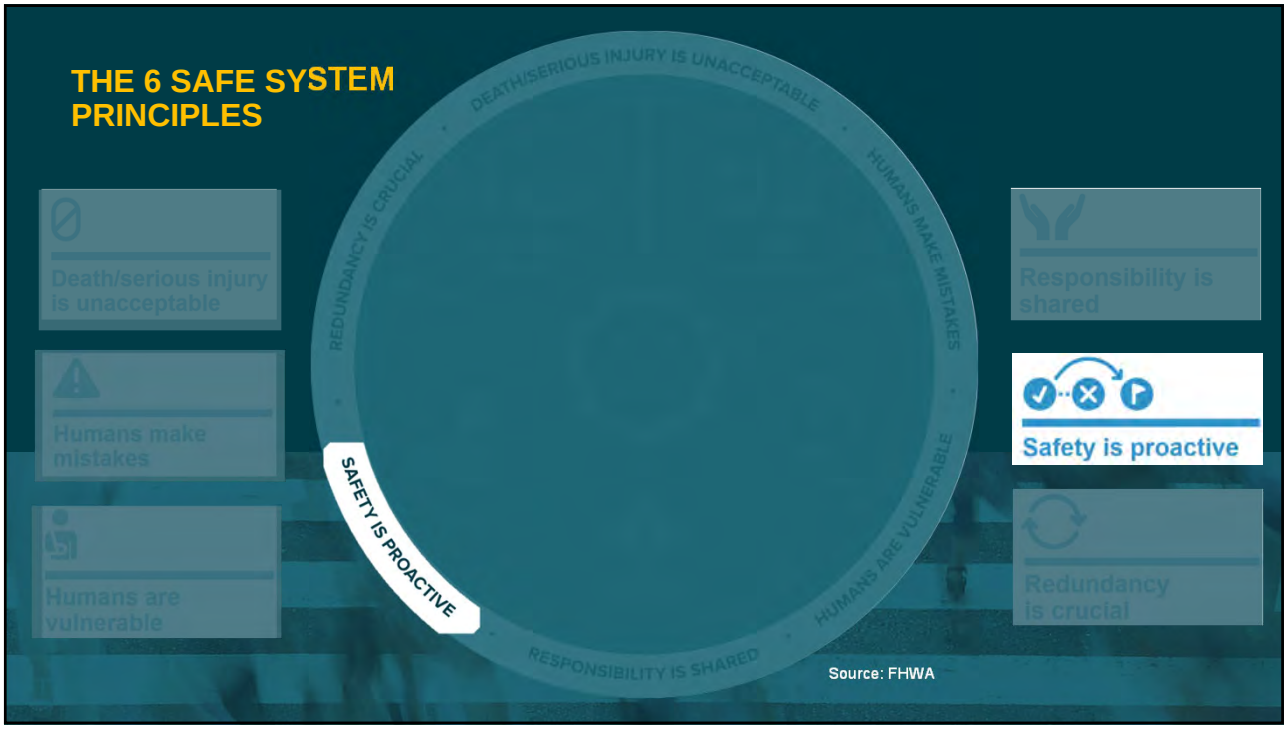
47


THE 5 SAFE SYSTEM ELEMENTS
DEATH/SERIOUS INJURY IS UNACCEPTABLE
HUMANS MAKE MISTAKES
HUMANS ARE VULNERABLE
RESPONSIBILITY IS SHARED
SAFETY IS PROACTIVE
REDUNDANCY IS CRUCIAL
Safe Road Users
Safe Vehicles
Safe Speeds
Safe Roads
Post-Crash Care
THE SAFE SYSTEM APPROACH
Source: FHWA

48


Post-Crash Care
Vital post-crash actions include:
First responders
Medical care
Crash investigation
Traffic incident management
Justice
Source: FHWA

49


THE 6 SAFE SYSTEM PRINCIPLES
Death/serious injury is unacceptable
Humans make mistakes
Humans are vulnerable
Responsibility is shared
Safety is proactive
Redundancy is crucial
DEATH/SERIOUS INJURY IS UNACCEPTABLE
HUMANS MAKE MISTAKES
HUMANS ARE VULNERABLE
RESPONSIBILITY IS SHARED
SAFETY IS PROACTIVE
REDUNDANCY IS CRUCIAL
Source: FHWA

50

Safety is proactive

Systemic Approach - using data and roadway characteristics to identify patterns of risk and proactively implementing targeted safety measures at locations with those risk characteristics (irrespective of past collision history).

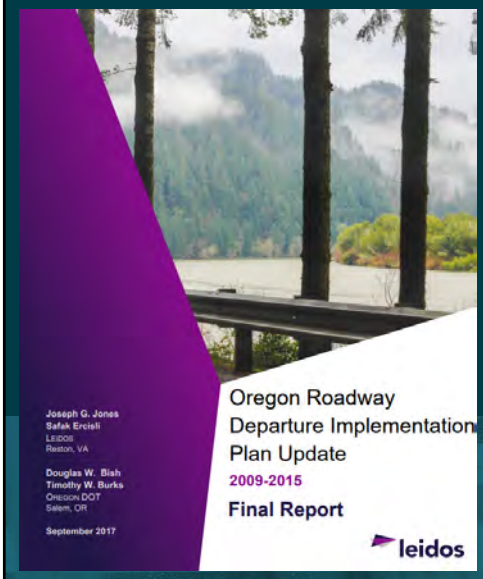
51

Systemic Approach

Safety is proactive

https://safety.fhwa.dot.gov/systemic/

52



APPROACH

To help reduce statewide RwD fatalities, this plan recommends the following to complement the traditional approach of improving safety at specific high-crash locations:

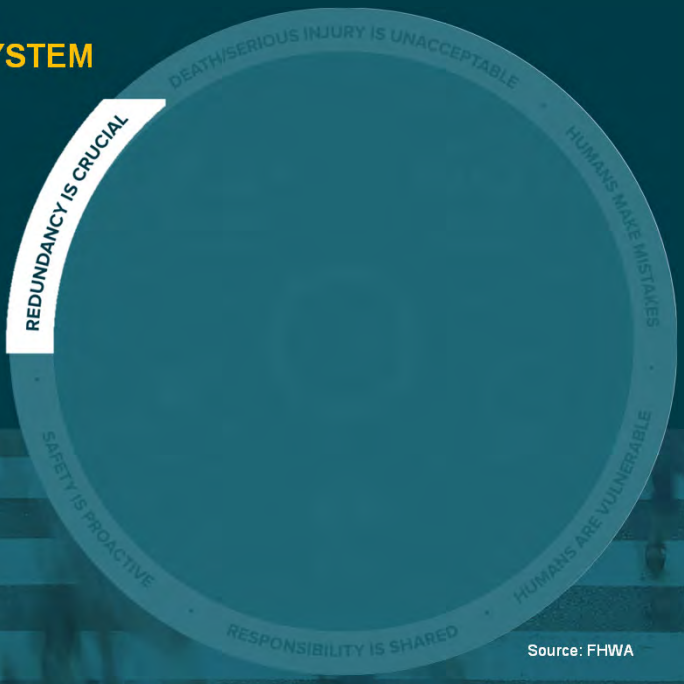
- Systemic application of low-cost countermeasures at locations that have a moderate or high number of RwD crashes above a specified crash frequency by subtype. This approach is based on FHWA's Strategic Approach to RwD Safety, which will be described in greater depth on page 10 in this report.
- Comprehensive application of education and enforcement initiatives targeted at corridors that exhibit a RwD crash history associated with unsafe driving characteristics (e.g., alcohol and drugs, and speed).

The systemic approach to safety involves widely implemented improvements based on high-risk highway features correlated with specific severe crash types. The approach provides a more comprehensive method for safety planning and implementation that supplements and complements traditional site analysis.

https://www.oregon.gov/odot/Engineering/Docs_TrafficEng/Departure-Implementation-Plan.pdf

53

THE 6 SAFE SYSTEM PRINCIPLES



Death/serious injury is unacceptable

Humans make mistakes

Humans are vulnerable

Responsibility is shared

Safety is proactive

Redundancy is crucial

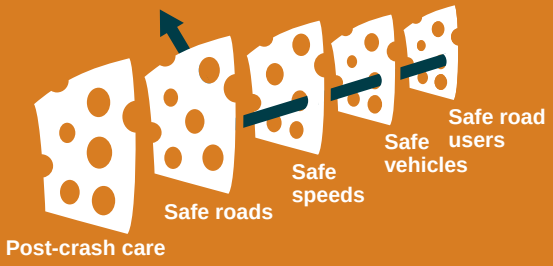
Source: FHWA

54

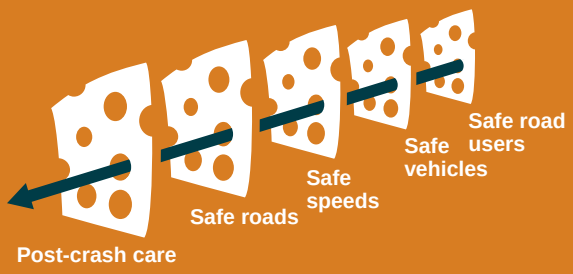
SAFE SYSTEM ELEMENTS CREATE REDUNDANCY

Redundancy is crucial

The “Swiss Cheese Model” of redundancy creates layers of protection



Death and serious injuries only happen when all layers fail



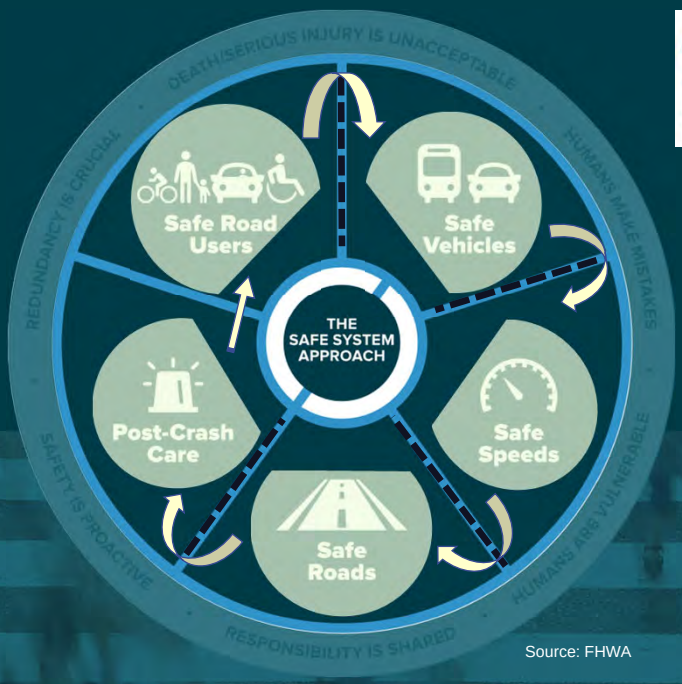
Adapted from James Reason’s model for analyzing accident causation
https://royalsocietypublishing.org/doi/10.1098/rstb.1990.0090

Image Source: FHWA

55

THE 5 SAFE SYSTEM ELEMENTS

Redundancy is crucial



Source: FHWA

56

56

What's Different?

PARADIGM SHIFT

Traditional Approach		Safe System Approach
Reduce Crashes	→	Eliminate Fatalities & Serious Injuries
Speed Management	→	Kinetic Energy Management
Safety "Four E's"	→	Five Safe System Elements
Apply Countermeasures at High Crash Locations	→	Proactively Apply Countermeasures in a "Systemic" Approach
Examine crash records to identify causes or "deficiencies"	→	Strengthen all elements to reduce "system failures"
"Balance" Safety vs. Mobility	→	Only "Safe Mobility"

Death/serious injury is unacceptable

Humans make mistakes

Humans are vulnerable

Responsibility is shared

Safety is proactive

Redundancy is crucial

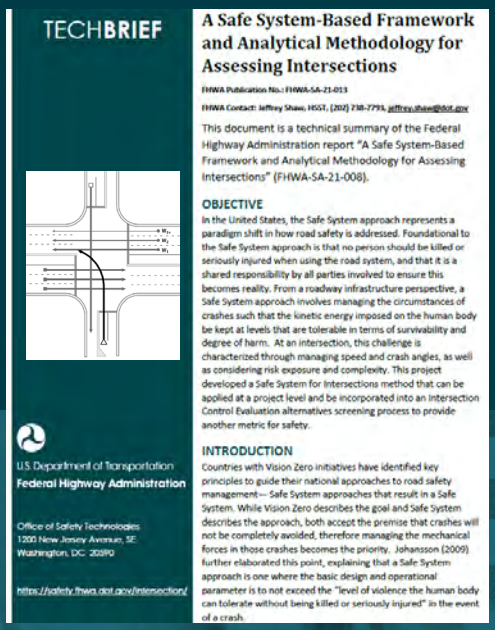
57

For More Information

FHWA Resources: https://safety.fhwa.dot.gov/zerodeaths/zero_deaths_vision.cfm

ITE Resources: https://www.ite.org/technical-resources/topics/safe-systems/

58


TECHBRIEF

A Safe System-Based Framework and Analytical Methodology for Assessing Intersections

FHWA Publication No.: FHWA-SA-21-013

FHWA Contact: Jeffrey Shaw, HSST, (202) 718-7795, jeffrey.shaw@dot.gov

This document is a technical summary of the Federal Highway Administration report "A Safe System-Based Framework and Analytical Methodology for Assessing Intersections" (FHWA-SA-21-008).

OBJECTIVE

In the United States, the Safe System approach represents a paradigm shift in how road safety is addressed. Foundational to the Safe System approach is that no person should be killed or seriously injured when using the road system, and that it is a shared responsibility by all parties involved to ensure this becomes reality. From a roadway infrastructure perspective, a Safe System approach involves managing the circumstances of crashes such that the kinetic energy imposed on the human body be kept at levels that are tolerable in terms of survivability and degree of harm. At an intersection, this challenge is characterized through managing speed and crash angles, as well as considering risk exposure and complexity. This project developed a Safe System for Intersections method that can be applied at a project level and be incorporated into an Intersection Control Evaluation alternatives screening process to provide another metric for safety.

INTRODUCTION

Countries with Vision Zero initiatives have identified key principles to guide their national approaches to road safety management— Safe System approaches that result in a Safe System. While Vision Zero describes the goal and Safe System describes the approach, both accept the premise that crashes will not be completely avoided, therefore managing the mechanical forces in those crashes becomes the priority. Johansson (2009) further elaborated this point, explaining that a Safe System approach is one where the basic design and operational parameter is to not exceed the "level of violence the human body can tolerate without being killed or seriously injured" in the event of a crash.

U.S. Department of Transportation
Federal Highway Administration

Office of Safety Technologies
1200 New Jersey Avenue, SE
Washington, DC 20590

https://safety.fhwa.dot.gov/intersection/

Source: FHWA

First step towards an objective analysis approach of intersection alternatives using Safe System concepts for practitioners in the U.S.

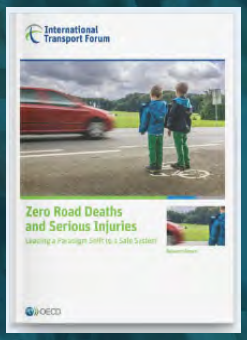
Focuses on alternative screening and potential inclusion within an Intersection Control Evaluation (ICE) process

Source: FHWA

59

Safe System Approach – What's Next?

"There is no single pathway for the adoption, establishment and implementation of a Safe System. Moving to a Safe System is a learning-by-doing process best described as a journey which presents opportunities, hazards and challenges along the way. The experiences of the pioneering countries show that each follows its own journey, shaped by the cultural, temporal, and local context, but guided by the underlying principles."



Source: Zero Road Deaths and Serious Injuries: Leading a Paradigm Shift to a Safe System; OECD (2016)

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

60

WHAT IS THE SAFE SYSTEM APPROACH?

Image: FHWA

61

TOP 3 TAKEAWAYS

- The Safe System Approach is “Principles Based”
- Achieving a Safe System requires all five elements to be strengthened
- Safe Roads is a continuum, not an absolute

62

THE SAFE SYSTEM APPROACH

Zero is our goal. A Safe System is how we get there.

Mark Doctor, P.E.
Senior Safety & Design Engineer / Team Leader
Federal Highway Administration Resource Center
Phone: (404) 895-6210
mark.doctor@dot.gov

FHWA Resources: https://safety.fhwa.dot.gov/zerodeaths/zero_deaths_vision.cfm

ITE Resources: https://www.ite.org/technical-resources/topics/safe-systems/