10-11-2019

The Safe System Approach: Considerations for Developing a Multi-Layered System

Offer Grembek
Safe Transportation Research and Education Center (SafeTREC)

The Safe System Approach: Considerations for Developing a Multi-Layered System

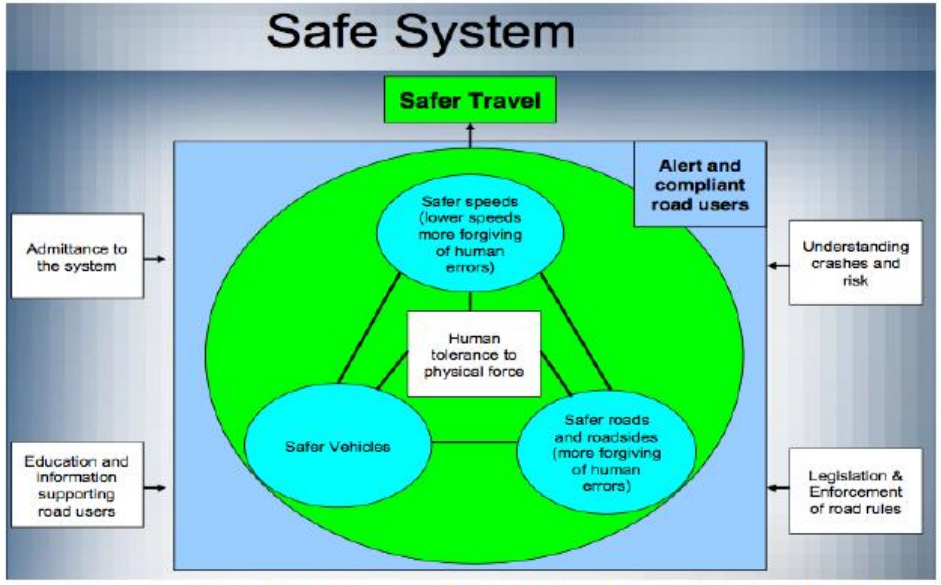


Figure 3 – The Safe System model reproduced from Howard, 2004 [25]

Presented by:

Dr. Offer Grembek

Berkeley SafeTREC

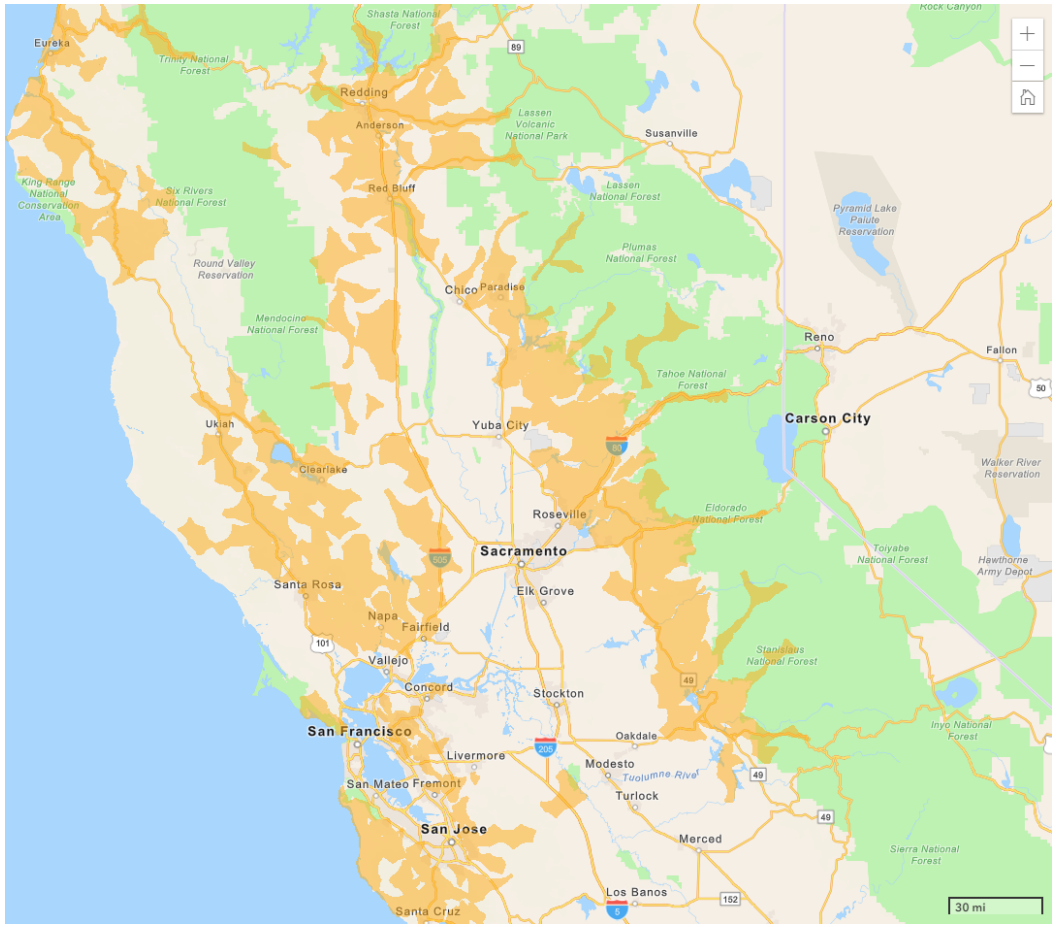
Collaborative Sciences Center for ROAD SAFETY

Presented at:

TREC Friday Seminar @ PSU

October 11, 2019

PG&E's Public Safety Power Shutoff

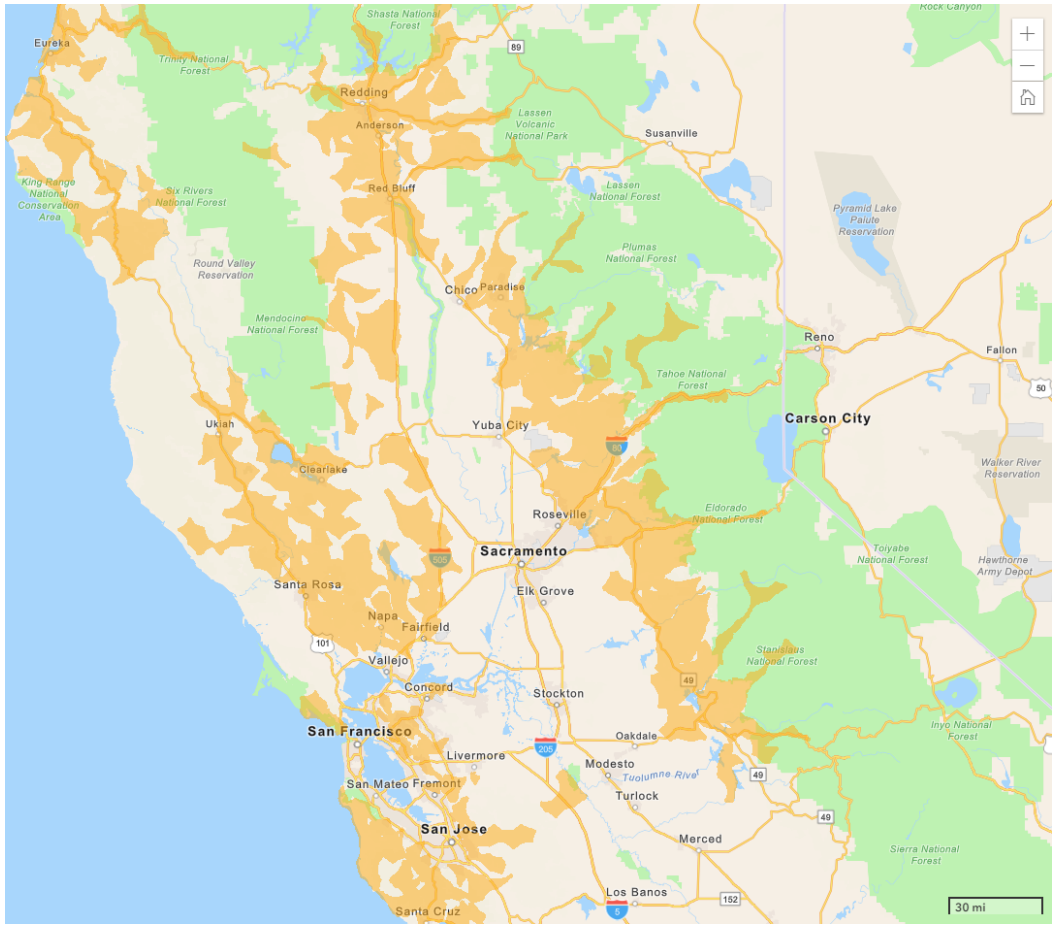


- Low humidity levels (20% and below)
- Sustained winds generally (above 25mph with 45mph gusts)
- Dry fuel on the ground

PG&E Public Safety Power Shutoff

Berkeley SafeTREC

PG&E's Public Safety Power Shutoff



- October 10/08-10/XX
- ~730,000 PG&E accounts
- Across 34 counties

Public Safety Power Shutoff

Provide electricity.

Outline

Safe System

- Safer Vehicles
- Safer Roads
- Safer Speeds

Safety Buffers

- Design and Ops
- Behavior
- Protection

Policy Implications

- Measure Outcome
- Measure System
- Proactive

Goal of the transportation system?

Provide mobility.

Goal of the transportation system?

Provide mobility.

Provide efficient,
cost-effective,
equitable, …, sustainable, and
safe mobility.

So, is our transportation system safe?

So, is our transportation system safe?

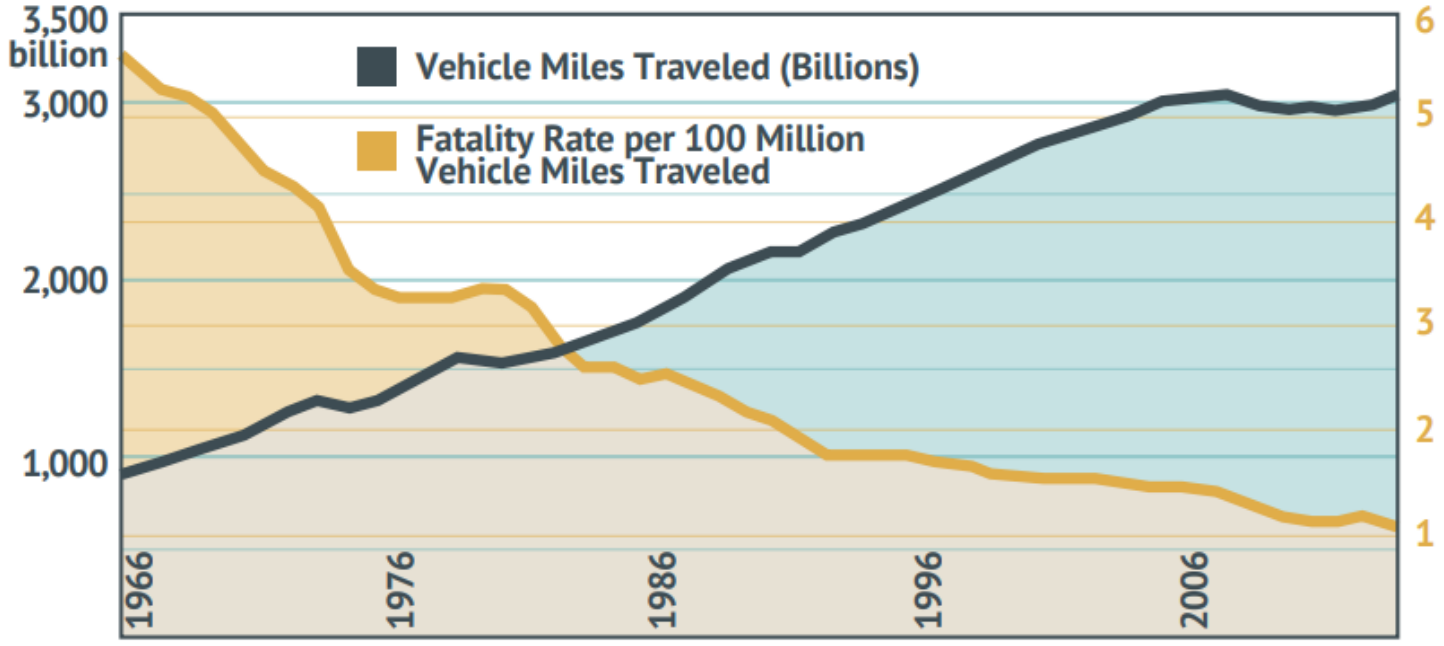


FIGURE 1-3: Fatality Rate and Vehicle Miles Traveled, 1966-2013 (Source: NHTSA FARS)

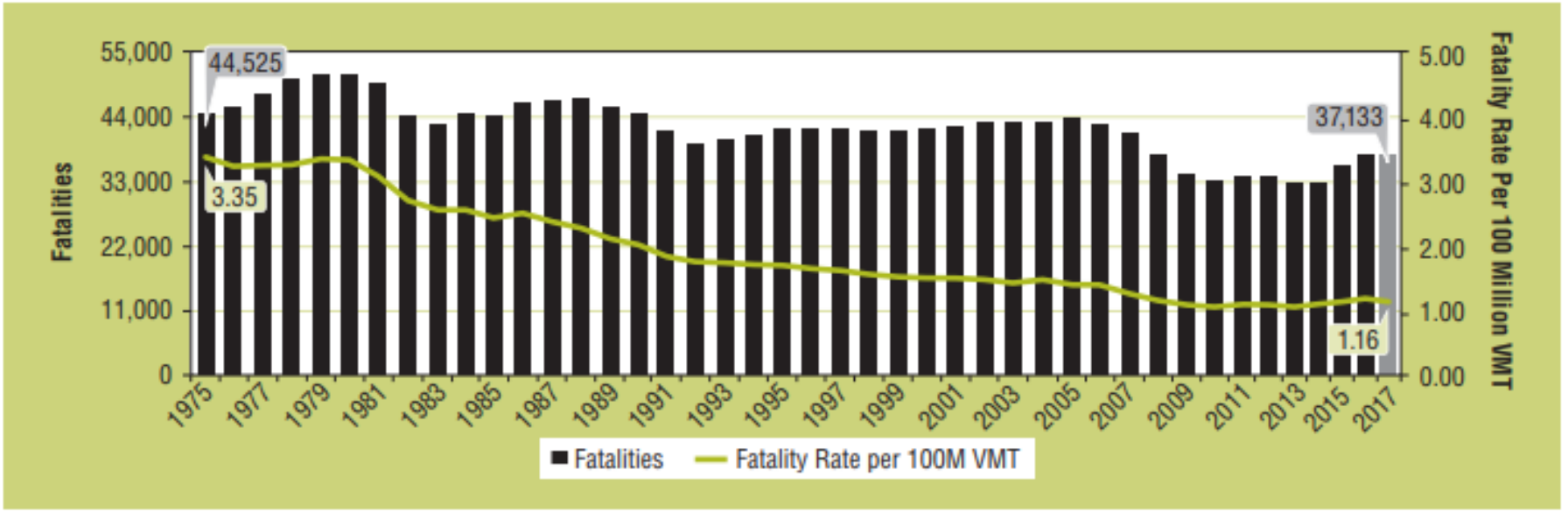
The fatality rate has demonstrated a downward trend for decades.

We're on the right track towards safety.

So, is our transportation system safe?

No. It is not safe.

Fatalities and Fatality Rate per 100 Million VMT, by Year, 1975–2017



Sources: FARS 1975–2016 Final File, 2017 ARF; Vehicle Miles Traveled (VMT): FHWA.

2017 Fatalities:

California:
3,602

USA:
37,133

Globally:
Over 1,300,000

So, is our transportation system safe?

No. It is not safe.

10 Leading Causes of Injury Deaths by Age Group Highlighting Unintentional Injury Deaths, United States – 2017

	Age Groups										
Rank	<1	1-4	5-9	10-14	15-24	25-34	35-44	45-54	55-64	65+	Total
1	Unintentional Suffocation 1,106	Unintentional Drowning 424	Unintentional MV Traffic 327	Unintentional MV Traffic 428	Unintentional MV Traffic 6,697	Unintentional Poisoning 16,478	Unintentional Poisoning 15,032	Unintentional Poisoning 14,707	Unintentional Poisoning 10,581	Unintentional Fall 31,190	Unintentional Poisoning 64,795
2	Homicide Unspecified 139	Unintentional MV Traffic 362	Unintentional Drowning 125	Suicide Suffocation 280	Unintentional Poisoning 5,030	Unintentional MV Traffic 6,871	Unintentional MV Traffic 5,162	Unintentional MV Traffic 5,471	Unintentional MV Traffic 5,584	Unintentional MV Traffic 7,667	Unintentional MV Traffic 38,659
3	Unintentional MV Traffic 90	Homicide Unspecified 129	Unintentional Fire/Burn 94	Suicide Firearm 185	Homicide Firearm 4,391	Homicide Firearm 4,594	Suicide Firearm 3,098	Suicide Firearm 3,937	Suicide Firearm 4,219	Suicide Firearm 5,996	Unintentional Fall 36,338
4	Homicide Other Spec., Classifiable 76	Unintentional Suffocation 110	Homicide Firearm 78	Homicide Firearm 126	Suicide Firearm 2,959	Suicide Firearm 3,458	Suicide Suffocation 2,562	Suicide Suffocation 2,294	Unintentional Fall 2,760	Unintentional Unspecified 5,125	Suicide Firearm 23,854
5	Undetermined Suffocation 56	Unintentional Fire/Burn 95	Unintentional Suffocation 36	Unintentional Drowning 110	Suicide Suffocation 2,321	Suicide Suffocation 3,063	Homicide Firearm 2,561	Suicide Poisoning 1,604	Suicide Suffocation 1,631	Unintentional Suffocation 3,920	Homicide Firearm 14,542

Data Source: National Center for Health Statistics (NCHS), National Vital Statistics System.
Produced by: National Center for Injury Prevention and Control, CDC using WISQARS™.

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First, or Second; Age > 1yr

So, is our transportation system safe?

a system in which people cannot die despite human error.

Job, and Sakashita. 2016a

safe system

So, is our transportation system dangerous?

So, is our transportation system dangerous?

dangerous system

a system in which people can die with no human error (e.g., mine field, avalanche area).

Job, and Sakashita. 2016a

Our system is not safe and also not dangerous

Our system is not safe and also not dangerous

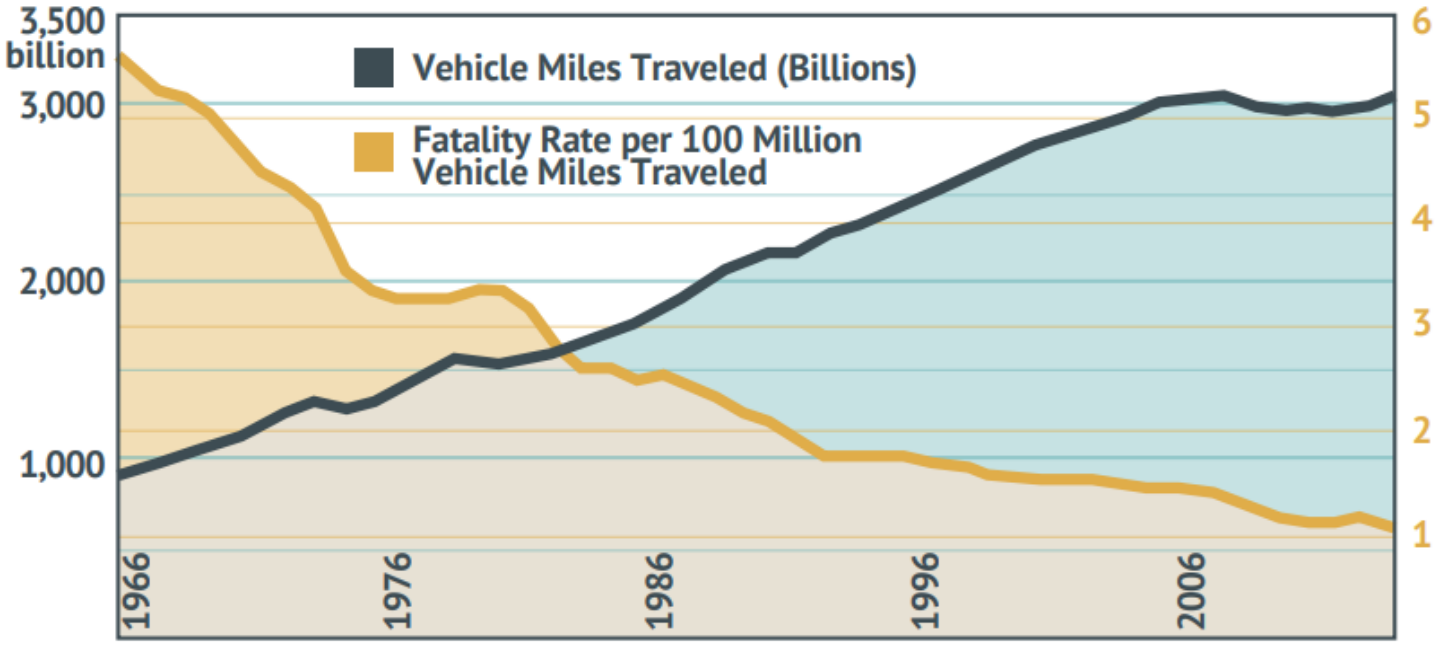


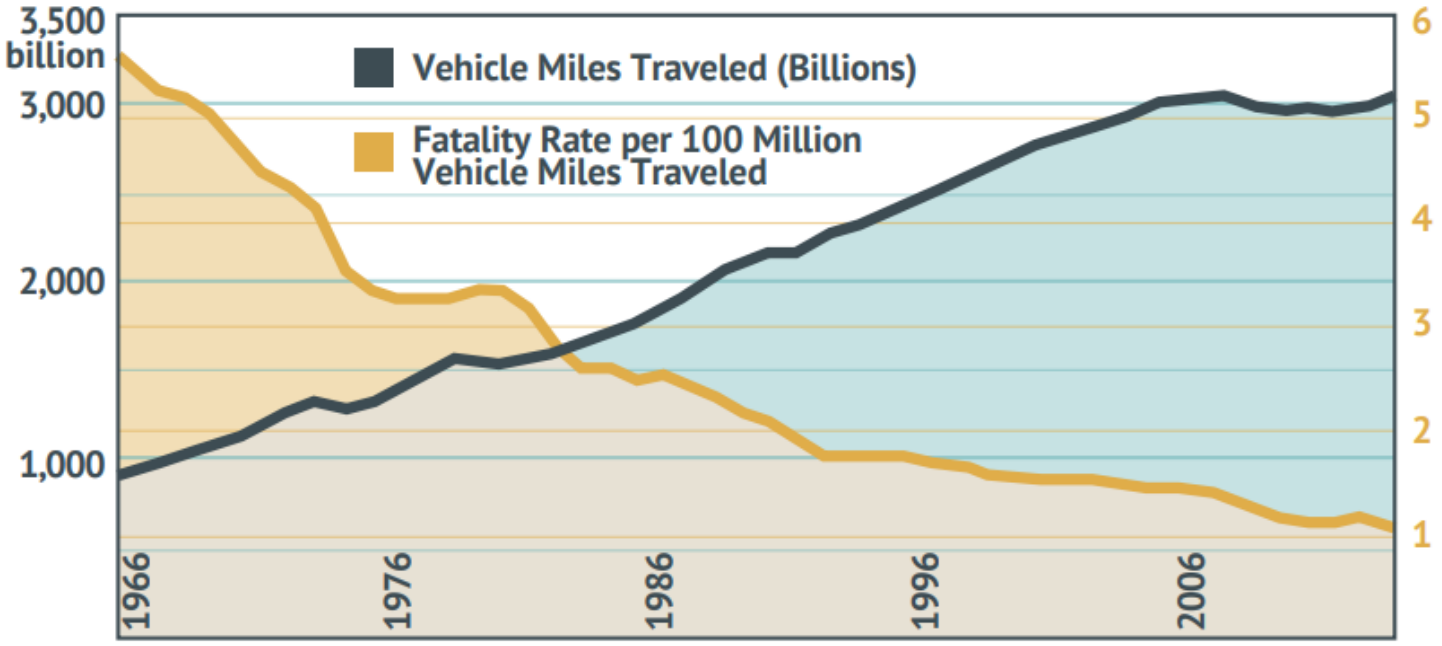
FIGURE 1-3: Fatality Rate and Vehicle Miles Traveled, 1966-2013 (Source: NHTSA FARS)

unsafe system

a system in which people can die through human error

Job, and Sakashita. 2016a

Our transportation system is unsafe



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unsafe system

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Kinetic Energy Transfer

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

$E_k = kinetic\ energy\ of\ object$

$m = mass\ of\ object$

$v = speed\ of\ object$

Kinetic energy is the energy associated with the movement of an object and is determined by a combination of velocity and mass.

Traffic is multimodal

Inherently different modes share the same network

Features\Mode	Foot	Bicycle	PTW	Car	SUV	Bus	Truck
Mass (lb)	178	200	620	3,178	5,178	33,560	~60,000
Average Speed (mph)	3.5	12	25	20	20	15	15
Kinetic energy (KJ)	0.1	1.3	17.6	57.6	93.9	342.2	611.9

Traffic Safety is multimodal

Inherently different modes share the same network

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Commonly studied:							
Injuries in CA (05-09)	40,202	37,821	39,976	432,822	90,195	4,877	6,267

Multimodal Injury Matrix

Injuries in California (2005-2009)		Mode *j* Inflicted an injury							
		Foot	Bicycle	PTW	Car	Transit	SUV	Truck	Object
Mode *i* Suffered an injury	Foot Bicycle PTW Car Transit SUV Truck Object	Square matrix, *X*, of dimension *n*							

Multimodal Injury Matrix

Injuries in California (2005-2009)		Mode *j* Inflicted an injury							
		Foot	Bicycle	PTW	Car	Transit	SUV	Truck	Object
Mode *i* Suffered an injury	Foot				x_{14}				
	Bicycle								
	PTW								
	Car								
	Transit								
	SUV								
	Truck								
	Object								

Element x_{ij} represents the number of injuries that were suffered by mode ***i*** and inflicted by mode ***j***.

Multimodal Injury Matrix: California

Injuries in California (2005-2009)		Mode *j* Inflicted an injury							
		Foot	Bicycle	PTW	Car	Transit	SUV	Truck	Object
Mode *i* Suffered an injury	Foot	31	488	327	32,455	631	5,736	531	3
	Bicycle	195	1,551	213	28,657	320	4,833	397	1,655
	PTW	159	106	4,847	21,036	118	4,199	647	8,864
	Car	607	331	2,814	221,444	2,655	76,543	18,323	110,105
	Transit	28	15	10	2,829	578	596	347	474
	SUV	66	46	332	43,543	330	23,403	3,262	19,213
	Truck	2	5	18	2,305	58	578	1,638	1,663
	Object	0	0	0	0	0	0	0	0

Injury crashes of two parties or less.

Multimodal Injury Matrix: California

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	Object	0	0	0	0	0	0	0	0	**0**
	Total	**1,088**	**2,542**	**8,561**	**352,269**	**4,690**	**115,888**	**25,145**	**141,977**	**652,160**

Relative Vulnerability Matrix

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RV for Individual modes	Foot	Bicycle	PTW	Car	Transit	SUV	Truck	Object
	36.95	**14.88**	**4.67**	**1.23**	**1.04**	**0.78**	**0.25**	**0.00**

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	36.95	**14.88**	**4.67**	**1.23**	**1.04**	**0.78**	**0.25**	**0.00**

Pedestrians suffer 36.95 times more injuries than they inflict.

Policy innovation to move the needle

V1.0

V2.0

dangerous system

unsafe system

safe system

Policy innovation to move the needle

Vision Zero & *Safe System*

challenge our ability to reach zero without a major change

ROAD TO ZERO

TZD Toward Zero Deaths®
National Strategy on Highway Safety

V1.0

V2.0

dangerous system

unsafe system

safe system

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Multi-layered systems approach

Mooren et al., 2011

Figure 3 – The Safe System model reproduced from Howard, 2004 [25]

dangerous system

unsafe system

safe system

System core: human tolerance to force

Mooren et al., 2011

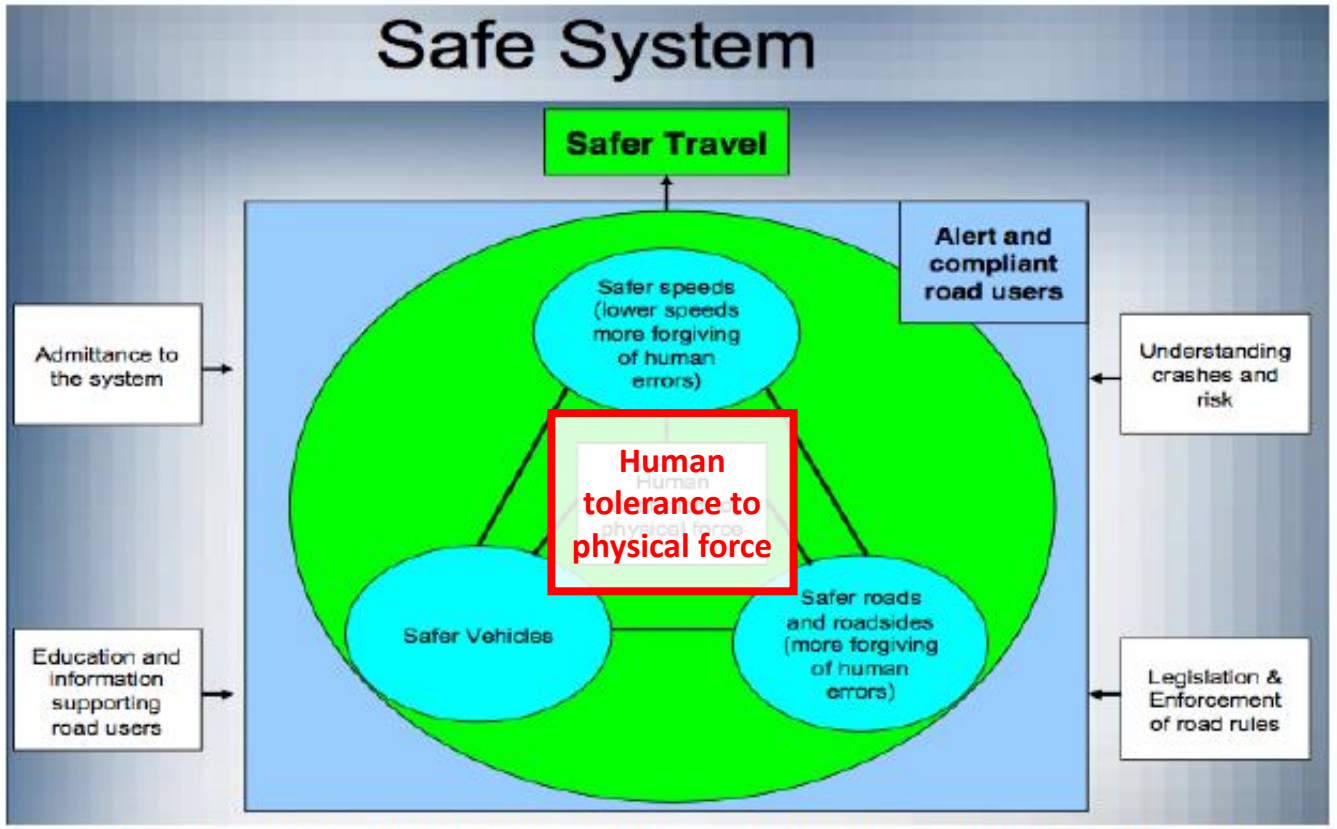


Figure 3 – The Safe System model reproduced from Howard, 2004 [25]

dangerous system

unsafe system

safe system

Safe System: safer roads, vehicles, speeds

Mooren et al., 2011

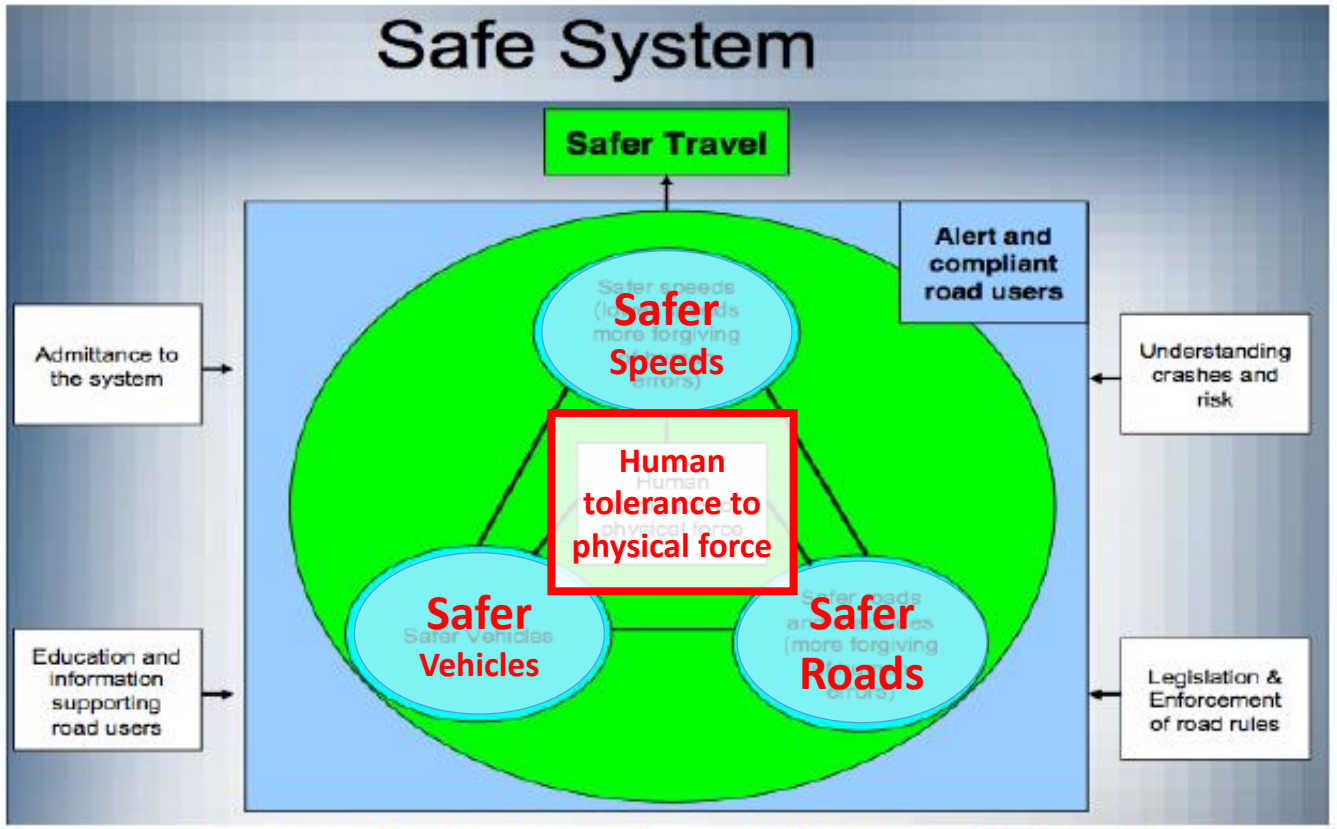


Figure 3 – The Safe System model reproduced from Howard, 2004 [25]

dangerous system

unsafe system

safe system

Safer Roads, Safer Vehicles, Safer Speeds

Danny Bagwell Flips Violently At Daytona 1999

https://www.youtube.com/watch?v=lIotGXqBH0Y

Safe System: safer roads, vehicles, speeds

Mooren et al., 2011

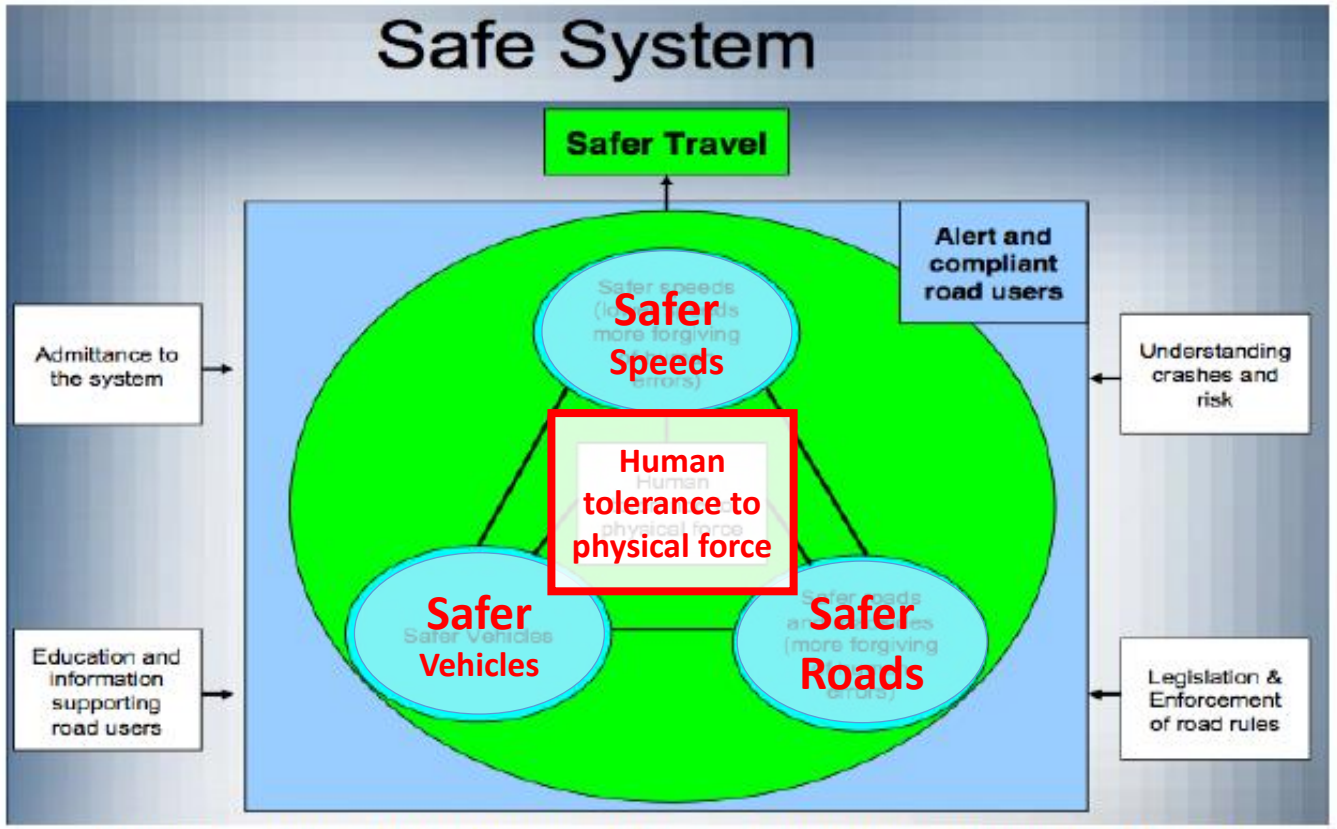


Figure 3 – The Safe System model reproduced from Howard, 2004 [25]

dangerous system

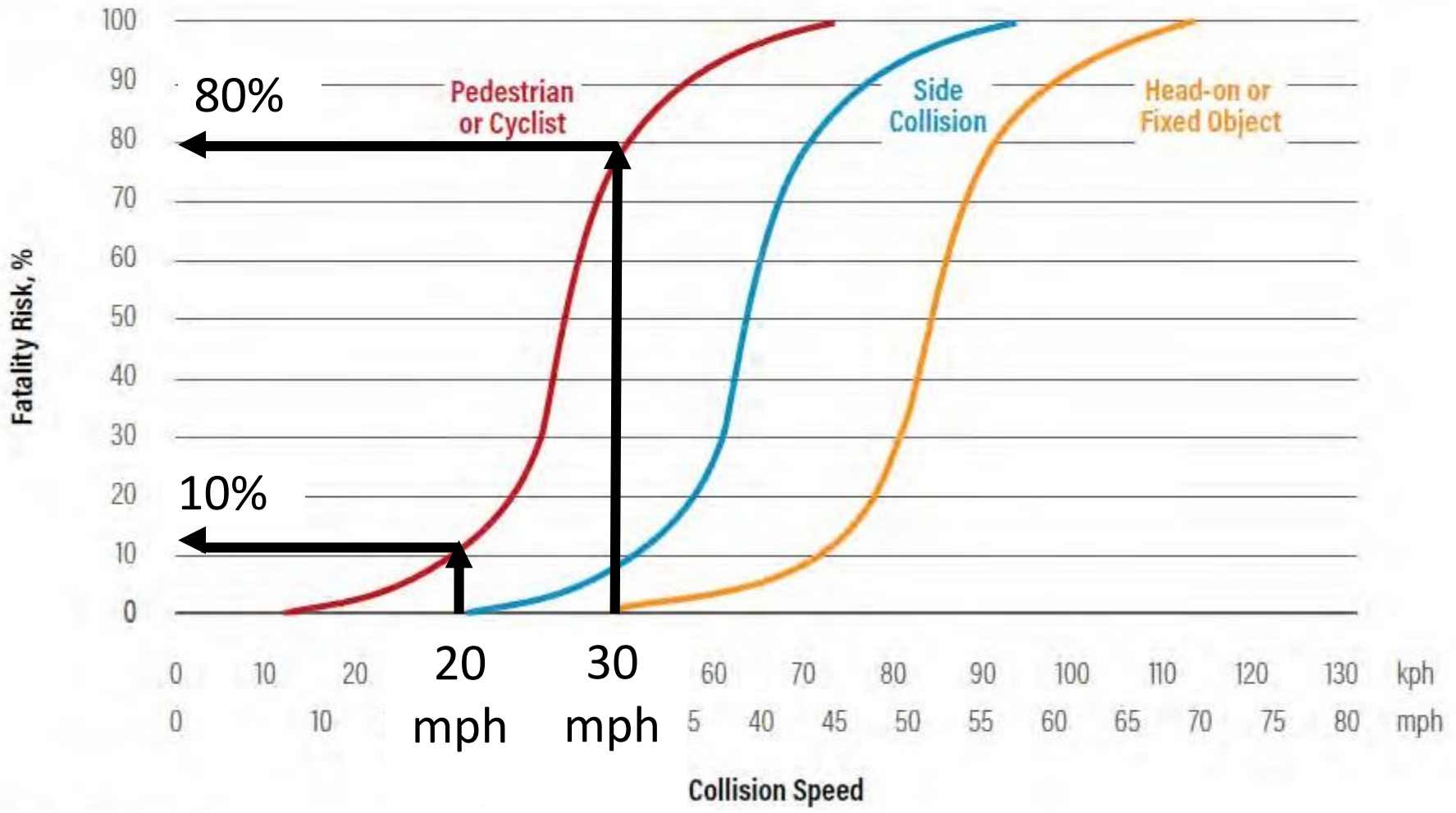
unsafe system

safe system

Speed management as a regulator

- Vehicle speed is the most important regulating factor for safe road traffic since it is subject to road-user behavior
- The kinetic energy that the human body can tolerate, forms the basic parameter in the design of a safe transport system

Fatality risk for collision speed, by crash type



Source: Wramborg, P. 2005." A New Approach to a Safe and Sustainable Road Structure and Street Design for Urban Areas." Paper presented at 13th International Conference on Road Safety on Four Continents, Warsaw, Poland, October 5–7.

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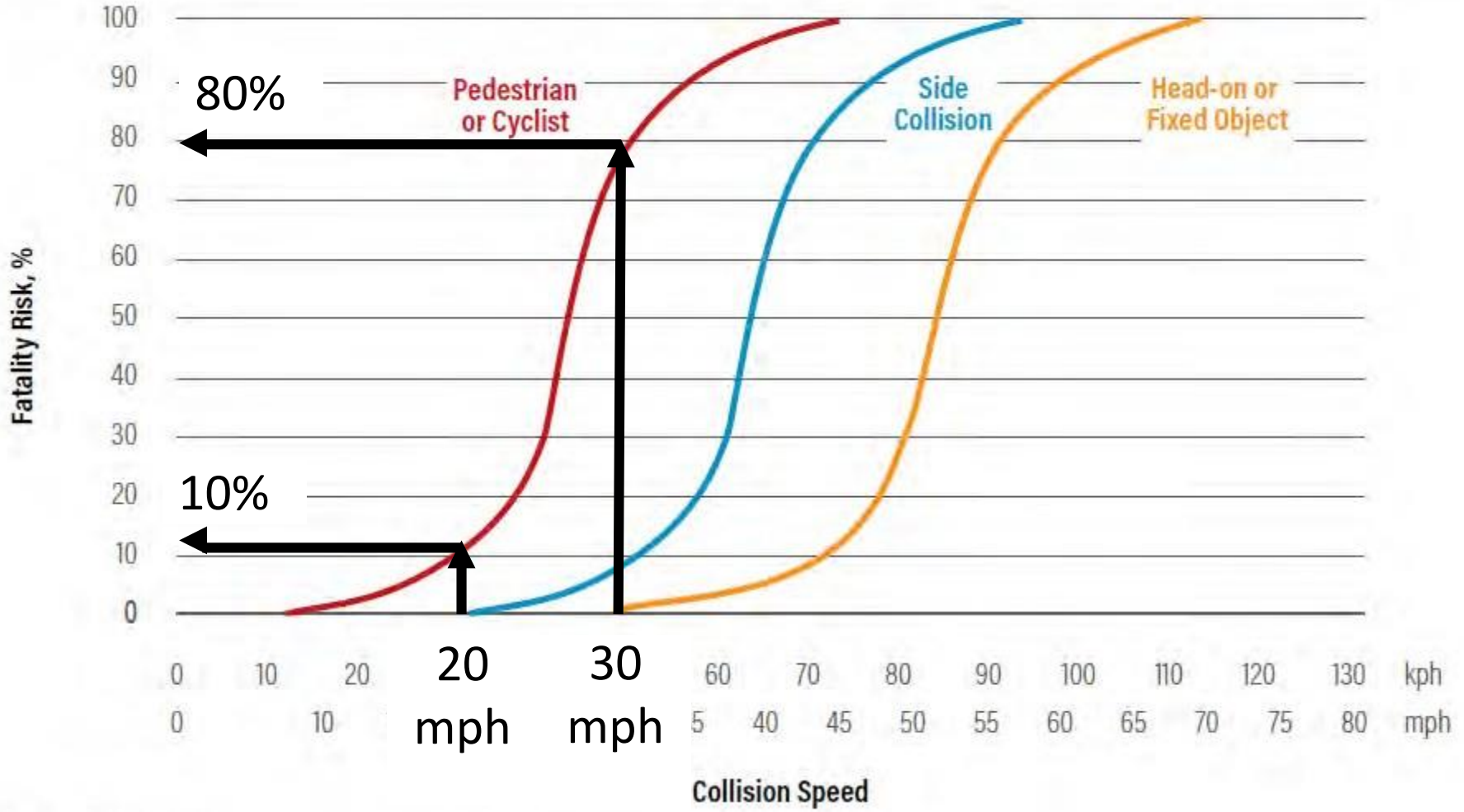
Fatality risk for collision speed, by crash type



Human tolerance to physical force

Source: Wramborg, P. 2005." A New Approach to a Safe and Sustainable Road Structure and Street Design for Urban Areas." Paper presented at 13th International Conference on Road Safety on Four Continents, Warsaw, Poland, October 5–7.

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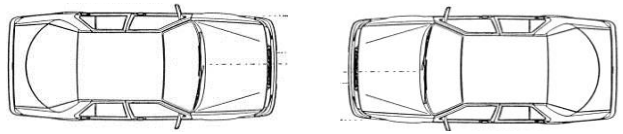
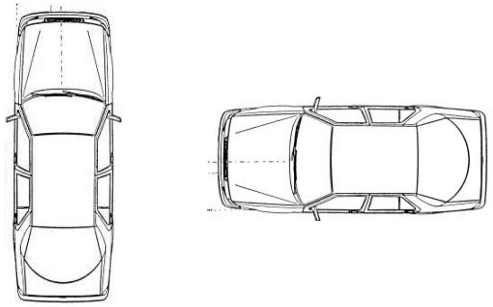
Speed limits for a safe system in Sweden

45 mph



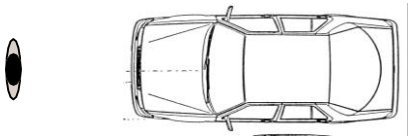
A safe car can protect occupants up to **45 mph** in a head-on collision

30 mph



A safe car can protect occupants up to **30 mph** in a side collision

20 mph



Most unprotected road users survive if a car travelling **20 mph** hits them

Source: Vision Zero and New Speed Limits in Sweden, Anna Vadeby, VTI

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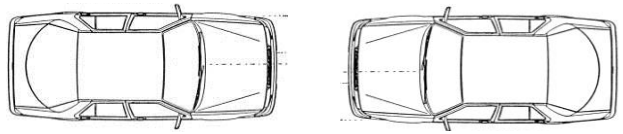
Speed limits for a safe system in Sweden

Safer Vehicles

45 mph



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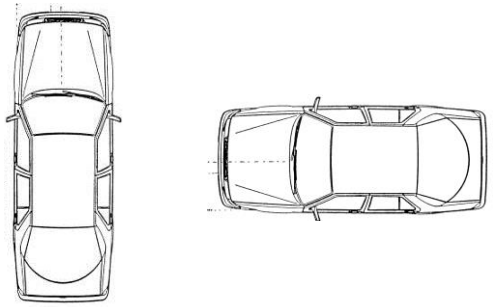
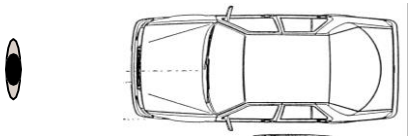


A safe car can protect occupants up to **30 mph** in a side collision

20 mph



Most unprotected road users survive if a car travelling **20 mph** hits them

Source: Vision Zero and New Speed Limits in Sweden, Anna Vadeby, VTI

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Rural speed limits for safe system, Sweden

- **45 mph** (70 km/h): default limit on rural roads
- **50 mph** (80-90 km/h): 2-lane roads (milled rumble strips in middle of road)
- **65 mph** (100 km/h): 2+1 roads with median barrier
- **70 mph** (110 km/h): motorways
- **75 mph** (120 km/h): motorways with high standard and low traffic flow

Year	Increased speed limit (km)	Decreased speed limit (km)
2008	1 000	2 500
2009	1 600	15 000

Source: Vision Zero and New Speed Limits in Sweden, Anna Vadeby, VTI

Rural speed limits for safe system, Sweden

Safer Roads

- **45 mph** (70 km/h): default limit on rural roads
- **50 mph** (80-90 km/h): 2-lane roads (milled rumble strips in middle of road)
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Source: Vision Zero and New Speed Limits in Sweden, Anna Vadeby, VTI

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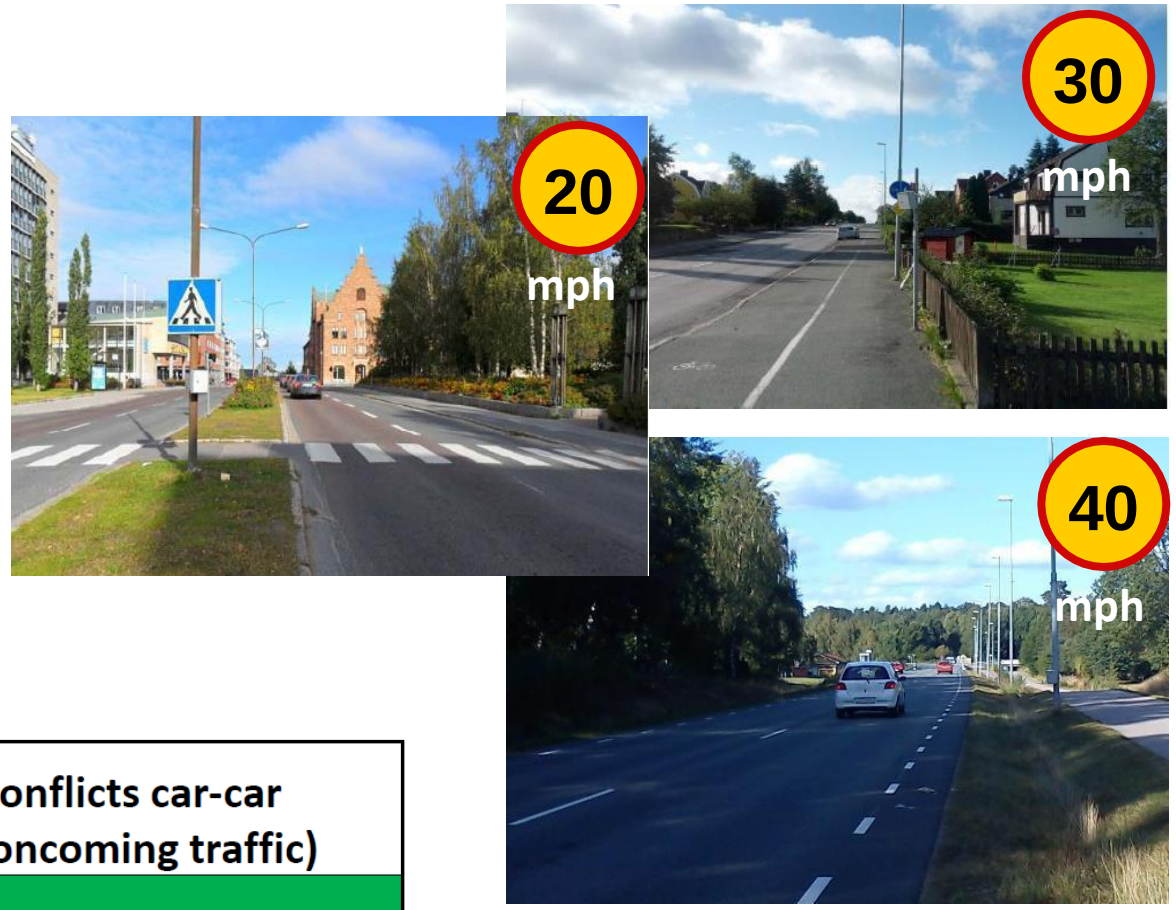
Urban speed limits for a safe system, Sweden

Guidelines consider:

- City's character
- Accessibility
- Security
- Traffic Safety
- Health and Environment



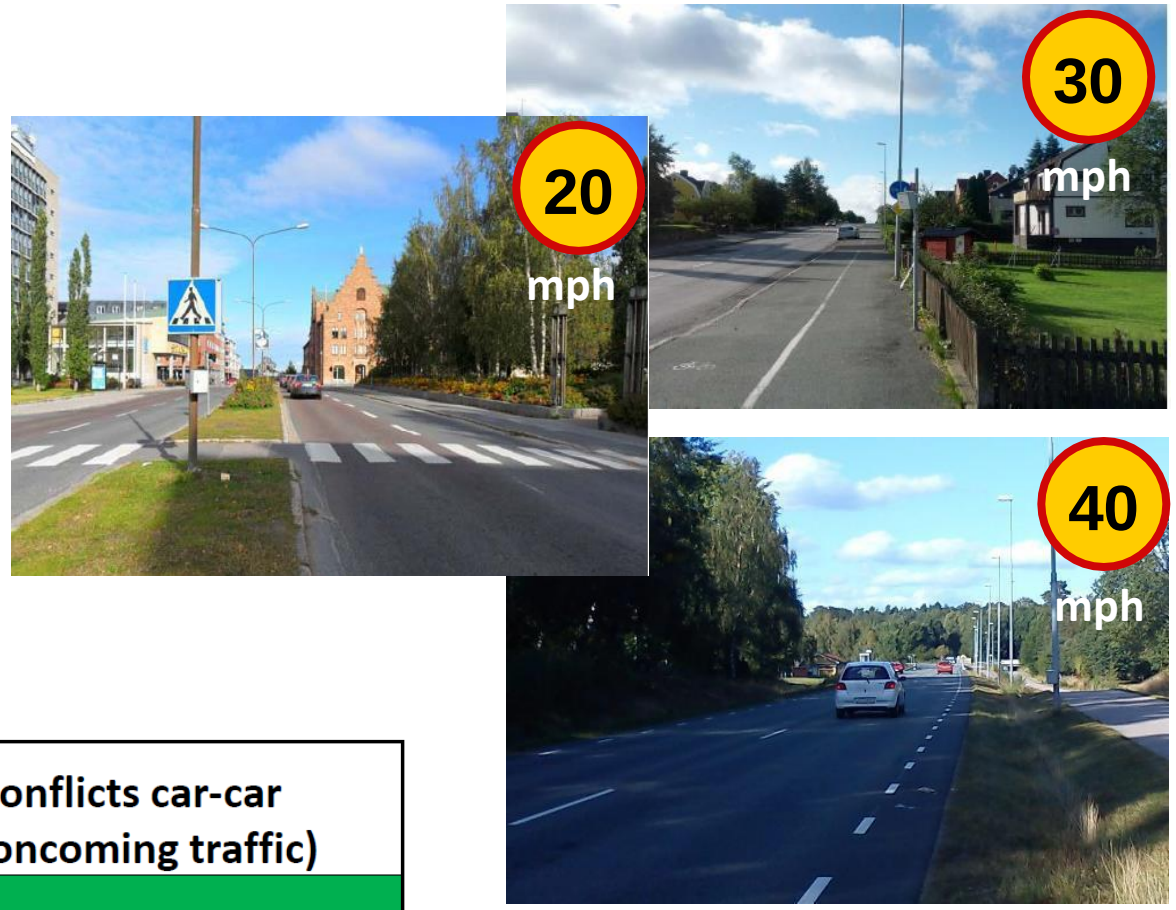
Safety Level	Conflicts VRU-car	Conflicts car-car (intersections)	Conflicts car-obstacle	Conflicts car-car (oncoming traffic)
High	≤ 20 mph	≤ 30 mph	≤ 40 mph	45 mph

Based on: Vision Zero and New Speed Limits in Sweden, Anna Vadeby, VTI.
Original Values have been converted from kph to mph and rounded.

Urban speed limits for a safe system, Sweden

Guidelines consider:

- City's character
- Accessibility
- Security
- Traffic Safety
- Health and Environment



Safety Level	Conflicts VRU-car	Conflicts car-car (intersections)	Conflicts car-obstacle	Conflicts car-car (oncoming traffic)
High	≤ 20 mph	≤ 30 mph	≤ 40 mph	45 mph

Based on: Vision Zero and New Speed Limits in Sweden, Anna Vadeby, VTI.
Original Values have been converted from kph to mph and rounded.

Berkeley SafeTREC

Safe System: alert and compliant users

Mooren et al., 2011

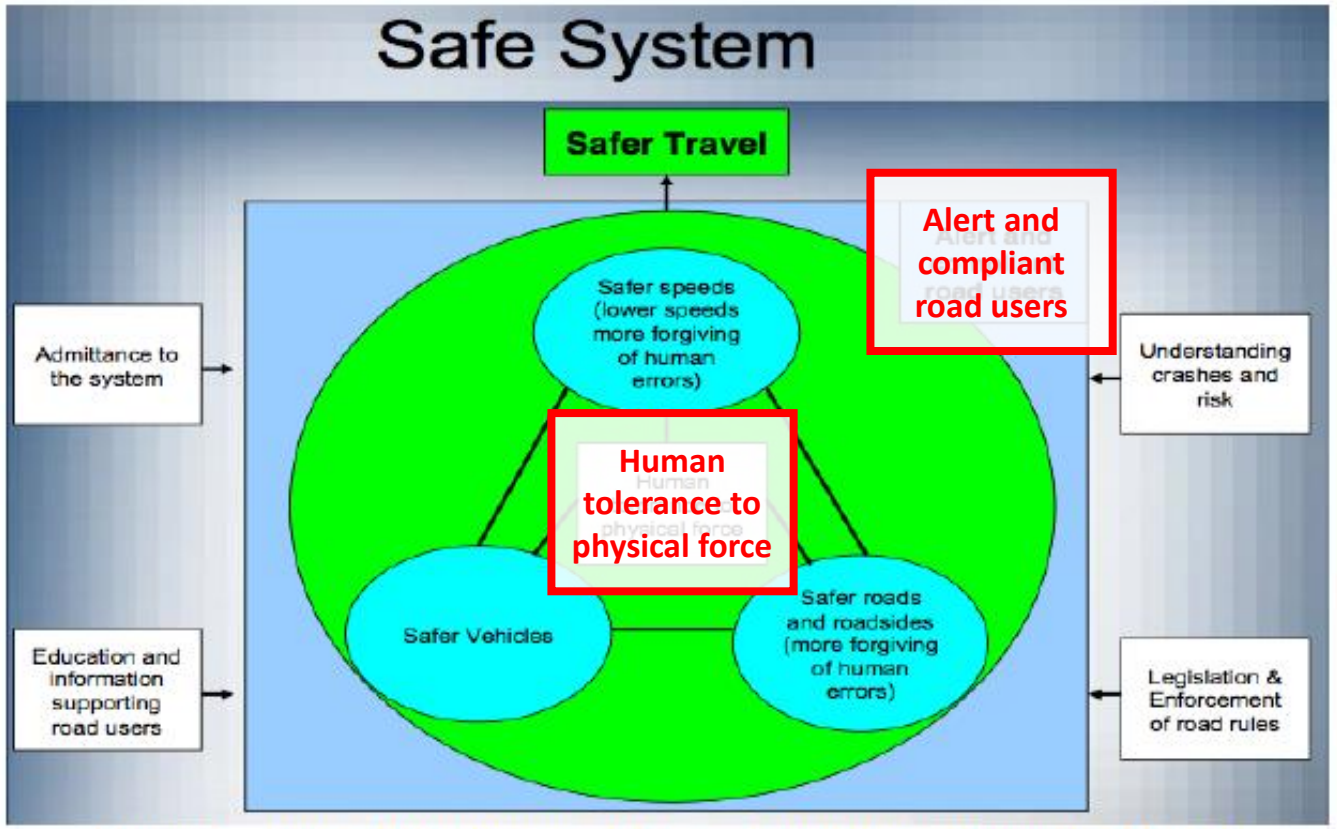


Figure 3 – The Safe System model reproduced from Howard, 2004 [25]

dangerous system

unsafe system

safe system

Who is this safe/r road user we design for?

Goody two shoes minion

Phil

Error-prone minion

Carl

Who is this safe/r road user we design for?

Goody two shoes minion

Phil

Error-prone minion

Carl

Unsafe system

Safe system

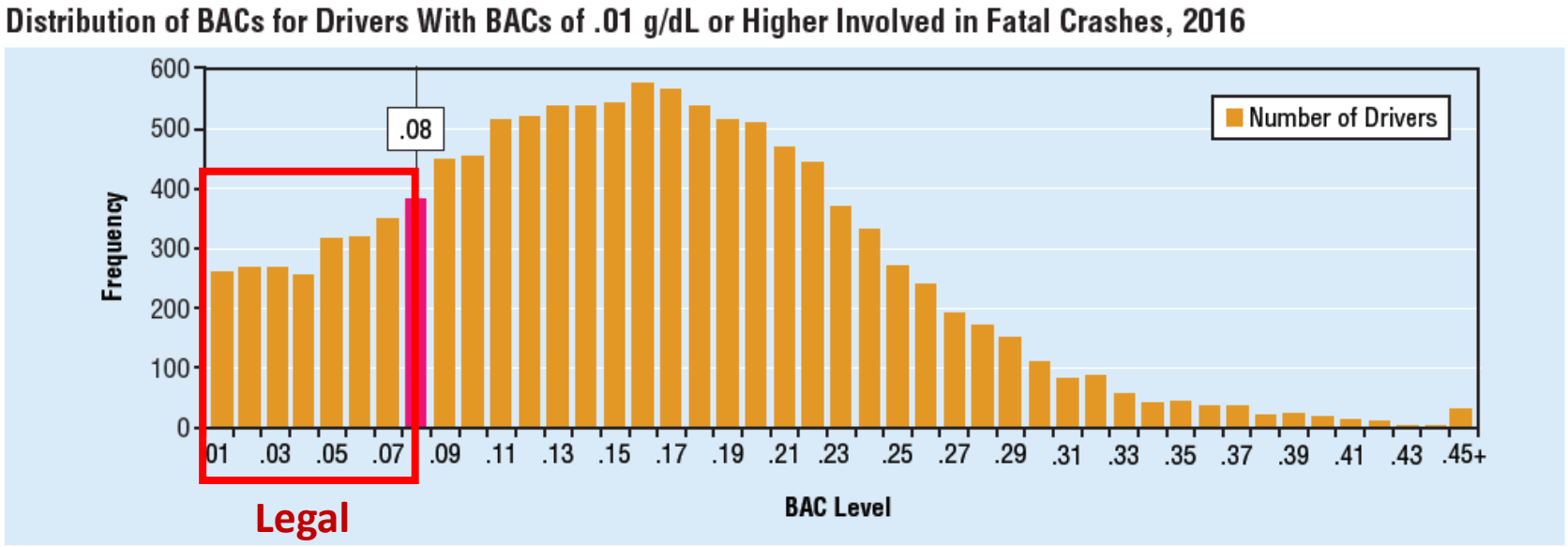
Safe/r road users and speed

Speed limits

and

Misjudgment

Safe/r road users and alcohol



Alcohol

and

Misjudgment

Diminished performance below 0.08 BAC may not be accounted for in perception reaction time assumptions for current design standards

Itani, I., Grembek, O., In preparation

Safe System: safer roads, vehicles, speeds

Mooren et al., 2011

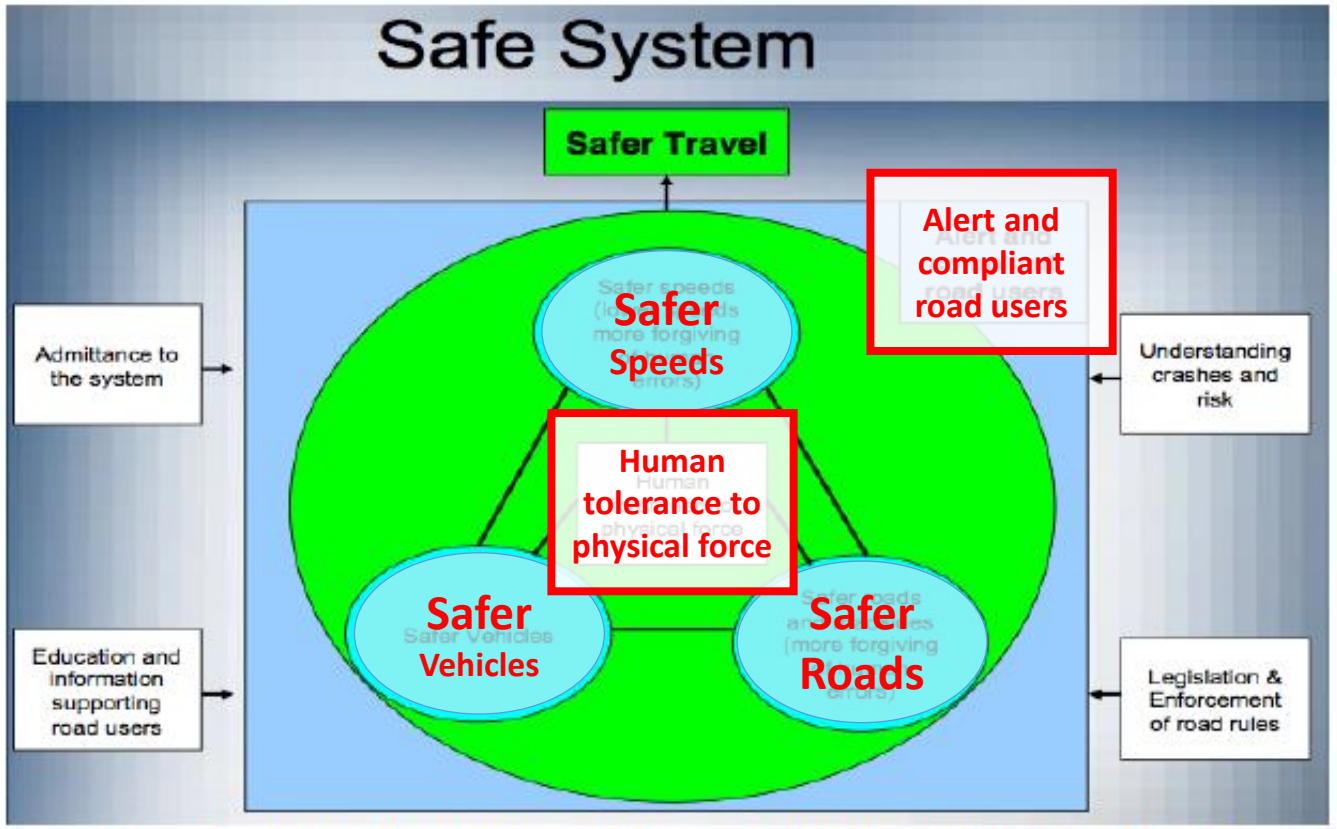


Figure 3 – The Safe System model reproduced from Howard, 2004 [25]

dangerous system

unsafe system

safe system

Where do we go from here?

Cyclist Safety Considerations

We would want alert and compliant riders, to make trips using safe bicycles, on safe street design with adequate separation from safe motorized traffic driven by alert and compliant drivers, all of which are governed by safe speeds, and supported by effective cyclist protection, and the medical emergency system, when needed.

Safety Considerations

1. street design
2. street operations
3. street-user behavior
4. street-user warning
5. street-user protection
6. emergency medical services

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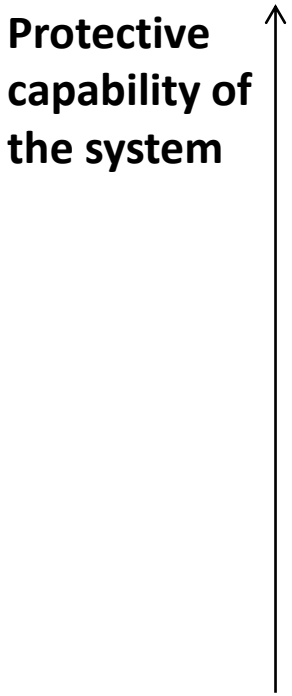

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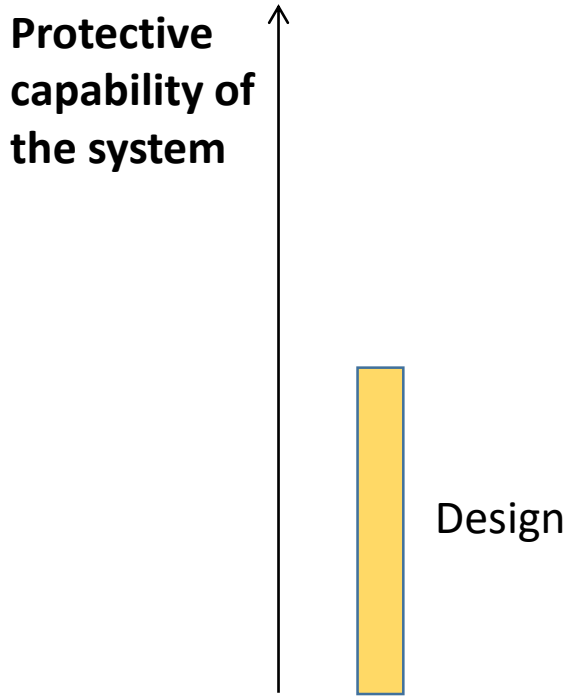

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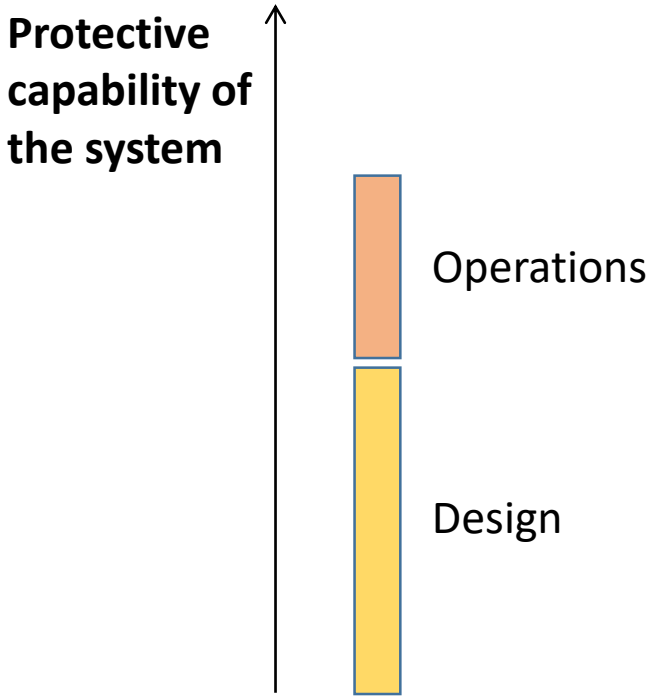

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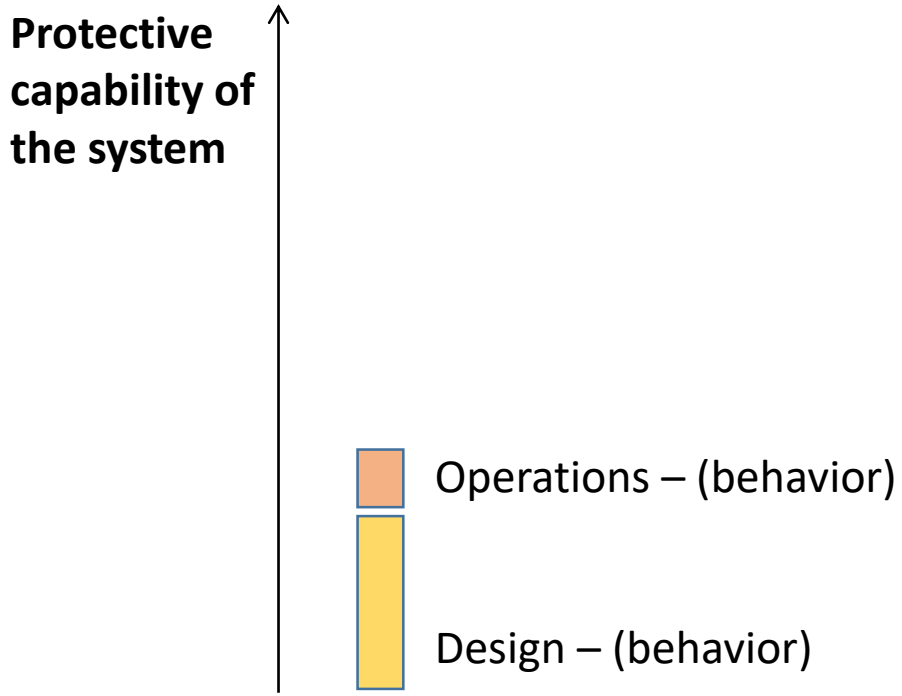

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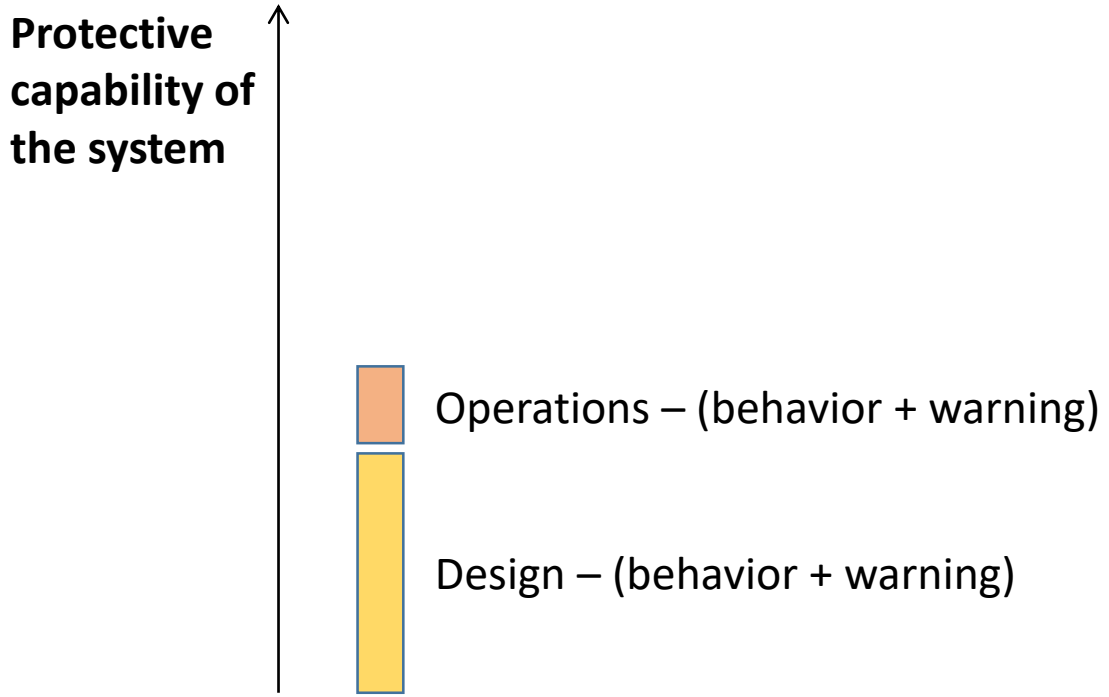

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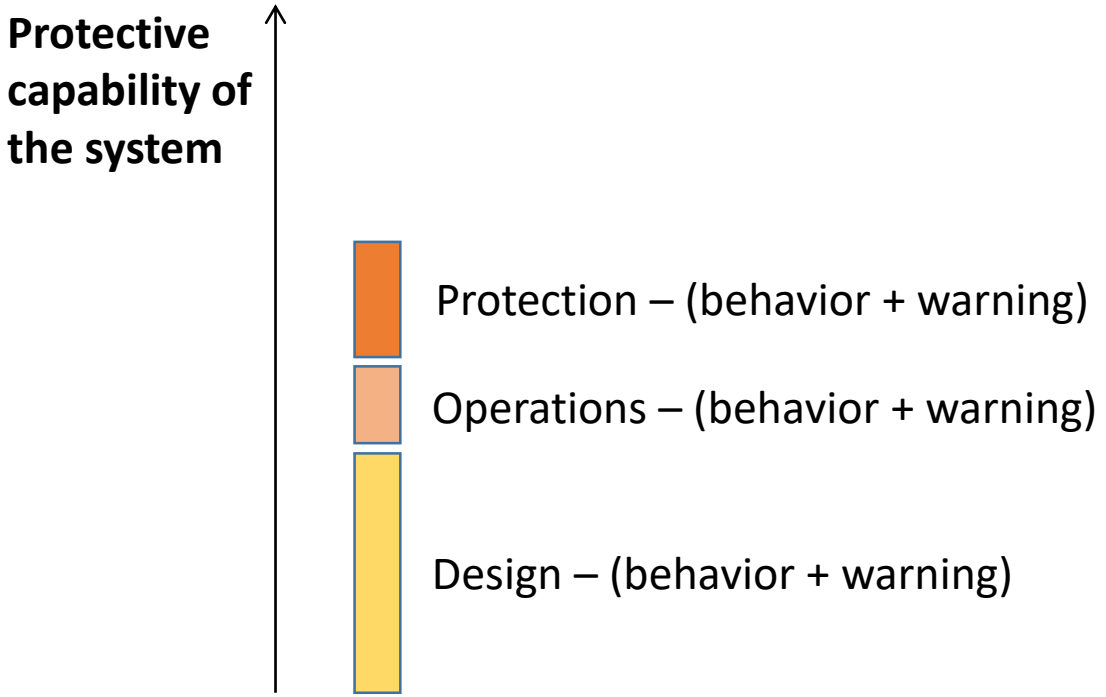

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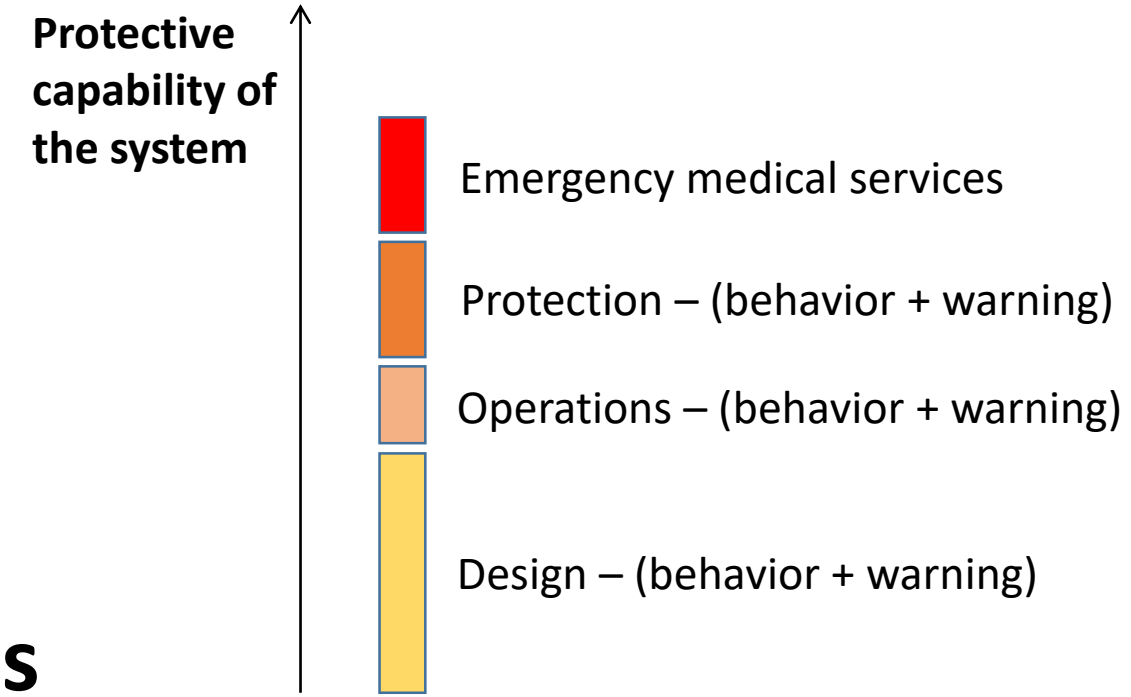

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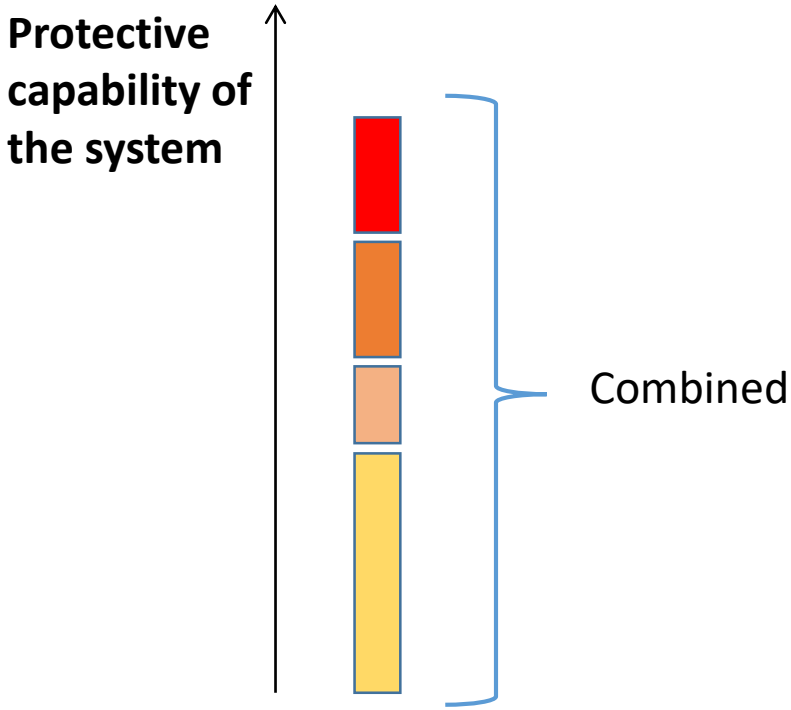
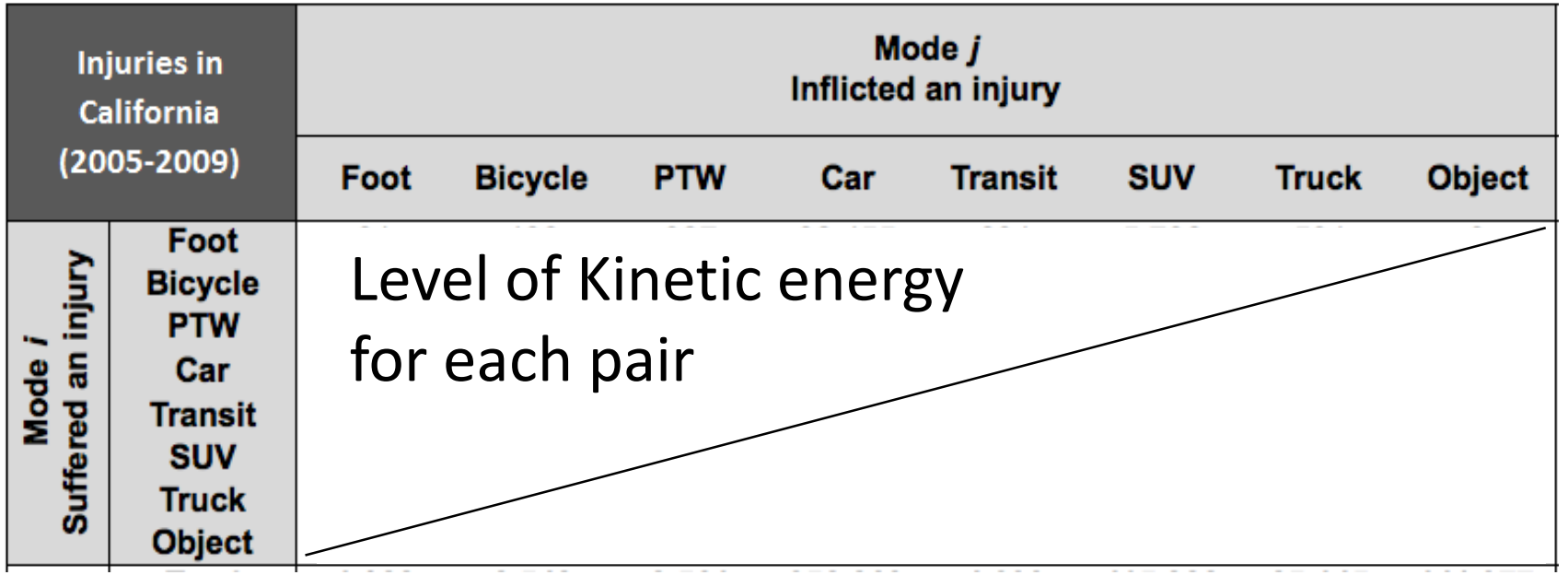


Integrated buffers of a safe system

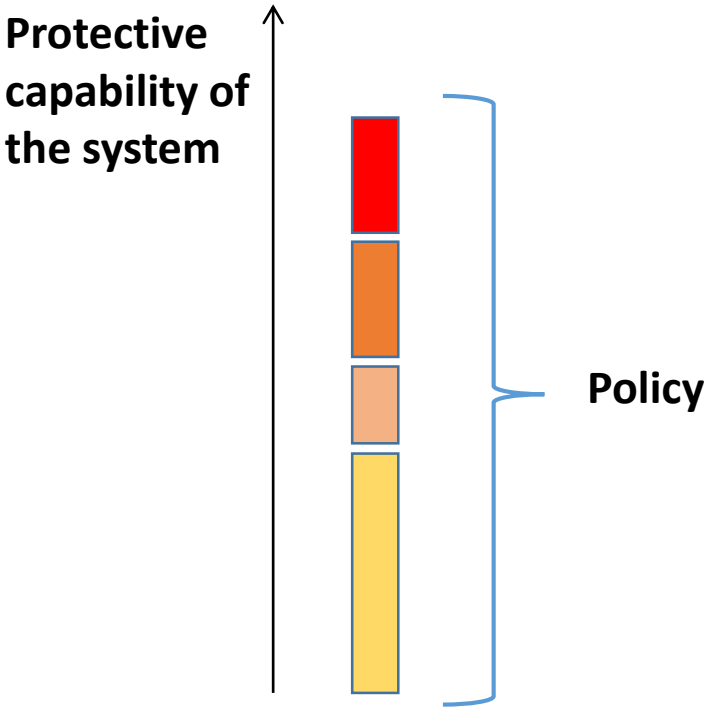
- Analyze levels of kinetic energy that road users are exposed to across different parts of the network. This will be done by mode and will be used to establish the desired capability of the system.



Policy Implications

Level of Kinetic energy carried by the users

Policy Implications



Level of Kinetic energy carried by the users

Summary

- Understand what is a safe system approach to road safety
- Recognize the different roles of the core protective opportunities provided by a safe system
- Appreciate the policy opportunities created by adding non-crash safety considerations

Thank you!

Offer Grembek, grembek@berkeley.edu

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ITSBerkeley Institute of Transportation Studies

SB1

Caltrans

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