Collaborative Sciences Center for ROAD SAFETY

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Safe Systems and Kinetic Energy Management

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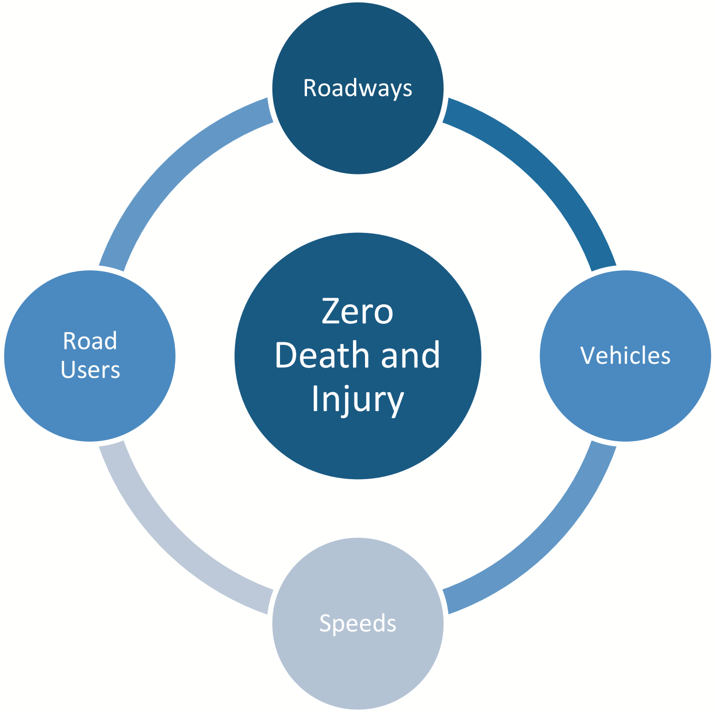
Introduction

- Humans make mistakes while using the road.
- Our transportation system is not always designed to mitigate harm when mistakes occur.
- The Safe System Approach gives us a different framework for managing human error and roadway risk.
- Kinetic energy management is a key way engineers can implement the Safe System Approach.
- HSRC and CSCRS have a number of projects, both inside and outside North Carolina, focused on kinetic energy, primarily through speed management.

Defining Safe Systems

- Some versions of Safe Systems:
  - The Netherland's "Sustainable Safety"
  - Sweden's "Vision Zero"
  - Australia's "Safe System Approach"
- CSCRS distinguishes 4 key principles of Safe Systems.
  - Adapt the structure and function of the transportation system to the complexities of human behavior.
  - Manage the kinetic energy transferred among road users.
  - Treat road user safety as the foundation of all system interventions.
  - Foster the creation of a shared vision and coordinated action.



Source: Signor et al., 2018

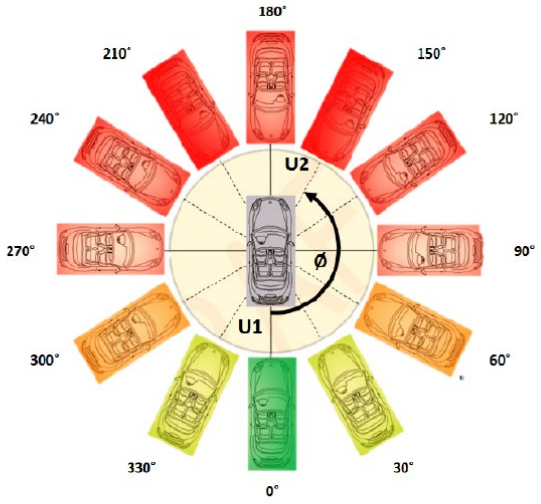
Defining Safe Systems

- Road to Zero has distilled Safe Systems into 2 key principles:
  - 1. Anticipating Human Error – Safe Systems are designed to anticipate and accommodate errors by drivers and other road users.
    - *Example: Even a momentary distraction can prevent a driver from seeing vulnerable road users or vice-versa. Separating vulnerable road users, such as pedestrians and bicyclists, from traffic wherever possible reduces the likelihood that such predictable errors will lead to a deadly collision.*
  - 2. Accommodating Human Injury Tolerance – Safe Systems are designed to reduce or eliminate opportunities for crashes resulting in forces beyond human endurance.
    - *Example: Where pedestrians and vehicles need to occupy the same space – such as urban crosswalks – reducing vehicle speeds through the use of lower speed limits combined with road design changes can reduce the likelihood of fatal collisions with pedestrians or bicyclists.*

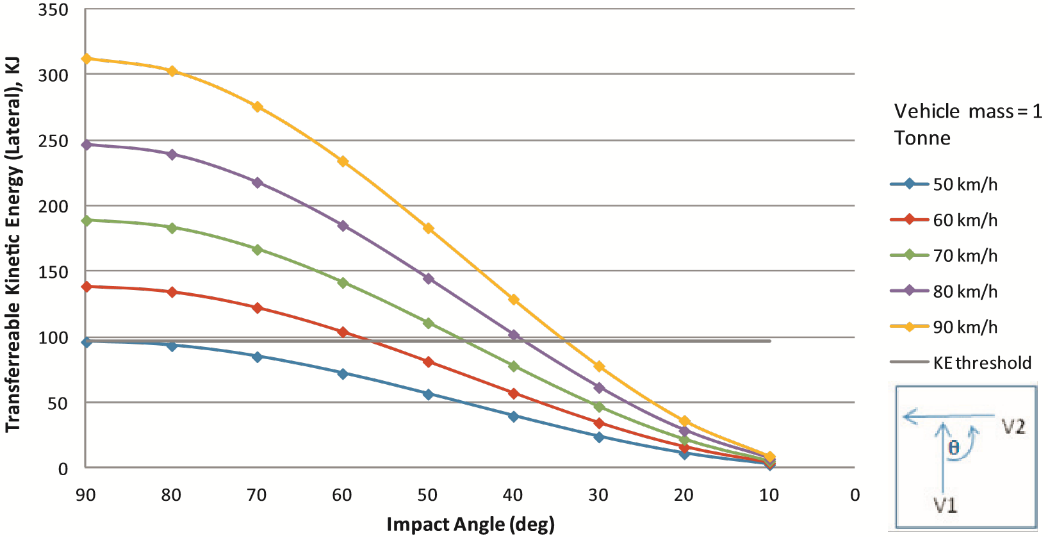
Source: ITE, 2019

Why Kinetic Energy Matters

- Humans have a physiological threshold for kinetic energy.
- Kinetic energy can also depend on the angle of collision.



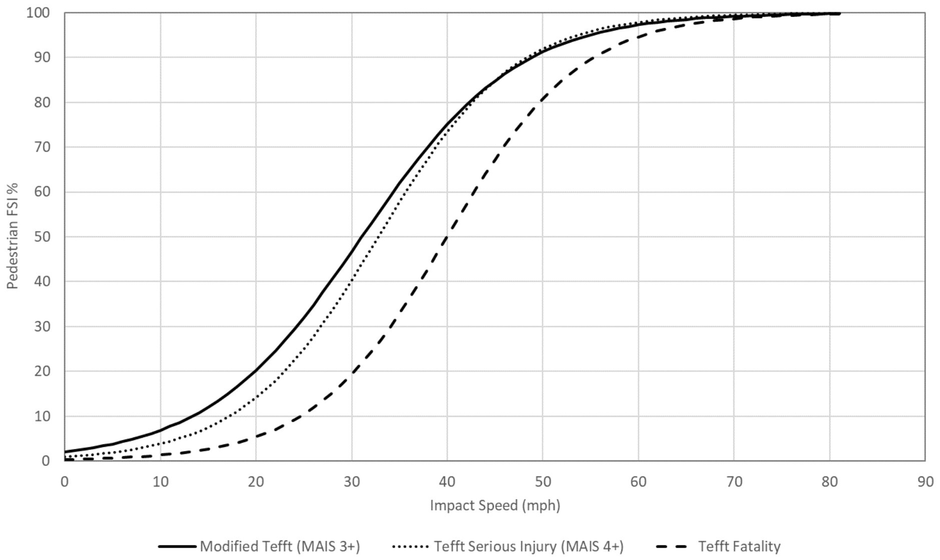
Jurewicz et al., 2017



Candappa et al., 2015

Why Kinetic Energy Matters

- Kinetic energy kills.



Source: Porter et al., 2021

Pedestrians

Impact Speed (mi/h)	Risk of Fatality (percent)
24-33	10
33-41	25
41-48	50
48-55	75
54-63	90

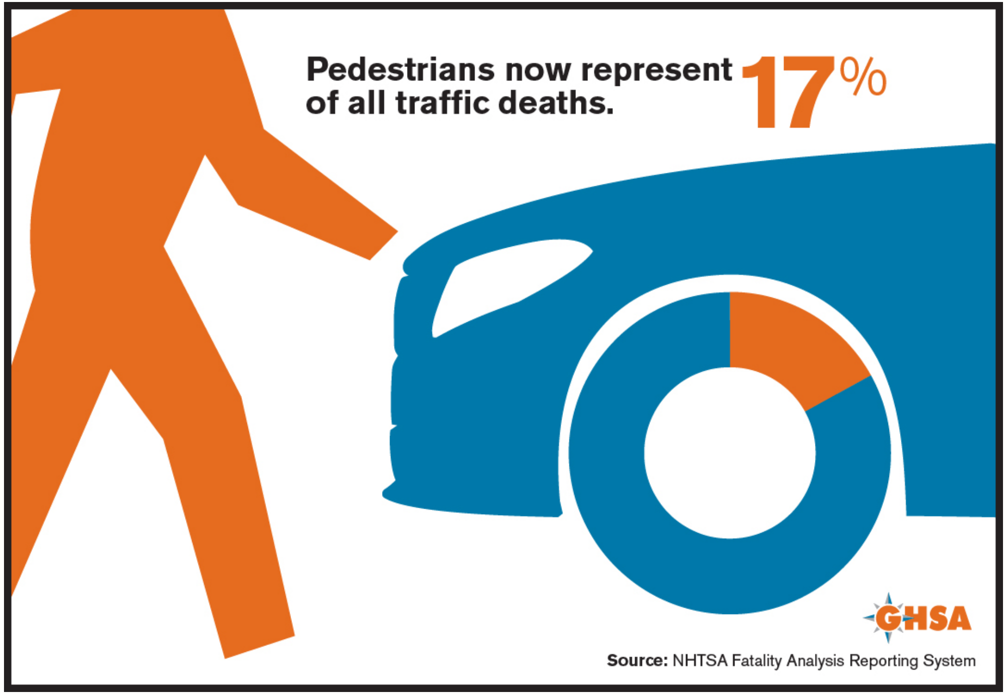
Source: Sanders et al., 2019

Bicyclists

Vehicle Travel Speed (mph)	Multiple for Fatality Risk
30	2
40	11
50	16

Source: Cushing et al., 2016

Why Kinetic Energy Matters

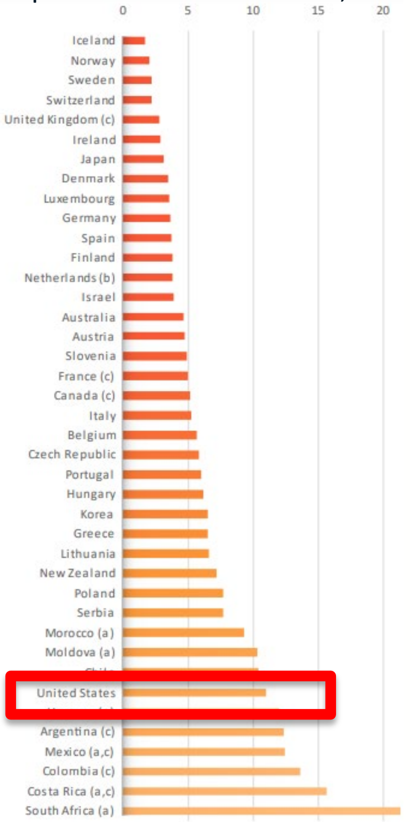


GHSA reports 6236 pedestrians and 891 bicyclists were killed in 2020

Why Kinetic Energy Matters

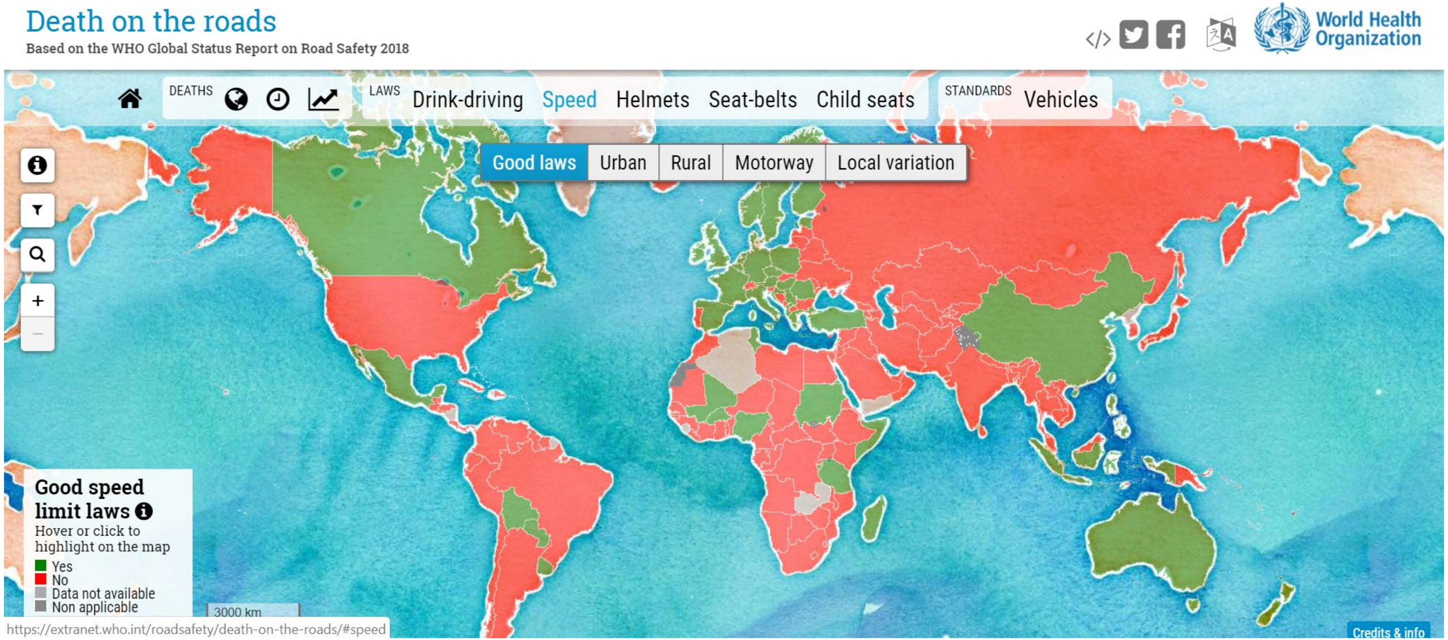
Percentage change in the number of road deaths, 2010-18

Road fatalities per 100 000 inhabitants, 2019



Source: ITF, 2020

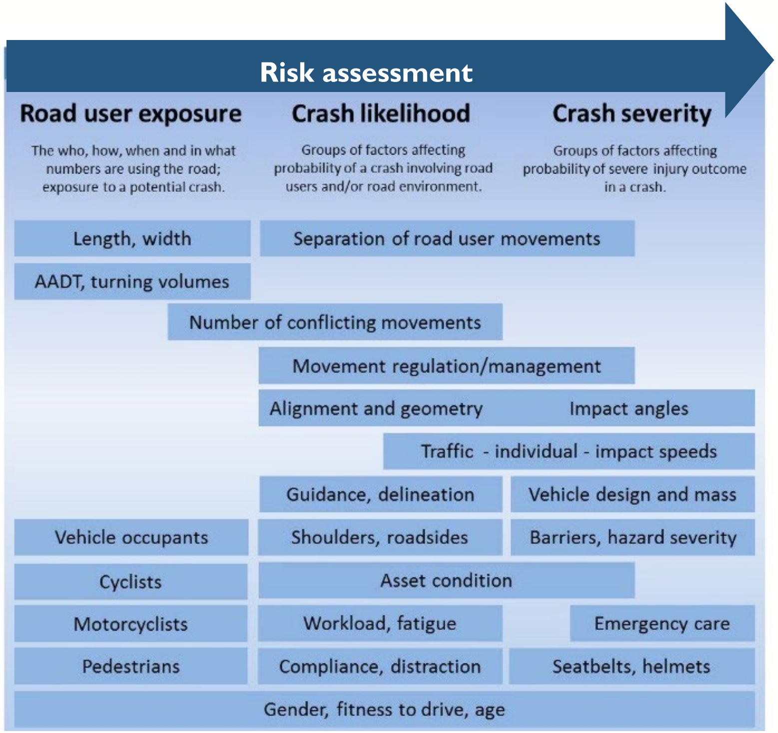
Why Kinetic Energy Matters



Source: WHO, 2020

Managing Kinetic Energy

- Roadway design affects the three key components of the Safe System Approach.



Source: Austroads, 2015

Managing Kinetic Energy

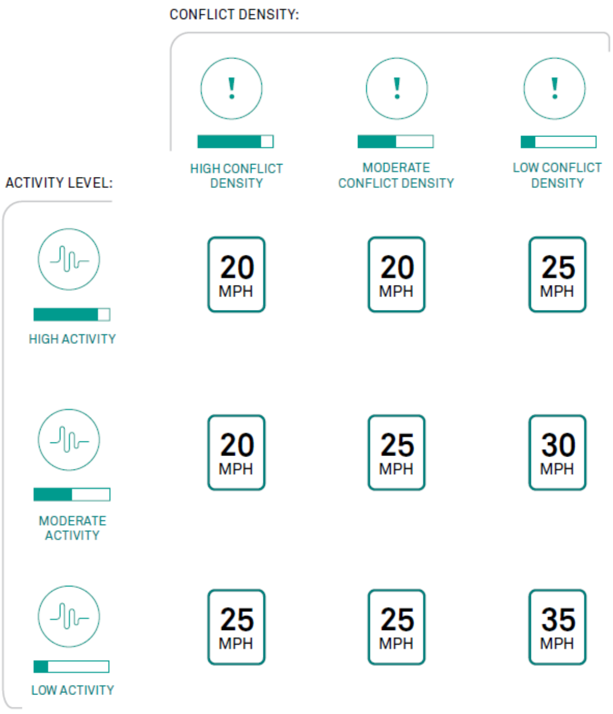
- Manage kinetic energy by managing speed and conflicts.

Source: Corben, 2020

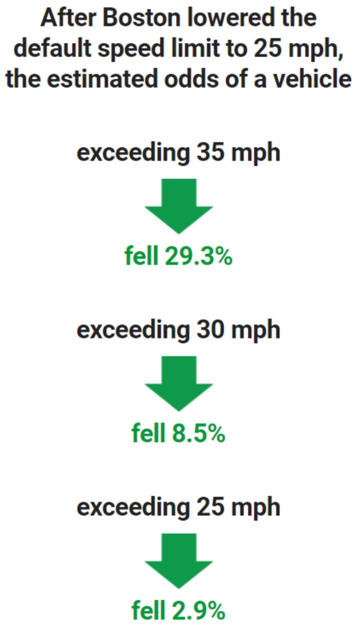
At intersections									
Safe System treatment	**Exposure**	**Likelihood**	**Severity**	**City Hubs**	**City Streets**	**City Places**	**Activity Streets & Boulevards**	**Movement Corridors & Connectors**	**Local Streets**
Signalised intersections with 'Scramble' phasing (30 km/h speed limit)		✓	✓	✓	✓		✓		
Limit access by mode	✓	✓	✓	✓		✓			
Raised signalised intersections with 30 km/h ramps		✓	✓	✓	✓		✓		
Safety platforms (30 km/h or lower) on all approaches		✓	✓	✓	✓	✓			✓
Geo-fencing technology for trams, trucks and other large vehicles		✓	✓	✓	✓	✓	✓		
Signalised roundabout with exclusive turn phases for public transport, cyclists and pedestrians		✓	✓	✓			✓	✓	
Grade-separation of pedestrians and cyclists from vehicular traffic		✓		✓					
Roundabouts with 20/30 km/h wombat crossings		✓	✓		✓	✓	✓	✓	✓
Threshold platforms at intersections with side-streets		✓	✓	✓	✓	✓		✓	
Raised intersections with 30 km/h (or lower) platforms		✓	✓	✓	✓	✓	✓	✓	✓
Signalised 'tennis ball' intersections (30 km/h design)		✓	✓					✓	
All-way stop signs		✓	✓			✓		✓	✓
Restricted access intersection	✓	✓	✓			✓		✓	✓

Managing Kinetic Energy

- Manage kinetic energy by managing speed and conflicts.



Source: NACTO, 2020



Example: Boston recently lowered citywide speed limits (Hu and Cicchino, 2019)

Managing Kinetic Energy

- Speed management is a major component of kinetic energy management. Speed management practices compliant with the Safe System Approach may include:
  - Altering the roadway cross section
  - Intersection redesign
  - Traffic calming
  - Speed limits
  - Speed safety cameras
- HSRC/CSCRS research touches on all of these aspects of speed management as part of the Safe System Approach.

Our Contribution

- HSRC staff were on the project team that developed the FHWA Safe System-Based Framework and Analytical Methodology for Assessing Intersections.

Intersection Type	Intersection SSI Score	Conflict Type SSI Scores			
		Nonmotorized	Crossing	Merging	Diverging
2x1 Roundabout	52	8	93	98	100
MUT	44	10	52	83	88
2x2 Roundabout	42	4	90	98	100
Signalized RCUT	40	5	74	77	86
Bowtie	31	4	23	94	96
Quadrant Roadway	30	6	14	93	94
Jughandle	27	3	18	93	97
Signalized Traditional (existing)	**24**	**2**	**19**	**93**	**100**
Unsignalized RCUT	19	0	65	69	86
FDLT	10	0	32	91	97
PDLT	9	0	26	91	97

SSI results show the 2x1 Roundabout has the highest SSI Score (i.e., best Safe System performance).

- Seven alternatives show improved overall Safe System performance compared to existing traditional signalized intersection
- Seven alternatives show improved performance at nonmotorized conflict points and eight show improvement at crossing conflict points

Source: Porter et al., 2021

Our Contribution

- HSRC staff are currently leading the NCHRP team to develop a new USLIMITS program.
- Proposing a Safe System Approach methodology as part of the program.
  - Scanned existing decision matrices like PBOT's.

Simplified Decision Matrix

Street and Limits:	Street								
	Advisory	Statutory							
	10 MPH	≤15 MPH	≤20 MPH	≤25 MPH	≤30 MPH	≤35 MPH	≤40 MPH	≤45 MPH	≤50 MPH
PED	Shared Roadway			5' Sidewalk 100% One Side	Both Sides Curb or Swale; 8' Separation	>8' Separation Both Sides NCHRP 562 Crossings: 20/Hr.	>12' Separation Both Sides	Impermeable Separation Barrier	
BIKE	Shared Roadway			≤ 5' Bike Lane	6' – 7' Bike Lane	Minimum 2' Separation from Autos	Permeable Barrier	Impermeable Separation Barrier	
AUTO	Gravel Roadway	≤ 9' Travel Lanes	10' Travel Lanes, Greenway	10' Travel Lanes		≤ 11' Travel Lanes Angle Crash Mitigations	Permeable Center Barrier; Roadside Object Setback or Shielding		Impermeable Center Barrier
Notes:	None								

Source: Vision Zero Network, 2018

Our Contribution

- HSRC staff contributed to new FHWA/NHTSA guidance on speed safety cameras (formerly called automated speed enforcement).

Safety Benefits:

Fixed units can reduce crashes on urban principal arterials up to:

54% for all crashes.[4]

47% for injury crashes.[4]

P2P units can reduce crashes on urban expressways, freeways, and principal arterials up to:

37% for fatal and injury crashes.[2]

Mobile units can reduce crashes on urban principal arterials up to:

20% for fatal and injury crashes.[5]

In New York City, fixed units reduced speeding in school zones up to 63% during school hours.[6]

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://safety.fhwa.dot.gov/provencountermeasures/ and

Applications

Agencies should conduct a network analysis of speeding-related crashes to identify locations to implement SSCs. The analysis can include scope (e.g., widespread, localized), location types (e.g., urban/suburban/rural, work zones, residential, school zones), roadway types (e.g., expressways, arterials, local streets), times of day, and road users most affected by speed-related crashes (e.g., pedestrians, bicyclists).

SSCs can be deployed as:

- **Fixed units**—a single, stationary camera targeting one location.
- **Point-to-Point (P2P) units**—multiple cameras to capture average speed over a certain distance.
- **Mobile units**—a portable camera, generally in a vehicle or trailer.

The table below describes suitable circumstances for SSC deployment.[1]

Considerations

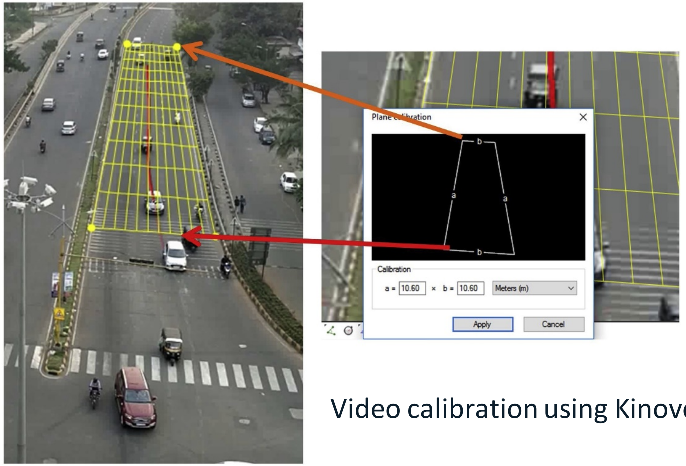
- SSCs can produce a crash reduction upstream and downstream, thus generating a spillover effect.[2]
- Public trust is essential for any type of enforcement. With proper controls in place, SSCs can offer fair and equitable enforcement of speeding, regardless of driver age, race, gender, or socio-economic status. SSCs should be planned with community input and equity impacts in mind.
- Using both overt (i.e., highly visible) and covert (i.e., hidden) enforcement may encourage drivers to comply with limits everywhere, not only at sites they are aware are enforced.
- Agencies should conduct evaluations regularly to determine if SSCs are accomplishing safety goals and whether changes in strategy, scheduling, communications, or public engagement are necessary.
- Agencies should conduct a legal and policy review to determine if SSCs are authorized within a jurisdiction and how the authorization and other traffic laws will affect a SSC program.
- Agencies should develop an SSC program plan with consideration of the USDOT SSC guidelines for planning, public involvement, stakeholder coordination, implementation, maintenance, evaluation, etc.[3]

Considerations for Selection	Fixed	P2P	Mobile
Problems are long-term and site-specific.	X	X	—
Problems are network-wide, and shift based on enforcement efforts.	—	—	X
Speeds at enforcement site vary largely from downstream sites.	—	X	X
Overt enforcement is legally required.	X	X	X
Sight distance for the enforcement unit is limited.	X	X	—
Enforcement sites are multilane facilities.	X	X	—

Source: https://safety.fhwa.dot.gov/provencountermeasures/pdf/PSC_New_Speed%20Camera_508.pdf

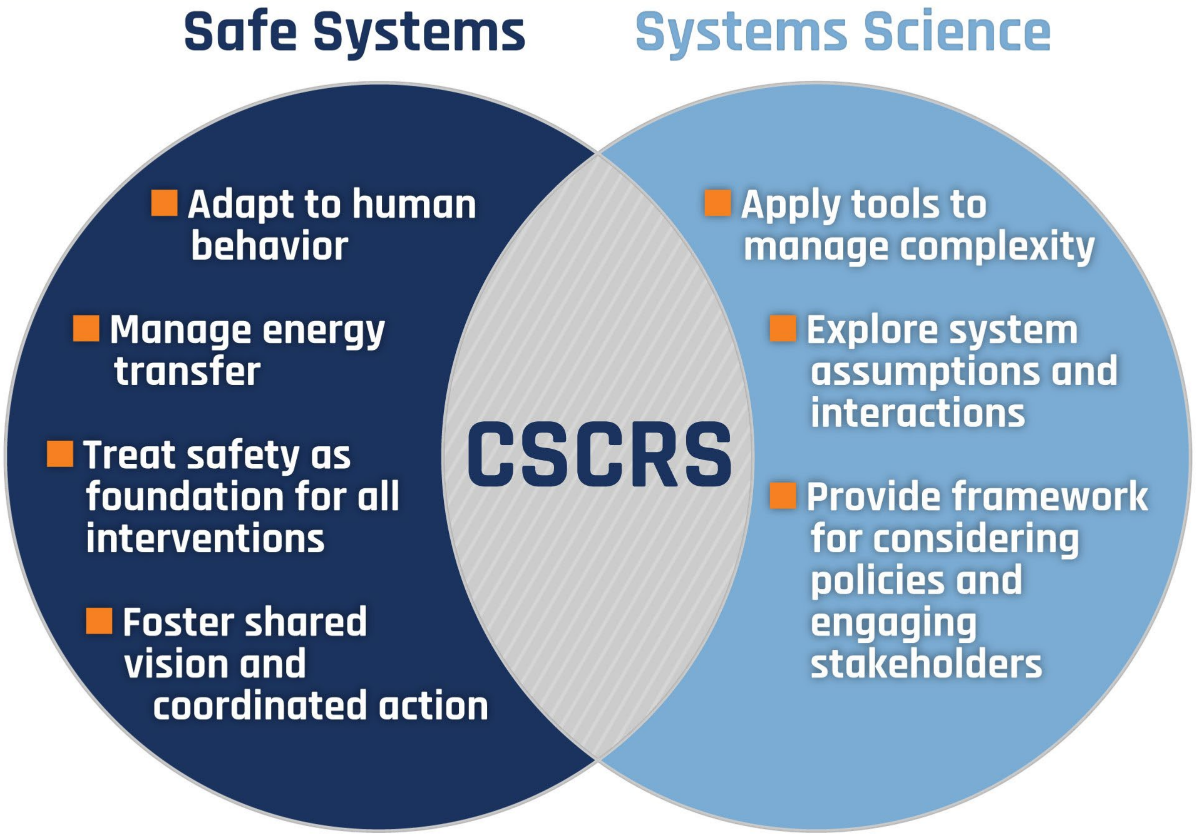
Our Contribution

- HSRC staff are examining speed and safety through two NCDOT projects that incorporate Safe System Approach principles.
  - NCDOT RP 2021-18: Crossing Treatment Process for Safer Shared Use Path Crossings
  - RP 2022-12: Validating the NCHRP 7-25 Pedestrian and Bicyclist Quality of Service “20-Flags” Method with Crash Data



Video calibration using Kinovea perspective grid.

Our Contribution



New Safe System Resources

- Dekra's Vision Zero Map
  - https://www.dekra-vision-zero.com/map
- ITE's Safe System Approach to Speed Management
  - Website will be live soon.
- FHWA's Zero Deaths – Saving Lives through a Safety Culture and a Safe System page
  - https://safety.fhwa.dot.gov/zerodeaths/resources.cfm

Thank you!

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