PRIMER ON

SAFE SYSTEM APPROACH FOR PEDESTRIANS AND BICYCLISTS

U.S. Department of Transportation
Federal Highway Administration

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

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Notice

Technical Documentation Page

1. Report No. FHWA-SA-21-065	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Primer on Safe System Approach for Pedestrians and Bicyclists		5. Report Date May 2021	
		6. Performing Organization Code	
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9. Performing Organization Name and Address Vanasse Hangen Brustlin, Inc (VHB) 940 Main Campus Drive, Suite 500 Raleigh, NC 27606		10. Work Unit No.	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address Federal Highway Administration Office of Safety 1200 New Jersey Ave., SE Washington, DC 20590		13. Type of Report and Period	
		14. Sponsoring Agency Code FHWA	
15. Supplementary Notes This report was produced under the direction of Tamara Redmon (FHWA Office of Safety).			
16. Abstract Historically, crashes have been viewed as the result of an error on the part of the individual roadway user—a law or rule was broken, a wrong decision made. The Safe System approach acknowledges that humans make mistakes and, importantly, are vulnerable to the forces that occur during a crash. By focusing on eliminating fatal and serious injuries the Safe System approach inherently places a priority on pedestrians and bicyclists, who are at a higher risk of fatal or serious injury than a person driving or traveling in a motor vehicle. The purpose of this primer is to provide transportation agencies a baseline understanding of the Safe System approach and how it relates to bicycle and pedestrian safety.			
17. Key Words: Safe System, Pedestrians, Bicyclists, Ped, Bike, Vision Zero, Road to Zero, Speed, Safety,	18. Distribution Statement No restrictions.		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 29	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed pages authorized

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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Introduction and Background

Technological advances in vehicle safety features and enhanced infrastructure have contributed to decreases in some crash types over the past decade. However, pedestrian and bicycle crashes have generally risen during the same period of time (NHTSA, 2020a; NHTSA 2020b).

Historically, crashes have been viewed as an error on the part of the driver or individual roadway user—a law or rule was broken, a wrong decision made. While this may be true to some extent, many agencies are rethinking roadway design to be more forgiving. This has become particularly relevant as State and local agencies have increasingly adopted goals of zero fatalities on their roadway systems and acknowledged that no fatality is acceptable.

The **Safe System approach** recognizes that humans make mistakes and, importantly, are vulnerable to the mechanical forces that occur during a crash. In any crash, the mass and speed of the objects involved, combined with the angle of collision, produce kinetic energy which is then transferred between the objects, in this case vehicles or roadway users. Managing the kinetic energy transferred among road users is a key principle of Safe System—**this means designing and operating a transportation system that accounts for and accommodates the users most likely to be injured or killed.**

When you consider the vulnerability of a pedestrian or bicyclist without the protection of a vehicle—especially one equipped with safety technologies design to protect the passengers—reduced speeds and increased visibility have significant impacts on the severity of injuries and likelihood of surviving a crash. Consider that pedestrian crashes accounted for 17 percent of all traffic fatalities in 2018 but only 3 percent of total people injured (NHTSA, 2020a). Reducing vehicle speeds by 10 miles per hour (mph) can increase survivability of pedestrians by 40 percent (ITE, 2019).

With 81 percent of pedestrian and 79 percent of bicycle fatalities occurring in urban settings (NHTSA, 2020a; NHTSA 2020b), context matters. A Safe System is designed to encourage vehicles to operate at speeds appropriate to the context. For example, urban areas would have lower speeds due to the different types of users interacting in a space with many uses (e.g., parked vehicles, driveways, intersections).

The Federal Highway Administration (FHWA), States, and Tribal and local agencies have made strides of setting goals for zero roadway fatalities, engaging multidisciplinary teams, and developing policies and plans to improve safety. These efforts are often siloed approaches where partners work toward the same goal but in different spaces, with limited communication and collaboration between groups. The Safe System approach is not is a program, policy, or plan, but rather a shift towards a more forgiving roadway environment.

The purpose of this primer is to provide transportation agencies a baseline understanding of the Safe System approach and how it relates to bicycle and pedestrian safety. This is a brief overview of the existing literature and will set the stage for future work to come. FHWA is fully committed to this approach and encourages transportation agencies to keep abreast of this paradigm shift.

What is the Safe System Approach?

A *Safe System* is one in which there are many safeguards in place to prevent fatalities or serious injury. The Safe System approach was pioneered in Sweden throughout the 1990s and has since been applied and further developed elsewhere in Europe as well as Australia and New Zealand. It is the primary method for realizing Vision Zero, the goal of eliminating fatalities and serious injuries from the roadway system.

The Safe System approach is built around six key principles (FHWA, 2020a):

- **Death/serious injury is unacceptable.** Ideally, all crashes would be prevented. But the Safe System approach prioritizes focusing on crashes that produce fatal and serious injuries.
- **Humans make mistakes.** Humans will continue to make mistakes and the transportation system must accommodate and prepare for these mistakes. Death or serious injury should not be the consequence of user errors.
- **Humans are vulnerable.** There are known physical limits to the amount of force the human body can withstand before serious injury. System planners, designers, and operators should therefore consider the physical limits of the human body in planning, designing, and maintaining roads and vehicles and in managing speeds.
- **Redundancy is critical.** All parts of the transportation system need to be strengthened so that if one part fails the others still protect road users.
- **Safety is proactive.** Identify and mitigate risks rather than react to crashes that have already occurred.
- **Responsibility is shared.** All stakeholders (road users, system managers, vehicle designers, etc.) must work together to prevent crashes leading to fatal or serious injuries.

Tingvall & Haworth (1999) proposed two methods for realizing a Safe System:

1. Eliminate harmful events (i.e., crashes).
2. Manage the events that do occur such that the resulting forces do not reach the limit of human tolerance.

Applying the first method of eliminating crashes, road users and road user movements can be separated in space (e.g., grade separation, buffered bike lanes) or in time (traffic signal phasing, traffic demand management). These forms of separation may not eliminate crashes but can lower the likelihood of crash occurrence by decreasing road user workload and movement complexity. Safe System literature suggests that temporal separation should receive a lower weight than spatial separation (Jurewicz et al., 2015; Johansson, 2009) because temporal separation relies on user compliance with traffic control devices or other constructs.

Since the Safe System principles detailed above assume that humans make mistakes and crashes are inevitable, the second method, managing crashes and their resulting forces, becomes the focus of the Safe System approach. Planning and design of the roadway system should revolve around the level of kinetic energy transfer the human body can tolerate without being killed or seriously injured in the event of a crash. Because of this, the Safe System approach inherently prioritizes nonmotorized road users due to their vulnerable nature when compared to their counterparts traveling in motor vehicles.

Safe System for Pedestrians and Bicyclists

Transportation agencies face the challenge of improving safety for all road users, and have generally developed mode-specific programs within their departments to develop solutions related to specific modes and identified safety problems. This is especially true for nonmotorized road users. Given the rise in pedestrian and bicyclist fatalities across the U.S. in the past decade, many agencies are interested in taking steps to improve safety for the most vulnerable road users. These agencies are faced with diverging choices: push more investment into the program areas they have used in the past, or reshape their programs to more completely address crash risks for pedestrians and bicyclists. The latter approach reflects a shift away from traditional paradigms of road safety programs (e.g., separating roadway and behavioral programs and building programs around the E's of road safety) and toward a Safe System framework for addressing pedestrian and bicyclist safety.

At its core, the Safe System approach emphasizes reducing the risk of fatal and serious injuries to road users, regardless of how they choose to get around. By focusing on eliminating death and injuries the Safe System approach inherently places a priority on pedestrians and bicyclists, who are at a higher risk of death and serious injury than a person driving or traveling in a motor vehicle. Pedestrians and bicyclists make up a growing share of U.S. traffic fatalities compared with those traveling inside of vehicles, a trend which can be corrected by setting goals based on death and serious injuries, rather than crashes.

The following section examines the ways in which pedestrians and bicyclists are accounted for in each of the five distinct elements of action that comprise the Safe System approach, illustrated in figure 1.

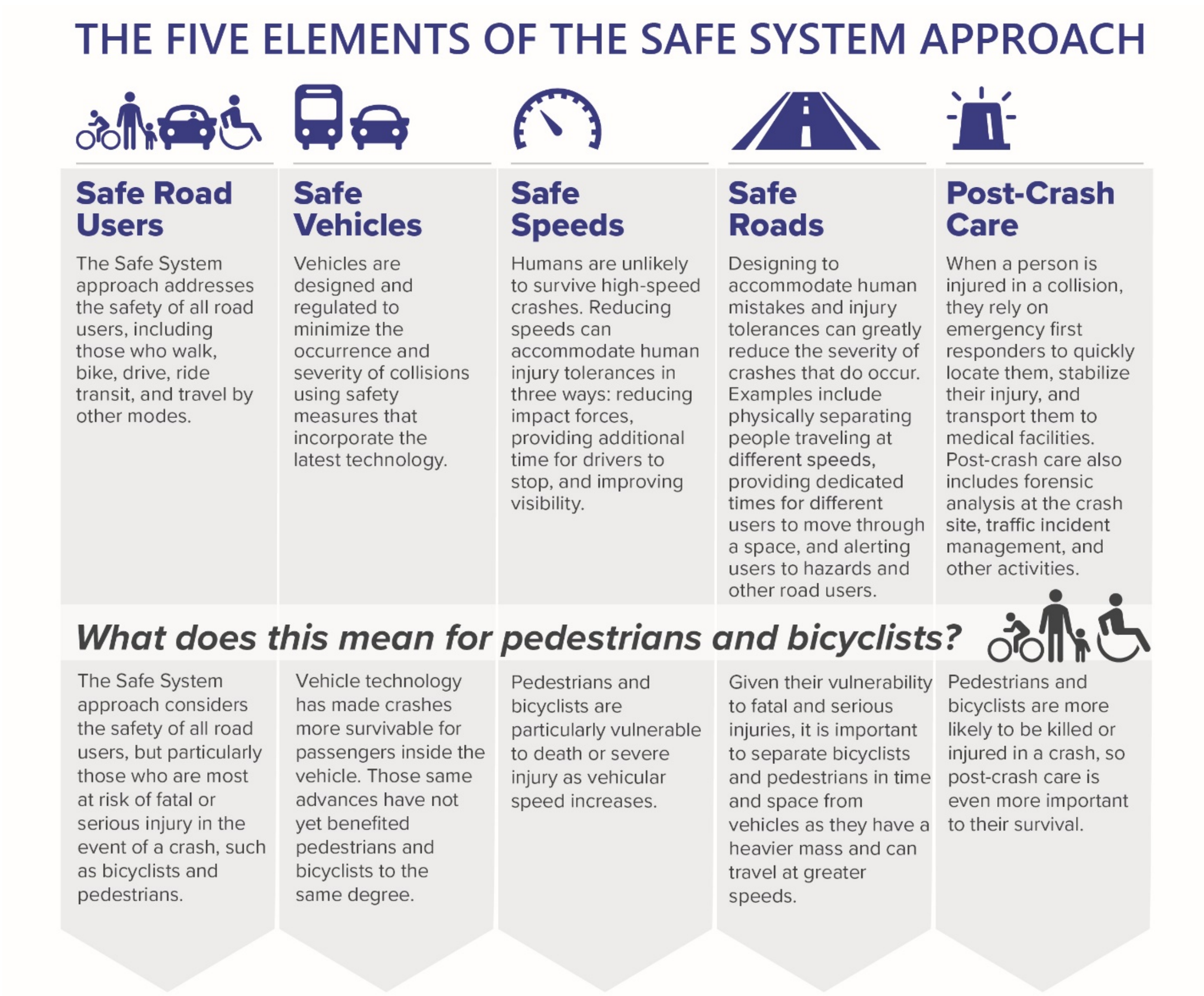


Figure 1. Graphic. The five elements of the Safe System approach and their relevance to pedestrians and bicyclists (FHWA, 2020a).

Safe Speeds

"HUMANS ARE UNLIKELY TO SURVIVE HIGH-SPEED CRASHES. REDUCING SPEEDS CAN ACCOMMODATE HUMAN INJURY TOLERANCES IN THREE WAYS: REDUCING IMPACT FORCES, PROVIDING ADDITIONAL TIME FOR DRIVERS TO STOP, AND IMPROVING VISIBILITY" (FHWA, 2020A).

As mentioned previously, the transfer of kinetic energy onto vehicles and human bodies is the primary factor that influences the severity of injuries sustained in a crash. As speeds increase, this energy transfer is more likely to result in a serious or fatal injury when a crash occurs. Figure 2 illustrates the relationship between vehicle speed and pedestrian risk of death.

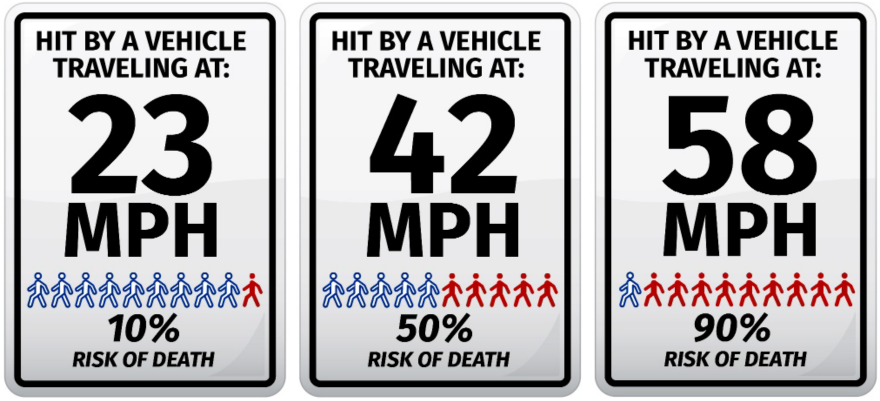


Figure 2. Graphic.Risk of pedestrian fatality based on vehicle speed, based on research from Tefft (2011).

Several other researchers have developed models to predict the risk of pedestrian fatality or serious injury based on vehicle impact speed (Tefft, 2011; Tefft, 2013; Garder, 2003; Rosen & Sander, 2009; Richards, 2010). The risk of injury or death also increases if the vehicle is larger or if the person struck is either young or old, as shown in figure 3 (Tefft, 2011).

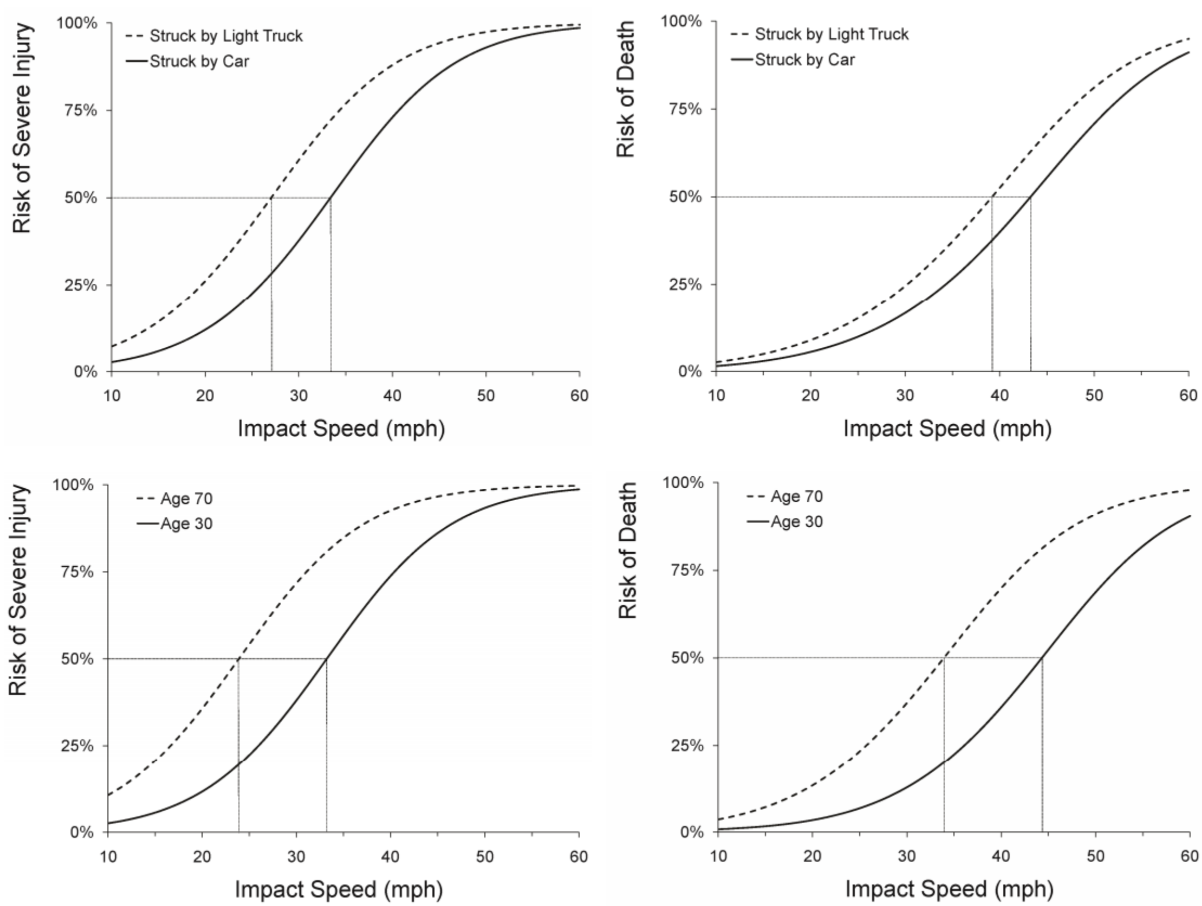


Figure 3. Graphic. Risk of severe injury and fatality based on impact speed in relation to vehicle type and pedestrian age (Tefft, 2011).

Speed also plays a critical role in the ability of a driver to detect a pedestrian or bicyclist and then avoid a crash. As speed increases, a driver will focus more on the road ahead than the roadside environment, where pedestrians, bicyclists, or other vehicles may be entering their path. By keeping operating speeds low, drivers are able to better detect pedestrians and bicyclists and have more time to avoid a collision.

In the Safe System approach, operating speed is a central factor in determining the design of a roadway and the need to separate different road users. Leaders in international road safety, including Claes Tingvall and Narelle Haworth (Tingvall & Haworth, 1999) and Roger Johansson (Johansson, 2009) identified that vulnerable road users should not be exposed to motor vehicles at speeds exceeding 20 mph (30 km/h). If this cannot be satisfied, the recommendation is to separate the movements.

Safe Roads

"Designing to accommodate human mistakes and injury tolerances can greatly reduce the severity of crashes that do occur. Examples include physically separating people traveling at different speeds, providing dedicated times for different users to move through a space, and alerting users to hazards and other road users" (FHWA, 2020a).

The design and operation of the transportation network itself—the streets and intersections that carry motor vehicle drivers and passengers, pedestrians, and bicyclists—plays a critical role in a Safe System approach. Though roadway design and engineering has traditionally been the focus of State Departments of Transportation (DOTs) and local transportation agencies, the Safe System approach presents opportunities to reconsider the assumptions and paradigms that drive the planning and design of our transportation system, beginning with the methods used to plan the transportation system. Functional classification systems traditionally used in transportation planning have been revised to reflect the context and purpose of a corridor in the new Expanded Functional Classification System for Highways and Streets (National Academy of Sciences, 2018). This new classification system allows planners and engineers the flexibility to select a roadway design that can achieve its safety and mobility goals. Previous iterations of the functional classification system limited designers to arterials, collectors, and local roads in either urban or rural settings. A designer working on an Urban Arterial, for example, might be dealing with many different land use contexts, user groups, and other characteristics. Yet, the standard category of Urban Arterial would likely dictate important design decisions such as lane width, design speed, multimodal facilities, and other important outcomes without considering these additional details. The expanded functional classification system provides more nuanced approach to design decisions. It includes five, rather than two, context settings: Rural, Rural Town, Suburban, Urban, and Urban Core. There are more roadway types, as well, with an overall emphasis on the role of the corridor within the transportation network. For the example cited earlier, a designer would now have the option to make design decisions for a Principal Arterial in the Urban Core, rather than simply an Urban Arterial. This nuanced definition sets up a design process that can more completely account for road user types, land use contexts, and other factors that should be considered when making important design decisions.

When making these design decisions in a Safe System framework, agencies emphasize the role of user expectations and the consistency and continuity of the transportation network. Rather than making standalone changes to individual segments and intersections, agencies should consider the needs of all users throughout the network and identify opportunities to mitigate factors that can increase complexity or crash risks for the most vulnerable, including:

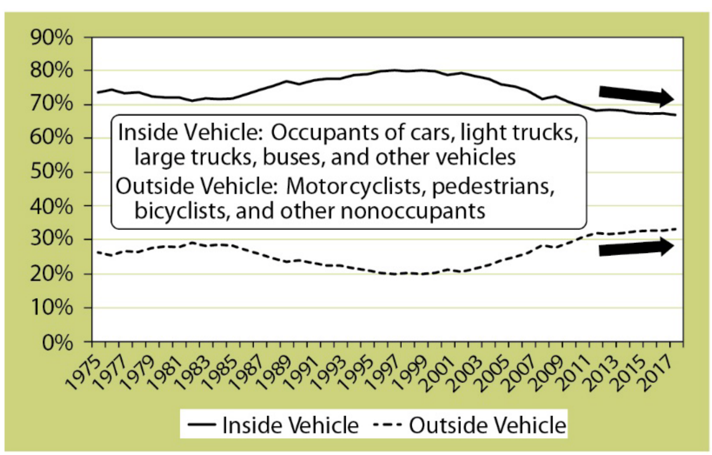
- Nonintuitive motor vehicle movements: Motor vehicle movements arriving from an unexpected direction.
- Indirect or unusual pedestrian or bicyclist paths: Pedestrian or bicyclist facilities that require or result in out-of-direction travel, such as sidewalks and bicycle facilities that end or exist only on one side of the roadway.
- Undefined crossings at intersections: Conflict zones where multiple users operate in the same space, whether turning or traveling through an intersection.
- Multilane crossings without refuge: Long crossing distances across multiple lanes present multi-threat issues and often exhibit higher vehicle speeds and traffic volumes.
- Bicyclist and motor vehicle paths crossing: Intersection approaches and conflict zones along the roadway where bicyclists are not fully separated from motor vehicles.

Several of these factors are expanded upon in NCHRP Research Report 948: *Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges* (Schroeder et al., 2021).

Safe Vehicles

"Vehicles are designed and regulated to minimize the occurrence and severity of collisions using safety measures that incorporate the latest technology" (FHWA, 2020a).

Vehicle technology and design has a major role to play in a Safe System approach for pedestrians and bicyclists. Manufacturers and designers have rolled out numerous technological advancements in recent years that protect those driving and traveling inside of motor vehicles. These technologies, termed "advanced driver assistance" by the Insurance Institute for Highway Safety (IIHS), include blind spot detection, lane departure prevention, adaptive cruise control, and both front and rear crash prevention (IIHS, 2021). The U.S. DOT also has plans to test Vehicle-to-Pedestrian (V2P) communications that can sense the environment around them and communicate that information to other vehicles, infrastructure, and personal mobile devices as noted in the *2020 Pedestrian Safety Action Plan* (USDOT, 2020). Considering the effect of these advances alongside more established technologies like seat belts and airbags, it is no wonder that national statistics show a decreasing share of traffic deaths from those individuals traveling inside of vehicles (NHTSA, 2019).



Source: FARS 1975 - 2017 Final File, 2018 ARF

Figure 4. Graphic. Proportion of U.S. traffic fatalities occurring inside and outside of vehicles, 1975-2017 (NHTSA, 2019).

A major factor influencing the safety of those outside of vehicles is the size and mass of vehicles. Coupled with high speeds, a larger and heavier vehicle colliding with another vehicle or person will transfer more kinetic energy during a crash and increase the likelihood of a serious injury or death, especially when that energy is transferred directly from the vehicle to a human body. Passenger vehicles have increased in both size and mass over the past decade, a period in which U.S. pedestrian fatalities have increased significantly. The figure below illustrates the increase in annual pedestrian fatalities alongside the rise in sales of "light trucks" and larger sport utility vehicles (SUVs).

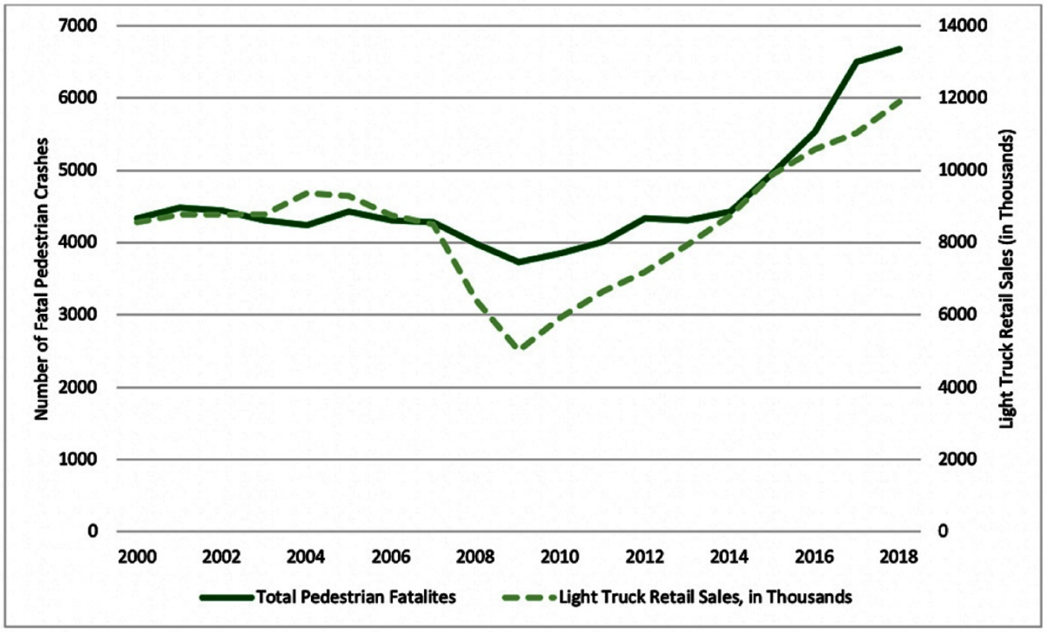


Figure 5. Graphic. Fatal pedestrian crashes (left axis) overlaid against the volume of light trucks sold in the U.S. (right axis), showing a visual correlation between vehicle size/fleet make up and pedestrian fatalities. Taken from Toward a Shared Understanding of Pedestrian Safety (Sandt et al, 2020).

The size and weight of vehicles is a complicated factor to address in a Safe System approach, and requires cooperation and collaboration with vehicle manufacturers. A shared understanding of the connection between vehicle size and safety outcomes can lead to the development of vehicle fleets that allow for safe and efficient travel while protecting all users of the road.

Vehicle technology plays a key role as well. A Safe System approach emphasizes the importance of expanding the use of proven technologies, such as those developed for vehicle drivers and passengers, as well as developing new technologies to protect those outside of vehicles. While manufacturers and designers point to pedestrian and bicyclist detection and avoidance technologies, there are numerous documented limitations to these technologies (Sandt and Owens, 2017). Under a Safe System approach, technologies that reduce injury risks for *individuals inside of vehicles* should be expanded to protect *individuals outside of vehicles*.

Safe Road Users

"THE SAFE SYSTEM APPROACH ADDRESSES THE SAFETY OF ALL ROAD USERS, INCLUDING THOSE WHO WALK, BIKE, DRIVE, RIDE TRANSIT, AND TRAVEL BY OTHER MODES" (FHWA, 2020A).

The concept of "shared responsibility," is central to a Safe System approach. In the context of pedestrian and bicyclist safety, this means that there will be a need to rebalance responsibility that has largely been placed on individual road users themselves. Researchers have demonstrated the tendency of media coverage to single out the unsafe actions of pedestrians or bicyclists as the cause of a crash, which influences public perception of these road users (Ralph et al., 2019). Oft-cited statistics claiming that more than 90 percent of crashes are the fault of road user behaviors can de-emphasize the role of the physical environment in influencing human behavior (Carter et al., 2017).

Emphasizing the need of individual road users to be safe and responsible has only limited success in achieving desired road safety outcomes. NHTSA's *Countermeasures that Work* (NHTSA, 2017), a definitive guide to behavioral road safety countermeasures, assigns only limited effectiveness to countermeasure strategies that simply communicate roles and responsibilities to pedestrians and bicyclists. Without accompanying policy or environmental modifications to influence safe behaviors, individual behaviors are not easily changed.

A Safe System offers a solution to rebalance the distribution of responsibility for road safety outcomes. While individual users play a role and their behavior is wrapped into the design of vehicles and roadways, a systems approach assigns responsibility to those who plan, build, and maintain the transportation system and the vehicles that travel upon it. When a person dies or is seriously injured, it reflects a failure of the transportation agency, the vehicle manufacturer, the policy makers, and others who make decisions that affect safety outcomes. This distributed responsibility helps stakeholders identify the elements of the system that can be further strengthened to improve safety.

Post-Crash Care

"WHEN A PERSON IS INJURED IN A COLLISION, THEY RELY ON EMERGENCY FIRST RESPONDERS TO QUICKLY LOCATE THEM, STABILIZE THEIR INJURY, AND TRANSPORT THEM TO MEDICAL FACILITIES. POST-CRASH CARE ALSO INCLUDES FORENSIC ANALYSIS AT THE CRASH SITE, TRAFFIC INCIDENT MANAGEMENT, AND OTHER ACTIVITIES" (FHWA, 2020A).

Emergency Medical Services (EMS), emergency departments, post-admit hospital care, and rehabilitation each have an important role to play in a Safe System approach to road safety. EMS response is characterized by its post-crash timing, at-scene and in-transit care, and transport to appropriately staffed and equipped facilities. EMS response goals often reference the "golden hour" as a benchmark for the rapid transport of trauma victims to a treatment facility. The distance (in time and miles) from a trauma center is clearly a factor in meeting the goal for timely arrival at the care facility. Equally important is having access to the right facility—one with the required mix of staff and equipment. As such, having sufficient trauma care resources in a geographic area is vital. Data from State Injury Surveillance Systems can help practitioners assess gaps in a State's post-crash trauma system relate to access of immediate treatment, hospitalization, and longer-term rehabilitation.

Technological advancements and intelligent transportation systems (ITS) can offer solutions that shave seconds or even minutes off of EMS response and transit times. Shorter delays in arrival at treatment facilities can decrease the likelihood of death or lasting injuries. Beyond the response and care itself, Safe System approaches must consider the forensic and aggregate analysis of crashes in order to properly prepare for treatments and resources needed. Advanced trauma centers track cases and compile data to know how best to fill the needs of their likely patients. This can happen in real time as EMS and other first responders communicate locus and extent of injuries to the medical teams awaiting the patient's arrival. Even a simple piece of information like knowing that the injured person was a pedestrian or bicyclist can help medical staff ask appropriate questions of EMS to assess likely injuries and get ready to treat the patient immediately upon arrival. It can also be a part of a trauma plan at the regional and State level designed to allocate resources effectively. Ultimately, State and regional practitioners can integrate post-crash investigations and injury surveillance system data. This helps decision makers understand their resource needs and align trauma responses to the types of cases they are most likely to see.

In addition to medical care, post-crash care also includes other aspects of roadway and safety management, such as Traffic Incident Management (TIM) technologies, strategies, and programs, as well as the judicial system components that are associated with traffic infraction adjudication. TIM is any combination of strategies designed to decrease the amount of time it takes emergency personnel to respond to and clear traffic incidents, with the objective of preventing secondary crashes, protecting the safety of emergency responders, and restoring traffic flow.

Implementing a Safe System Approach Now

While research and information regarding the Safe System approach specifically for bicycle and pedestrian needs continue to emerge, agencies can use existing structures as conduits for taking action now. National organizations, statewide and local plans, and agency practices are all opportunities to start the conversation and work towards formalizing Safe System approaches. Many of the approaches described in the following section rely on feedback from multiple stakeholders, which already lays the framework for cross collaboration and buy-in.

Broader Strategies

The Safe System approach was born from international Vision Zero efforts, and is based in the belief that all fatalities resulting from roadway crashes are preventable (Johansson, 2009; Tingvall & Haworth, 1999). Cities, counties, and Metropolitan Planning Organizations (MPOs) across the country are committing to Vision Zero and developing plans that detail strategies for eliminating all roadway fatalities. The primary focus of managing speeds and prioritizing the safety needs of vulnerable road users align with the Safe System concepts, and the action plans allow transportation agencies to formalize the strategies into planning, design, and policy initiatives.

Similarly, the National Safety Council's Road to Zero (RTZ) Coalition seeks to eliminate traffic fatalities in the U.S. by 2050, detailed in an extensive report with three main initiatives: double down on what works through proven, evidence-based strategies; advance life-saving technology in vehicles and infrastructure; and prioritize safety by adopting a Safe System approach and creating a positive safety culture (2021). The RTZ plan aligns with the growing movement of Vision Zero goals, efforts, and action plans adopted across the country and provides a national context and motivation for implementing and formalizing a Safe System approach in the U.S. RTZ understands that to be fully effective, all agencies need to adopt a culture of safety.

Federal Programs

The Highway Safety Improvement Program (HSIP) is a core Federal-aid program that requires States to adopt a data-driven, strategic approach to improving highway safety with the purpose of reducing traffic fatalities and serious injuries (FHWA, 2021a; Finkle et al., 2020). HSIP requires States to identify and dedicate funding to projects addressing safety, taking a proactive approach to safety management. States also send annual safety performance targets for addressing fatalities and serious injuries. The annual targets must align with the State's Strategic Highway Safety Plan (SHSP), a component of the HSIP. SHSPs are data-driven, strategic plans developed in partnership with multidisciplinary teams that identify the State's key safety needs and detail actions to address the safety concerns (FHWA, 2021c). Many States include specific Emphasis Areas for pedestrians, bicyclists, and vulnerable users that detail countermeasures, data, and stakeholders working toward statewide goals.

As a whole, both the HSIP and SHSP components either partially or fully align with a Safe System approach and can provide a foundation for fully incorporating the approach into the State's processes. Both HSIP and SHSP can act as the foundation for institutionalizing the Safe System tenets in a State's safety processes. California, Washington State, and others explicitly discuss the topic as a fundamental theme in their SHSPs (Caltrans, 2020; Washington State DOT, 2019).

State and Local Safety Efforts – Policies, Plans, and Programs

There are several ways that the Safe System principles have already begun to be applied to roadway design in the U.S. to reduce the transfer of kinetic energy resulting from crashes. One primary method is speed management, accomplished through speed limit reductions or various roadway and intersection features that encourage slower interactions between roadway users. For example, many local agencies across the U.S. have adopted Complete Streets policies that support the implementation of separated bike facilities, road diets, protected intersections, and other measures that lower speeds, separate movements, and reduce crash severity. Alternative and emerging intersection designs may incorporate Safe System principles through removal of conflict points and reduction of vehicle speeds or movement complexity. Additionally, kinetic energy management metrics can be incorporated into performance-based planning and design. Tingvall & Haworth (1999) noted that one of the first steps road planners, designers, and operators might take—even in the absence of a broader political commitment for achieving a Safe System—is to analyze and/or rank infrastructure from a kinetic energy management perspective. Addressing speed at the contextual level can result in significant safety improvements.

At a planning level, many State and local transportation agency safety-related plans embody Safe System principles (Boodlal et al., 2021). Mode-specific Bicycle and Pedestrian Safety Action Plans are specifically directed at improving safety for non-motorized road users. More broadly, local roads have higher rates of fatalities and serious injury crashes than their more traveled State highways, and Local Road Safety Plans (LRSP) provide transportation agencies a framework for identifying, analyzing, and prioritizing safety improvements on such roads (FHWA, 2017; FHWA, 2021b).

Through each of these types of plans, multidisciplinary and collaborative teams address safety with data-driven approaches to match safety problems and locations with improvements. In alignment with the Safe System approach, the plans evaluate interaction between transportation modes, traffic laws, and the corridor and community context.

Safety Culture and Agency Structure

A Safe System requires broad, sustained political commitment. The Safe System approach provides the background for these efforts but also requires working towards actionable programs and tools that impact design, investments, and strategies that also encourage safer user behaviors. This often requires establishing a safety culture by adjusting internal agency cultures to align with the Safe System principles and elements.

The system aspect of the Safe System approach requires strong partnerships and collaboration across departments and between agencies. This means integrating safety needs across departments or units instead of in confining them to a separate group. For example, the North Carolina SHSP includes Safety Culture as the fifth Focus Area, which explores how safety can be included in all statewide practices from considering land use, road function, and context to enforcement and adjudication policies and practices (NCDOT, 2019). The Ohio Department of Transportation leverages its HSIP to fund bicycle and pedestrian projects by connecting multimodal needs with safety. Locally, Vision Zero cities are leaders in safety culture and are typically supported by a strong, and very public, political commitment to improving transportation safety. Through San Francisco's Vision Zero efforts, departments across the City collaborate to eliminate traffic deaths and reduce serious injuries on City streets. One example of this is San Francisco's Vision Zero SF Injury Prevention Research (VZIPR) Collaborative which brings together epidemiologists, trauma surgeons, emergency physicians, nurses, geospatial analysts, and other staff from the San Francisco Department of Public Health. The VZIPR Collaborative highlights the use of public health data and evidence to support traffic safety initiatives (Vision Zero SF, 2019).

Research

Finally, agencies can conduct, support, and invest in research to better inform implementation of the Safe System approach. Potential topics may include user-specific research, such as pedestrian and bicyclist risk of fatal or serious injury, road user characteristics, and human factors considerations (e.g., traffic control compliance, fatigue, distraction). Speed may be researched through kinetic energy transfer, classification of crashes, vehicle speed prediction, and the effectiveness of speed management. Equity and the Safe System approach is a broader topic that impacts all other research topics. The Virginia DOT analyzed pedestrian crashes with respect to the State Department of Health’s Health Opportunity Index and ultimately quantified the strong connection between pedestrian crashes and other socio-economic determinants of health (FHWA, 2020b).

While not all-inclusive, the research topics presented here cover foundational topics and the core of the Safe System approach as it relates to pedestrians and bicyclists. Research should continue to evaluate the impact of Safe System approaches that are being institutionalized through HSIP, SHSPs, local planning efforts, and agency-level policies and practices. Lessons learned and best practices are essential tools for widespread adoption and implementation.

Ongoing Work and Upcoming Resources

While the Safe System approach has been a common framework for road safety programs in many parts of the world for decades, it has only become part of U.S. practice in recent years. For that reason, there is an ever-evolving collection of research, tools, and resources that can support agencies in their efforts to integrate a Safe System approach in their practices. The following resources can serve as a starting point for agencies having these conversations.

***A Safe System-Based Framework and Analytical Methodology for Assessing Intersections* (Federal Highway Administration)**
This report provides a technical basis that practitioners can apply Safe System principles to inform intersection planning and design decisions. It relies on commonly-available project-level data and results in objective performance metrics (Porter et al., 2021).

***Safe System Framework* (Institute of Transportation Engineers)**
This resource lays out a concise framework that reflects key principles of a Safe System approach to road safety programs (ITE, 2019).

***Implementing Safe Systems in the United States: Guiding Principles and Lessons from International Practice* (Collaborative Sciences Center for Road Safety)**
This research report explains the concept of Safe System and draws connections between established programs in international settings and opportunities for implementation in the United States (Dumbaugh et. al, 2019).

***Guide to Developing a Vision Zero Plan* (Collaborative Sciences Center for Road Safety)**
This resource lays out a comprehensive strategy for developing a plan of action to drive a community's Vision Zero program. It focuses on critical steps to develop a high-quality, action-oriented plan, including public participation, analysis of trends, development of goals and objectives, and methods for measuring implementation (LaJeunesse et. al, 2020).

***Vision Zero Safety Procedures* (North Carolina Vision Zero)**
This brief, practitioner-oriented guide synthesizes a short list of the most effective ways to improve road safety through a Vision Zero program (NC Vision Zero, 2020b).

***Vision Zero Implementation Milestone Checklist* (North Carolina Vision Zero)**
This checklist allows communities to consider the resources and timeline needed to implement their adoption and implementation of Vision Zero programs (NC Vision Zero, 2020a).

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Appendix A: Safe System Benchmarking Tool

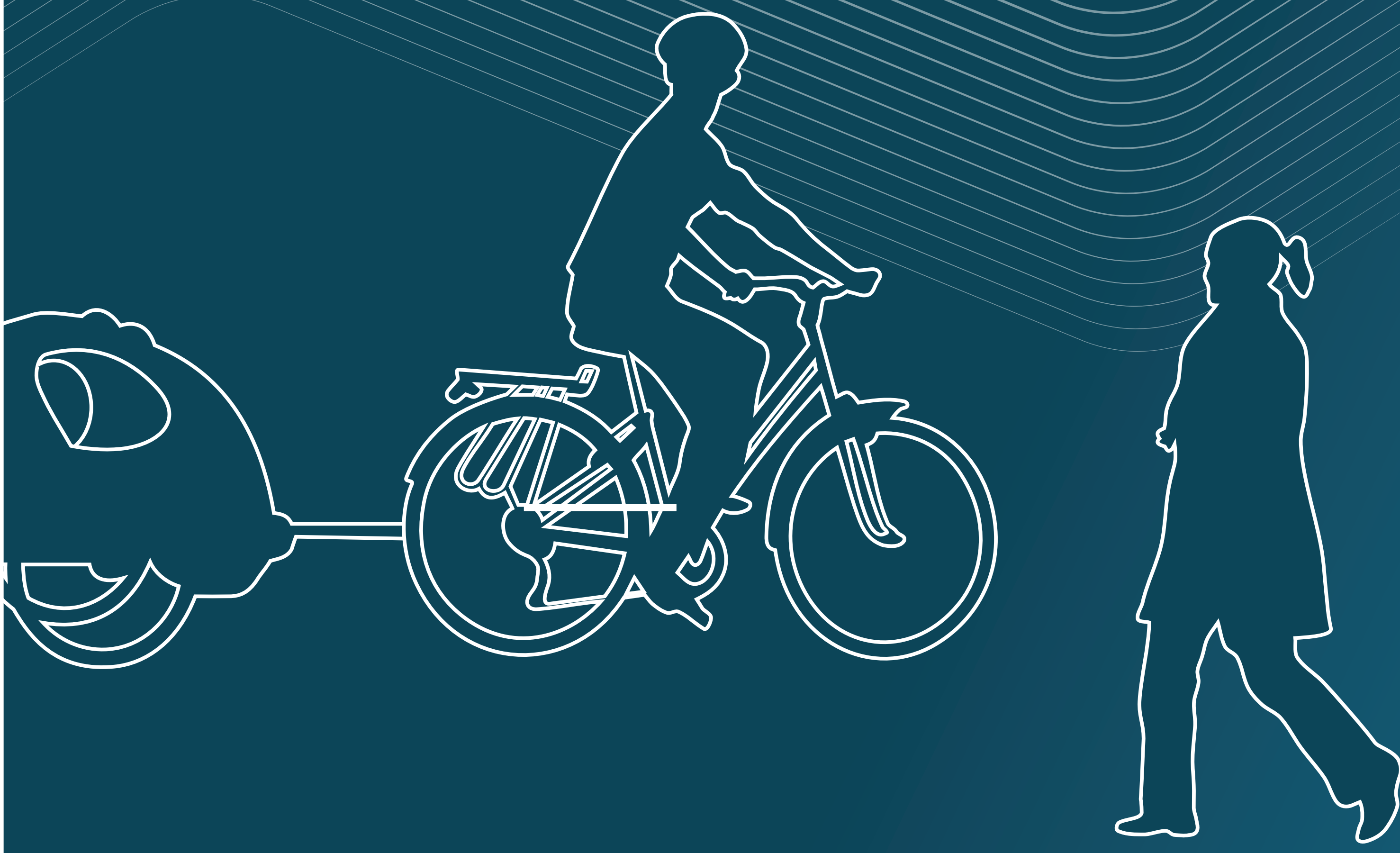
The following is a tool to help agencies investigate ways to incorporate the Safe System approach into their business practices. This tool is not all encompassing, but is a collection of ideas and some potential resources derived in part from recommendations included in the FHWA resource, *Integrating the Safe System Approach with the Highway Safety Improvement Program* (Finkle et al., 2020). This tool is meant to be adapted and edited as more information becomes available or as agencies identify new opportunities to incorporate the Safe System approach.

Core Element	Category	Benchmark	Assessed Level of Commitment/Implementation			
			Not a Current Practice	Occasional Practice	Institutionalized Practice	Resource
Safe Users	Education	Perform outreach through educational programs on rules of the road and the use of protective equipment, with a focus on those behaviors and target audiences most linked to death and serious injuries.				NHTSA. (2017). Countermeasures That Work: A Highway Safety Countermeasure Guide For State Highway Safety Offices, Ninth Edition, 2017. https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/812478_countermeasures-that-work-a-highway-safety-countermeasures-guide-.pdf
		Install advisory signs for curves and speed zones, as well as speed feedback signs and chageable message signs, to provide warnings and encourage safe behavior.				
		Use demonstration projects to raise awareness of new designs and encourage support for controversial safety projects among stakeholders.				ITF, Zero Road Deaths and Serious Injuries. (2016). 45, http://www.towardszerofoundation.org/wp-content/uploads/2016/10/Zero_road_deaths-SafeSystems.pdf.
	Enforcement	Investigate and document the impacts of traffic safety enforcement and traffic safety surveillance on minority communities.				Pryor, M., Goff, P.A., Heydari, F., and Friedman, B. (2020). Collecting, Analyzing, and Responding to Stop Data: A Guidebook for Law Enforcement Agencies, Government, and Communities. Center for Policing Equity.
		Reallocate enforcement activities to target those behaviors and locations most linked to death and serious injury.				Example: City of Sacramento, Vision Zero Sacramento: Action Plan. 2018, August. https://www.cityofsacramento.org/-/media/Corporate/Files/Public-Works/Transportation/VisionZero/Vision-Zero-Action-Plan-Adopted-August-2018.pdf?la=en.
	Research	Develop and implement strategies for robust demographic data collection in crash reporting.				
Safe Roadways	Collision avoidance	Systemically install proven countermeasures to separate users in space, separate users in time, and increase attentiveness and awareness, such as: protected signal phases, clear zones, and vertical and horizontal separation for pedestrians and bicyclists.				Example: Caltrans, 2016 Pilot Pedestrian Collision Monitoring Program, retrieved from https://dot.ca.gov/-/media/dot-media/programs/safety-programs/documents/ped-bike/f0018144-2016-pilot-pedestrian-collision-monitoring-program-fact-sheet-version-1-a11y.pdf.
		Complete infrastructure connectivity for pedestrians and bicyclists and make progress toward providing separation where needed based on crash exposure, crash history, and characteristics of the roadway and adjacent land use associated with higher levels of use.				Example: Washington Traffic Safety Commission, Washington State Strategic Highway Safety Plan 2019 (2019), http://targetzero.com/wp-content/uploads/2020/03/TargetZero2019_Lo-Res.pdf.
	Kinetic energy reduction	Systemically install proven countermeasures to manage motor vehicle speed and collision angles, such as roadside appurtenances, roundabouts, refuge islands, hardened center lines, and road diets.				Hawkins, N., and Hallmark, S. (2020). Noteworthy Speed Management Practices. Federal Highway Administration and Institute of Transportation Engineers. FHWA-SA-20-047. https://www.ite.org/pub/?id=BCD0260A-BF52-D7D0-44BD-1C3CBE531AE8
		Evaluate intersection design and control decisions in the planning or scoping stage for opportunities to reduce kinetic energy transfer, following new FHWA guidance.				FHWA (forthcoming), *A Safe System-Based Framework and Analytical Methodology for Assessing Intersections.*
	Policies and tradeoffs	Designate functional class and modal priority for roadways to pinpoint the most effective safety countermeasures and streamline tradeoff decisions.				National Academies of Sciences, Engineering, and Medicine. (2018). An Expanded Functional Classification System for Highways and Streets. Washington, DC: The National Academies Press. https://doi.org/10.17226/24775.
		Ensure safety for all users is prioritized, and accessibility maintained, during construction and road maintenance projects.				Webinar: Improving Pedestrian and Bicyclist Safety in Work Zones. (2019). http://pedbikeinfo.org/webinars/webinar_details.cfm?id=92
	Innovation	Provide infrastructure for smarter roadways and intelligent transportation systems (ITS) in support of data collection and analysis, as well as proactive system management.				
		Use pilot projects to measure safety effects, and encourage innovation and design flexibility.				ITF, Zero Road Deaths and Serious Injuries. (2016). 45, http://www.towardszerofoundation.org/wp-content/uploads/2016/10/Zero_road_deaths-SafeSystems.pdf.
		Form design innovation working groups to initiate and research new interventions to safety challenges.				Texas Transportation Researcher, Two Decades of Super 2 Research and Implementation for TxDOT Continue to Produce Benefits, retrieved from https://tti.tamu.edu/researcher/two-decades-of-super-2-research-and-implementation-for-txdot-continues-to-produce-benefits/.

Core Element	Category	Benchmark	Assessed Level of Commitment/Implementation			
			Not a Current Practice	Occasional Practice	Institutionalized Practice	Resource
Safe Vehicles	**Supportive infrastructure**	Enable infrastructure-to-vehicle communication to provide warnings to drivers that support safe behavior.				1) D. McTiernan and A. Rensen, "The Safe System Hierarchy of Control Framework for Local Roads," in Australasian Road Safety Conference (Canberra, ACT, Australia: September 2016). 2) Example: Caltrans, Strategic Highway Safety Plan, 58, retrieved from https://dot.ca.gov/-/media/dot-media/programs/safety-programs/documents/shsp/2020-2024-shsp-report.pdf.
		Provide supportive infrastructure for autonomous vehicles to enable active safety technology.				Example: Washington Traffic Safety Commission, Washington State Strategic Highway Safety Plan 2019 (2019), 190–191, http://targetzero.com/wp-content/uploads/2020/03/TargetZero2019_Lo-Res.pdf.
	Vehicle design	If applicable, collaborate with or lobby the automobile industry to prioritize safety technology including active and passive strategies, such as: 1) active: autonomous emergency braking, lane departure warning, blind spot monitoring, speed alerts, bicyclist and pedestrian detection, vehicle size and design, and 2) passive: seatbelts and airbags, crumple zones, emergency braking, electronic stability control, and pedestrian airbags.				Sandt, L. and Owens, J.M. (2017). Discussion Guide for Automated and Connected Vehicles, Pedestrians, and Bicyclists. Pedestrian and Bicycle Information Center. Chapel Hill, NC. http://www.pedbikeinfo.org/cms/downloads/PBIC_AV_Discussion_Guide.pdf.
	Data	Collect data about the involvement of AVs in crashes for future data analysis, and to inform design and policies.				Example: Washington Traffic Safety Commission, Washington State Strategic Highway Safety Plan 2019 (2019), 190–191, http://targetzero.com/wp-content/uploads/2020/03/TargetZero2019_Lo-Res.pdf.
Safe Speeds	**Design and operations**	Adopt roadway design standards that are focused on speed management, such as target speed-based design. Adjust roadway geometries for context-appropriate speeds.				1) Federal Highway Administration (FHWA), "USLIMITS2," page last modified April 28, 2020, https://safety.fhwa.dot.gov/uslimits/. 2) Institute of Transportation Engineers, ITE Recommended Practice on Designing Walkable Urban Thoroughfares: A Context Sensitive Approach (2010), https://www.ite.org/pub/?id=E1CFF43C-2354-D714-51D9-D82B39D4DBAD. 3) Example: City of Sacramento, Vision Zero Sacramento: Action Plan (August 2018), https://www.cityofsacramento.org/-/media/Corporate/Files/Public-Works/Transportation/VisionZero/Vision-Zero-Action-Plan-Adopted-August-2018.pdf?la=en.
		Use speed harmonization strategies to achieve safe speeds in congested areas.				https://www.fhwa.dot.gov/publications/research/operations/15012/15012.pdf.
	Enforcement	Deploy automated speed enforcement, with a focus on equitable fee structures.				Poole, B., Johnson, S., and Thomas, L. (December 2017). An Overview of Automated Enforcement Systems and Their Potential for Improving Pedestrian and Bicyclist Safety. Pedestrian and Bicycle Information Center. Chapel Hill, NC. http://www.pedbikeinfo.org/cms/downloads/WhitePaper_AutomatedSafetyEnforcement_PBIC.pdf.
	Policy and training	Follow speed limit setting methodologies that determine appropriate speeds based on roadway context and modal priority, rather than the historic behavior of road users. Set speed limits based on the human body's ability to tolerate crash forces.				1) FHWA, Speed Management: A Manual for Local Rural Road Owners, FHWA-SA-12-027 (November 2012), https://safety.fhwa.dot.gov/local_rural/training/fhwasa010413spmgmt/. 2) FHWA, Speed Management Toolkit, FHWA-SA-15-017, https://safety.fhwa.dot.gov/speedmgt/ref_mats/docs/speedmanagementtoolkit_final.pdf.
		Provide speed management training to staff focused on injury minimization.				Example: Washington Traffic Safety Commission, Washington State Strategic Highway Safety Plan 2019 (2019), http://targetzero.com/wp-content/uploads/2020/03/TargetZero2019_Lo-Res.pdf.
Post Crash Care	**Traffic incident management**	Provide infrastructure to support emergency services equipment at crash sites for quick response and proper triage (this is especially important in rural communities).				
	Crash investigation	Enhance reporting practices to ensure complete and accurate data collection and documentation of road user behavior and infrastructure.				
		Create a feedback loop such that key insights from crash investigations are shared with roadway designers and/or influence outreach and education.				
	Partnerships	Share data across agencies and organizations, including first responders and hospitals, to develop a holistic understanding of the safety landscape and improve accuracy.				Vision Zero SF, "Evaluating & Monitoring Our Progress," retrieved from https://www.visionzerosf.org/vision-zero-in-action/evaluating-monitoring-our-progress/.
		Connect with victims' families and the advocacy community to offer support and resources, and encourage partnerships with outreach and education.				

Core Element	Category	Benchmark	Assessed Level of Commitment/Implementation			
			Not a Current Practice	Occasional Practice	Institutionalized Practice	Resource
Safety Planning and Culture	Redundancy	When deploying safety interventions, define primary and secondary countermeasures as packages across the Safe System elements to provide redundancy.				Austroads, Safe System Roads for Local Government (April 2016), https://austroads.com.au/publications/road-safety/ap-r518-16/media/AP-R518-16_Safe_System_Roads_for_Local_Government.pdf.
	Data and analysis	Apply a proactive and transparent approach to data-driven safety analysis, including the use of systemic profiles, roadway and roadside condition, and modal specific condition assessments (e.g., bicycle network stress or distance between marked crossings).				National Academies of Sciences, Engineering, and Medicine 2018. Systemic Pedestrian Safety Analysis. Washington, DC: The National Academies Press. https://doi.org/10.17226/25255. Example: Seattle Department of Transportation. (2016). City of Seattle Bicycle and Pedestrian Safety Analysis. Phase 1. https://www.seattle.gov/Documents/Departments/SeattleBicycleAdvisoryBoard/presentations/BPSA_Draft_Public_093016.pdf. Example: Seattle Department of Transportation. (2020). City of Seattle Bicycle and Pedestrian Safety Analysis. Phase 2. https://www.seattle.gov/Documents/Departments/SDOT/VisionZero/SDOT_Bike%20and%20Ped%20Safety%20Analysis_Ph2_2420(0).pdf
		Focus network screening and benefit/cost calculations on fatal and serious injuries, instead of all collisions, to identify the core safety issues for human vulnerability.				1) Example: Arizona Department of Transportation (ADOT), Arizona Highway Safety Improvement Program Manual (2018), 12, https://azdot.gov/sites/default/files/2019/06/2015-hsip-manual.pdf. 2) Example: Caltrans, 2016 Pilot Pedestrian Collision Monitoring Program, retrieved from https://dot.ca.gov/-/media/dot-media/programs/safety-programs/documents/ped-bike/f0018144-2016-pilot-pedestrian-collision-monitoring-program-fact-sheet-version-1-a11y.pdf.
		Connect each emphasis area in a Safety Plan to roadway or contextual safety contributing factors, such as the disproportionate number of fatalities and serious injuries among pedestrians in communities of color, and recognize this specific factor for pedestrian crashes—higher rates of crashes in minority communities—where transportation system gaps (e.g., sidewalks/bike lanes/crossing opportunities) can help proactively inform recommendations.				1) Safe Routes to School National Partnership, At the Intersection of Active Transportation and Equity, retrieved from https://www.saferoutespartnership.org/sites/default/files/resource_files/at-the-intersection-of-active-transportation-and-equity.pdf. 2) Example: Washington Traffic Safety Commission, Washington State Strategic Highway Safety Plan 2019 (2019), 126, http://targetzero.com/wp-content/uploads/2020/03/TargetZero2019_Lo-Res.pdf.
		Use innovative data collection and analysis approaches, such as crowdsourcing or video detection data, to identify emphasis areas related to near misses or crashes previously unreported by vulnerable communities.				Example: Loewenherz, F., Bahl, V., and Wang, Y. (2017). Video Analytics towards Vision Zero. ITE Journal. Volume 87, Issue 3. https://trid.trb.org/view/1459592.
	Leadership and commitment	Organize a Safety Plan around the Safe System Core Principles and Elements OR perform a Safe System assessment to determine how well each Safety Plan emphasis area aligns with the Safe System elements and principles, and make adjustments as necessary.				LaJeunesse, S., Naumann, B., Sandt, L., Spade, C., and Evenson, K. (2020). Guide to Developing a Vision Zero Plan. Collaborative Sciences Center for Road Safety. https://www.roadsafety.unc.edu/wp-content/uploads/2020/08/CSCRS_VZGuide_FINAL.pdf. Example: Vision Zero Implementation Milestone Checklist (North Carolina Vision Zero). https://ncvisionzero.org/wp-content/uploads/2020/06/NCVZ_ImplementationChecklist.pdf.
		Commit to a "Zero" Goal and establish performance management strategies.				
		Backcast to establish the rate of decrease in fatalities and serious injuries needed to achieve zero by the target year. This approach will show the level of investments necessary to reach long-term goals.				J. Holmberg and K-H Robèrt, "Backcasting from Non-overlapping Sustainability Principles – a Framework for Strategic Planning," International Journal of Sustainable Development and World Ecology 7 (2000): 291-308.
		Implement a monitoring process to measure against the backcasting trend and force intervention changes the agency is not on track.				John Whitelegg and Gary Haq, *Vision Zero: Adopting a Target of Zero for Road Traffic Fatalities and Serious Injuries* (Stockholm Environment Institute: 2006).
		Establish key performance indicators (KPIs). These key performance indicators could be tied to each of the five Safe System elements or a particular strategy.				European Commission, EU Road Safety Policy Framework (2019): 5-10. https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/1_en_document_travail_service_part1_v2.pdf.

Core Element	Category	Benchmark	Assessed Level of Commitment/Implementation			
			Not a Current Practice	Occasional Practice	Institutionalized Practice	Resource
Safety Planning and Culture (cont.)	**Public relations**	Safety leaders show buy-in for the Safe System approach through media, public events, and support for related policies and programs.				
	Funding	Change project evaluation methods for funding to primarily focus on fatal and serious injury crash reduction opportunities.				
		Use equity considerations in project prioritization, with a change to benefit-cost analysis or through a set-aside program.				
		Instutionalize safety considerations in all project types to systematically fund projects through operations and mainteance efforts (such as repaving projects).				
	Development review	Conduct safety impact assessments of new developments to identify mitigation and cost sharing opportunities.				
	Equity first	Clearly define equity in Safety Plans and include equity considerations throughout the emphasis areas and strategies.				1) FHWA, Environmental Justice, Title VI, Non-Discrimination, and Equity, retrieved from https://www.fhwa.dot.gov/environment/environmental_justice/equity/ 2) Example: New Jersey Department of Transportation, New Jersey 2020 Strategic Highway Safety Plan, retrieved from https://www.saferoadsforallnj.com/resources.
		Incorporate equity considerations in implementation and assessment plans, such as goals related to safety improvements for populations that are traditionally underserved.				1) FHWA, Environmental Justice, Title VI, Non-Discrimination, and Equity, retrieved from https://www.fhwa.dot.gov/environment/environmental_justice/equity/ 2) Example: Virginia Department of Transportation, 2019 Pedestrian Safety Action Plan Analysis Update - User Guide (December 2019).
	Stakeholder engagement	Meaningfully engage populations that are traditionally underserved in shared decision-making for the SHSP and subsequent safety programs, policies, or infrastructure projects.				
	Research	Prioritize research for countermeasures focused on bicycle and pedestrian safety.				National Cooperative Highway Research Program, Pedestrian and Bicycle Safety Performance Functions for the Highway Safety Manual, paragraph 1, retrieved from https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4203.
		Conduct CMF research that specifically focuses on fatal and serious injury crashes.				Example: Arizona Department of Transportation (ADOT), Arizona Highway Safety Improvement Program Manual (2018), 12, https://azdot.gov/sites/default/files/2019/06/2015-hsip-manual.pdf.
		Develop safety performance functions specifically for fatal and serious injury crashes.				
		Review existing crash data records to estimate the crash magnitude, in terms of kinetic energy, that was carried by involved parties prior to the crashes. After determining the range of kinetic energy magnitudes, make safety intervention and prioritize decisions with this in mind.				Austroads, Safe System Infrastructure on Mixed Use Arterials (2017), https://austroads.com.au/publications/road-safety/ap-t330-17/media/AP-T330-17_Safe_System_Infrastructure_on_Mixed_Use_Arterials.pdf.



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FHWA-SA-21-065