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IMPLEMENTING THE SAFE SYSTEM APPROACH AT INTERSECTIONS IN UTAH

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RESEARCH
UDOT Keeping Utah Moving
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16. Abstract

This research project investigates the principles and elements of the Safe System Approach, a new paradigm in roadway safety. A compendium of practice was created to determine recommendations on how to implement the Safe System Approach at intersections and observe how other jurisdictions are implementing it. Several strategies identified include the Safe Systems at Intersections (SSI) methodology, Safe System Alignment Frameworks, Vision Zero communities, incorporating the Safe System Approach into the Strategic Highway Safety Plan (SHSP) or Highway Safety Improvement Program (HSIP), mandating the Safe System Approach be considered in all projects, and the Organizational Safety Culture Self-Assessment. These policies do not exclusively implement the Safe System Approach at intersections but help organizations to adopt the Safe System Approach and move beyond traditional safety methods. Guidance for Safe System design was also investigated, including the Safe System Roadway Design Hierarchy and the Safe System Approach Framework.

Commonly identified physical countermeasures that implement the Safe System Approach at intersections were evaluated. The countermeasures were sorted into tables according to the type of safety impact provided. Commonly identified policies and practices were also organized, although they do not apply specifically to intersections. Based on the results of this research, several recommendations for UDOT include encouraging local communities to become Vision Zero communities, incorporating SSI into the Intersection Control Evaluation (ICE) program, institutionalizing the Safe System Approach through the FHWA Organizational Safety Culture Self-Assessment, updating the SHSP, strategic goals, vision, and implementing pilot programs or additional research on various countermeasures and strategies.

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LIST OF ACRONYMS

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
BYU	Brigham Young University
Caltrans	California Department of Transportation
Cap-X	Capacity Analysis for Planning of Junctions
CRISP	Capital Region Intersection Safety Partnership
DOT	Department of Transportation
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
GDOT	Georgia Department of Transportation
HIN	High Injury Network
HSIP	Highway Safety Improvement Program
HSM	Highway Safety Manual
ICE	Intersection Control Evaluation
ICWS	Intersection Conflict Warning System
INDOT	Indiana Department of Transportation
ITE	Institute of Transportation Engineers
ITF	International Transport Forum
LPI	Leading Pedestrian Interval
MAIS	Maximum Abbreviated Injury Scale
MassDOT	Massachusetts Department of Transportation
MnDOT	Minnesota Department of Transportation
MUT	Median U-Turn
MUTCD	Manual on Uniform Traffic Control Devices
NCHRP	National Cooperative Highway Research Program
P2P	Point-to-Point
RCUT	Restricted Crossing U-Turn
RRFB	Rectangular Rapid Flashing Beacon
RSAP	Road Safety Action Plan
RTZ	Road to Zero

SHSP	Strategic Highway Safety Plan
SPF	Safety Performance Function
SPICE	Safety Performance for Intersection Control Evaluation
SSI	Safe System Approach at Intersections
UDOT	Utah Department of Transportation
VMT	Vehicle Miles Traveled
WSDOT	Washington State Department of Transportation

EXECUTIVE SUMMARY

The objective of this research was to investigate the principles and elements of the Safe System Approach and determine how they could be implemented at intersections in Utah. The Safe System Approach is a comprehensive approach to road safety that acknowledges human errors and vulnerabilities. It contains a multi-faceted strategy to create a safer and more resilient transportation system, aiming to diminish the crash severity between road users, adjust travel speeds to align with roadway conditions, and mitigate impact forces to ensure that collisions do not result in a fatality or serious injury.

A state of the practice was created to determine recommendations on how to implement the Safe System Approach and observe how other jurisdictions are implementing it. Several policies, practices, and programs were identified including the Safe System Approach at Intersections (SSI) methodology, Safe System Project and Policy-Based Alignment Frameworks, Vision Zero communities with Vision Zero Action Plans, incorporating the Safe System Approach into the Strategic Highway Safety Plan (SHSP) or Highway Safety Improvement Program (HSIP), mandating via an executive order or director's policy that the Safe System Approach be considered in all projects, and the Organizational Safety Culture Self-Assessment. These policies do not exclusively implement the Safe System Approach at intersections but help organizations to adopt the Safe System Approach and move beyond traditional safety methods. Guidance for Safe System design was also investigated, including the Safe System Roadway Design Hierarchy and the Safe System Approach Framework. The guidance provided in these tools can be applied to intersection design and alternative selection.

Commonly identified physical countermeasures that implement the Safe System Approach at intersections were evaluated. Countermeasures that do not apply to intersections are not discussed in this research. The countermeasures discussed in the compendium of practice were sorted into tables according to the type of safety impact provided. Commonly identified policies and practices were also organized, although they do not apply specifically to intersections.

Based on the results of this research, several recommendations for UDOT include encouraging local communities to become Vision Zero communities, incorporating SSI into the Intersection Control Evaluation (ICE) program, institutionalizing the Safe System Approach through the FHWA Organizational Safety Culture Self-Assessment, updating the SHSP, strategic goals, vision, and implementing pilot programs or additional research on various countermeasures and strategies.

During this research project, a couple of challenges and limitations were identified, including the safety impacts of Vision Zero Action Plans and countermeasures being offset by the COVID-19 pandemic. In several locations, fatalities decreased from 2019 to 2020. However, this is not necessarily due to the safety countermeasures, but the decrease in vehicles on the roadway. Traffic fatalities tended to increase after the pandemic as more vehicles returned to the roadway. Additionally, it is important to note that some of the case studies, as well as policies enacted by other Departments of Transportation (DOTs), are relatively recent, and their impact is not fully known.

1.0 INTRODUCTION

1.1 Problem Statement

In 2016, a partnership between the National Safety Council, National Highway Traffic Safety Administration, Federal Highway Administration (FHWA), and Federal Motor Carrier Safety Administration announced the Road to Zero (RTZ) coalition that seeks to eliminate traffic fatalities in the U.S. by 2050 (Porter et al., 2021). Prior to this initiative, in 2006, the Utah Department of Transportation (UDOT) created the Zero Fatalities program, emphasizing individual drivers' responsibility for their own safety and the safety of others on the roadway. Since the establishment of the Zero Fatalities program, UDOT has continually worked to address safety in the state through a variety of partnerships and campaigns (Clarke, 2008).

In the original *The Road to Zero: A Vision for Achieving Zero Roadway Deaths by 2050*, the RTZ coalition determined that three interrelated approaches are needed: Double Down on What Works, Accelerate Advanced Technology, and Prioritize Safety. Within the third strategy, a shift toward a Safe System Approach was emphasized. The Safe System Approach assumes that people will make mistakes while on the roadway. To combat this, the overall transportation system should be designed to be forgiving so mistakes do not result in fatalities or serious injuries. Additionally, the Safe System Approach involves commitment to analyzing safety issues, identifying changes that bring the best return on investment, and implementing these improvements systematically (Ecola et al., 2018).

1.2 Objectives

The purpose of this research is to evaluate the guiding principles and elements of the Safe System Approach and determine ways that improvements can be made at intersections in Utah using the Safe System Approach methodologies. Case studies of locations that have implemented the Safe System Approach will be analyzed, and measures and policies recommended by the Institute of Transportation Engineers (ITE) and the FHWA will be discussed. This research will also investigate how other state Departments of Transportation (DOTs) are applying the Safe

System Approach into their intersections. Through this evaluation and implementation, UDOT will continue its pursuit of ‘Zero Fatalities: A Goal We Can All Live With.’

1.3 Scope

This report is intended to provide information and recommendations concerning the Safe System Approach and how it should be implemented at intersections within Utah. To accomplish this, the research team completed a comprehensive literature review, evaluated the state of the practice in other states and jurisdictions, and provided recommendations for implementation for UDOT.

A comprehensive literature review was completed to train and inform new research assistants regarding the general topic of safety and to address specific topics in the research including the history of the Safe System Approach, principles and elements of the Safe System Approach, and background on the FHWA Safe System Approach tools currently under development. One of the byproducts of the safety research being conducted in the state is the transfer of knowledge and information to help develop the next generation of safety engineers.

The research team identified several jurisdictions where the Safe System Approach has been effectively used at intersections and prepared a synthesis of best practices from these jurisdictions. These practices were evaluated to determine how the Safe System Approach can be implemented in Utah. The original scope of work states that locations in Utah where specific strategies could be implemented would be identified. In conversation with UDOT leaders, it was determined that how a measure is installed is more important than where it should be installed. Therefore, strategies and countermeasures were organized and prioritized according to the safety benefit provided. Included in each category is a table summarizing how each of the different countermeasures can be used to implement the Safe System Approach at intersections in Utah.

The research team identified limited conclusions and recommendations based upon observations and analyses in each of the tasks above that will aid UDOT in better implementing the Safe System Approach at intersections across the state.

1.4 Outline of Report

This report contains the following chapters.

- Chapter 1 introduces the research topic, objectives, scope, and report outline.
- Chapter 2 includes a literature review exploring topics connected to the research.
- Chapter 3 contains a state of the practice.
- Chapter 4 evaluates and categorizes measures and policies discussed in the state of the practice.
- Chapter 5 provides conclusions about research results including findings, limitations, and challenges.
- Chapter 6 provides recommendations and implementation for how the Safe System Approach can be implemented at intersections in Utah.

The chapters are followed by a References section.

2.0 LITERATURE REVIEW

2.1 Overview

A literature review has been conducted to understand the Safe System Approach and its elements and principles. This chapter contains the literature review and discussion on several key topics. The first topic is a background and history of the Safe System Approach and its origins. Next is a discussion on systemic safety analysis, a common practice in roadway safety and a precursor to the Safe System Approach. Each of the principles and elements of the Safe System Approach are then discussed. Following this, the Safe System Pyramid and how it relates traffic safety to public health is discussed. A discussion on the FHWA methodology to implement the Safe System Approach at intersections is then provided. The final topics discussed in this section are the FHWA Safe System Project and Policy-Based Alignment Frameworks including the Safe System audit currently implemented in New Zealand.

2.2 History of the Safe System Approach

Vision Zero is a road safety initiative that originated in Sweden in 1997. It has been adopted by many cities and countries around the world. The fundamental principle of Vision Zero is to achieve zero fatalities or serious injuries on the road. It recognizes that people will make mistakes, but the transportation system should be designed and managed in a way that prevents these mistakes from resulting in severe injuries or fatalities. It is important to recognize that since Vision Zero acknowledges that people will make mistakes and crashes will happen, there is an emphasis on preventing fatal and serious injury crashes, not all crashes. This is different from traditional approaches regarding safety. Additionally, while traditional safety approaches place a heavy amount of responsibility for roadway safety on individual users, Vision Zero sets the responsibility for roadway safety on system designers. Then individual users have the responsibility to follow the laws, policies, and system set in place by the designers. If safety problems continue, then the system designers should take further action to ensure safety (Shahum and Vanderkooy, 2017). Through Vision Zero and the Safe System Approach, Sweden has reduced traffic fatalities by 47 percent (FHWA, 2024a).

The Safe System Approach is the method by which Vision Zero is achieved (FHWA, 2023). Elements of the Safe System Approach can be directly addressed by states and other jurisdictions to reach a goal of zero fatalities. The Safe System Approach is a comprehensive approach to road safety that acknowledges human errors and vulnerabilities. This approach emphasizes the focus toward one unified system, not many separate systems. This single system contains a multi-faceted strategy to create a safer and more resilient transportation system. The Safe System Approach aims to diminish the crash severity between road users, adjust travel speeds to align with roadway conditions, and mitigate impact forces to ensure that collisions are never fatal (FHWA, 2023). The goal is to ensure that, even if a road user makes a mistake, the consequences are minimized to prevent severe injuries or fatalities. The Safe System Approach is different from traditional safety approaches in that it is more focused on reducing kinetic energy than controlling speeding. The Safe System Approach also seeks to be proactive, installing safety countermeasures before crashes occur. A summary of how the Safe System Approach differs from a traditional safety approach is shown in Figure 2.1 (FHWA, 2024a).

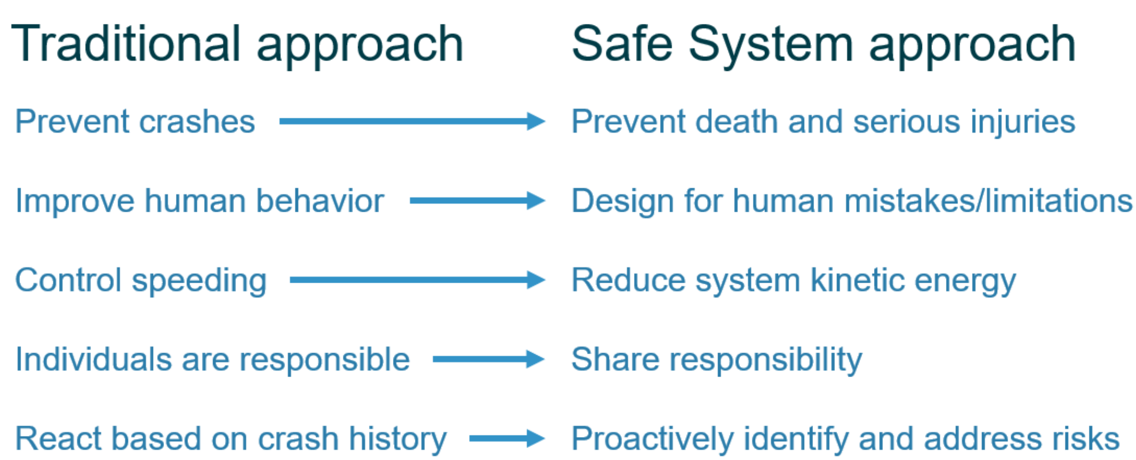

Figure 2.1 Traditional Safety Approach versus the Safe System Approach (FHWA, 2024a).

The Safe System Approach states that no person should be killed or seriously injured if a crash occurs when using the road system, and that it is a shared responsibility of all parties involved to achieve this outcome. For road design, the Safe System Approach involves managing crashes so that the kinetic energy imposed on the human body does not result in death or serious injury. At intersections, this is achieved through minimizing conflict points, speed, and crash angles, and simplifying road user decisions (Jurewicz et al., 2015; Shaw et al., 2022).

2.3 Systemic Safety Analysis

Systemic safety analysis uses historical crash data to identify recurring severe crash patterns associated with specific roadway features (Grembek et al., 2019). Countermeasures are then selected and installed in locations where those common roadway features are located, regardless of whether crashes are occurring there or not. A systemic approach to safety relies on data to identify locations for potential safety improvements. Safety projects may be identified that may not have been identified with traditional analysis (Preston et al., 2013). Instead of focusing on locations with a history of severe crashes, the systemic approach recognizes that severe crashes occur throughout the road system and few specific locations have a sustained higher number of severe crashes (Abel et al., 2023).

A proactive systemic safety analysis necessitates comprehensive and detailed data, considering safety, mobility, health impacts, and community perceptions and feedback. Incorporating equity data into safety analysis is vital to address gaps in crash reporting and incomplete roadway data. Various types of quantitative and qualitative data can be used to further understand crash occurrence and severity, including demographic data, health data such as social determinants of health and hospital records, and community perception data derived from interviews, surveys, focus groups, and road safety audits (Abel et al., 2023). These data provide further insight on potential locations for proactive safety projects. The goal of systemic safety analysis is to prevent crashes before they occur. This proactive approach to safety is one of the key principles of the Safe System Approach.

2.4 Safe System Principles

“The goal of ‘zero’ is to eliminate fatal and serious injuries, not to eliminate crashes” (Doctor and Ngo, 2022). Understanding this distinction is crucial when examining how the road safety issue is perceived within the framework of the Safe System Approach (Doctor and Ngo, 2022). Figure 2.2 shows the Safe System Approach principles and elements (FHWA, 2023). The principles that guide the Safe System Approach include:

- Death/Serious Injury is Unacceptable;
- Humans Make Mistakes;
- Humans are Vulnerable;
- Responsibility is Shared;
- Safety is Proactive; and
- Redundancy is Crucial.

The following subsections summarize each of these principles.

Figure 2.2 The Safe System Approach Principles and Elements (FHWA, 2023).

2.4.1 Death/Serious Injury Is Unacceptable

The primary objective of the Safe System Approach is to protect road users from harm and ultimately death. Every other principle and element are created to support this goal. While eliminating crashes is unrealistic, the Safe System Approach focuses on eliminating crashes that result in death and serious injuries. This emphasis applies to all road users, regardless of their socio-economic backgrounds, abilities, and the modes they use (Doctor and Ngo, 2022).

2.4.2 Humans Make Mistakes

It is important to recognize that road users will inevitably make mistakes, which lead to potential crashes. The Safe System Approach advocates for the road system to be planned, designed, and operated to be forgiving of these errors (Doctor and Ngo, 2022). This proactive approach recognizes human error and aims to minimize the likelihood of severe harm by incorporating forgiving road system elements. By adopting this approach, emphasis is placed on creating a safer environment that accounts for human imperfections and reduces the impact of inevitable mistakes on road safety.

2.4.3 Humans Are Vulnerable

Recognizing the inherent vulnerability of the human body to external forces, the Safe System Approach underscores the importance of designing road systems, vehicles, and speed limits with the explicit goal of minimizing the impact on individuals in the event of a crash. When crashes do happen, they should be managed so the "kinetic energy exchange on the human body is kept below the tolerable limits for serious harm to occur" (Doctor and Ngo, 2022). This involves acknowledging that humans may make errors but ensuring that these errors do not result in life-threatening or severe injuries, and, in doing so, prioritizing the protection and well-being of road users.

2.4.4 Responsibility Is Shared

The Safe System Approach emphasizes shared responsibility, requiring active engagement from individuals, effective safety measures from designers, and advanced safety features in vehicles. It is important that all stakeholders work together to ensure that crashes do not lead to fatal or serious injuries (Doctor and Ngo, 2022). This collaborative effort aims to comprehensively address road safety, recognizing that preventing traffic-related fatalities and severe injuries is a shared responsibility across the entire transportation system.

2.4.5 Safety Is Proactive

Rather than being reactive by only implementing countermeasures after a crash, the Safe System Approach emphasizes the importance of being proactive by identifying and addressing latent risks in the transportation system before crashes occur. By leveraging data and proactive strategies, agencies can preemptively mitigate potential hazards, contributing to a safer and more resilient road environment. Those designing the road systems should use "proactive and data-driven tools to identify and mitigate latent risks in the system" (Doctor and Ngo, 2022). This forward-looking perspective aligns with the goal of the Safe System Approach to prevent fatal and serious injury crashes rather than merely responding to them.

2.4.6 Redundancy Is Crucial

The principle of redundancy emphasizes using each element of the Safe System Approach to ensure that if one element fails, the remaining elements continue to safeguard road users. This fosters a resilient system where the failure of one part does not compromise the safety of the overall system. The goal is to create a robust system that provides layered protection and reduces the potential for severe consequences in the event of a crash. This principle of redundancy is visualized through the "Swiss Cheese Model" shown in Figure 2.3 (FHWA, 2024a). This model illustrates how the elements of the Safe System Approach work together so that if one part fails, other elements can prevent fatal or serious crashes. Elements are represented as slices of Swiss cheese, with the holes representing the individual weaknesses of each element. When the weaknesses of the Safe System elements are not aligned, individuals are protected.

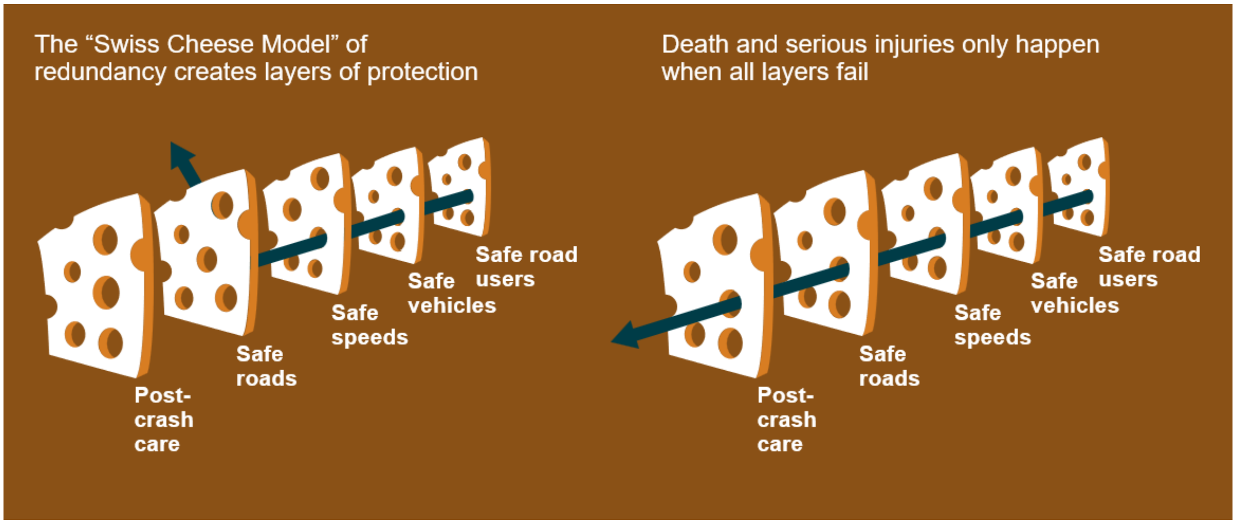

Figure 2.3 The Swiss Cheese Model (FHWA, 2024a).

An example of this redundancy includes the interaction between the elements of Safe Road Users and Safe Vehicles (these elements are described in Sections 2.5.1 and 2.5.2). Safe road users travel unimpaired, follow traffic laws, and drive responsibly. Safe vehicles provide collision avoidance systems as well as airbags and seatbelts. A safe vehicle may provide an adequate number of safety features, but if a driver chooses to ignore them (such as failure to wear a seatbelt), then redundancy within the system is compromised. When a driver drives safely and adheres to the safety features within the vehicle, the system is more resilient so that mistakes are less likely to be fatal or severe.

2.5 Safe System Elements

The Safe System Approach is based on the understanding that each of the elements working together creates a more forgiving and resilient road transport system, reducing the likelihood and severity of road traffic crashes. It emphasizes a shared responsibility among road users, vehicle manufacturers, road designers, policymakers, and the community to create a safer road environment. The elements of the Safe System Approach, as shown previously in Figure 2.2, include:

- Safe Road Users;
- Safe Vehicles;

- Safe Speeds;
- Safe Roads; and
- Post-Crash Care.

The following subsections summarize each of the elements.

2.5.1 Safe Road Users

Within the Safe System Approach, the element of Safe Road Users refers to the principle that Responsibility is Shared for safety on the roadway. Most people travel safely on a trip, but risky driver behaviors still occur. It is the responsibility of those using the roadway to do so with their full attention to limit putting others at risk. Roadway users are safer when they are not distracted or impaired, follow traffic laws, and act within the limits of the road design (FHWA, 2024a). The most frequent and persistent behavioral safety factors in fatal crashes are people not wearing seatbelts, people driving while impaired from alcohol, and speeding (USDOT, 2023).

It is important that the safety of all road users is addressed, not just those who are using a private vehicle. One way that the Vision Zero Action Plan for Portland, Oregon has addressed this element is by implementing guidelines for delayed parking enforcement start times to "encourage impaired drivers to leave their car overnight (without having to worry about getting ticketed or towed)" (Doctor and Ngo, 2022). Parking enforcement begins around 10:00 a.m. in new parking districts. Portland's "Safe Ride Home" program allows bar owners to provide rideshare and taxi discount coupons to impaired drivers to incentivize them to take one of these services home (FHWA, 2019). These actions reduce impaired driving as drivers feel less pressure to relocate their vehicle to avoid a parking fine. This improves the safety of drivers on the roadway and those who use active transportation, as they are less likely to be hit by an impaired driver.

2.5.2 Safe Vehicles

Within the Safe System Approach, the Safe Vehicles element refers to the improvements in vehicle technology that improve safety and reduce crash severity. This technology includes collision avoidance systems, air bags, seat belts, and guidance cameras. These vehicle features assist drivers in recognizing other roadway users, and can help reduce kinetic energy when crashes occur, increasing chances of survival. Vehicles should be designed to "minimize the frequency and severity of collisions using safety measures that incorporate the latest technology" (Doctor and Ngo, 2022). Safer vehicles can be the most forgiving element in the Safe System Approach as they can absorb more kinetic energy than a human when crashes occur. Improvements in vehicle technology have already greatly reduced fatality rates from when the automobile was first invented. It is important to keep improving vehicle technology to further create a forgiving system for human mistakes.

2.5.3 Safe Speeds

Speed is the key factor of kinetic energy in crashes (Porter et al., 2021). Lower speeds result in lower kinetic energy. "Humans are less likely to survive high-speed crashes. Reducing speeds accommodates human injury by reducing impact forces, providing additional time for drivers to stop, and improving visibility" (Doctor and Ngo, 2022). Safe speeds are particularly important for the safety of pedestrians. An example of this is in Portland, Oregon, where 9 percent of all trips are pedestrian trips, but nearly one-third of traffic fatalities involve pedestrians. One way to decrease pedestrian death and serious injury is to manage driving speeds. A pedestrian struck by a vehicle traveling at "40 miles per hour is 8 times more likely to die than one hit at 20 miles per hour" (Doctor and Ngo, 2022). This emphasizes the significance of Portland's policies, which include appropriate speed limits, street design for safe speeds, and speed safety camera programs.

Figure 2.4 shows the relationship between traveling speeds and the risk of severe injury and death (Porter et al., 2021). These curves are modified from the findings from the document *Impact Speed and a Pedestrian's Risk of Severe Injury or Death* (Tefft, 2013). In this research, a maximum abbreviated injury scale (MAIS) score of 4 or higher is considered severe. The FHWA considers a MAIS score of 3 or higher to be severe. The reasoning is discussed further in Section 2.7.2. As shown in Figure 2.4, the likelihood of severe injury and death increases with higher speeds. Setting lower speed limits is not the only solution to lowering speeds. Speed management techniques such as medians and driver feedback signs can help to lower speeds, and therefore increase survival rates when crashes occur.

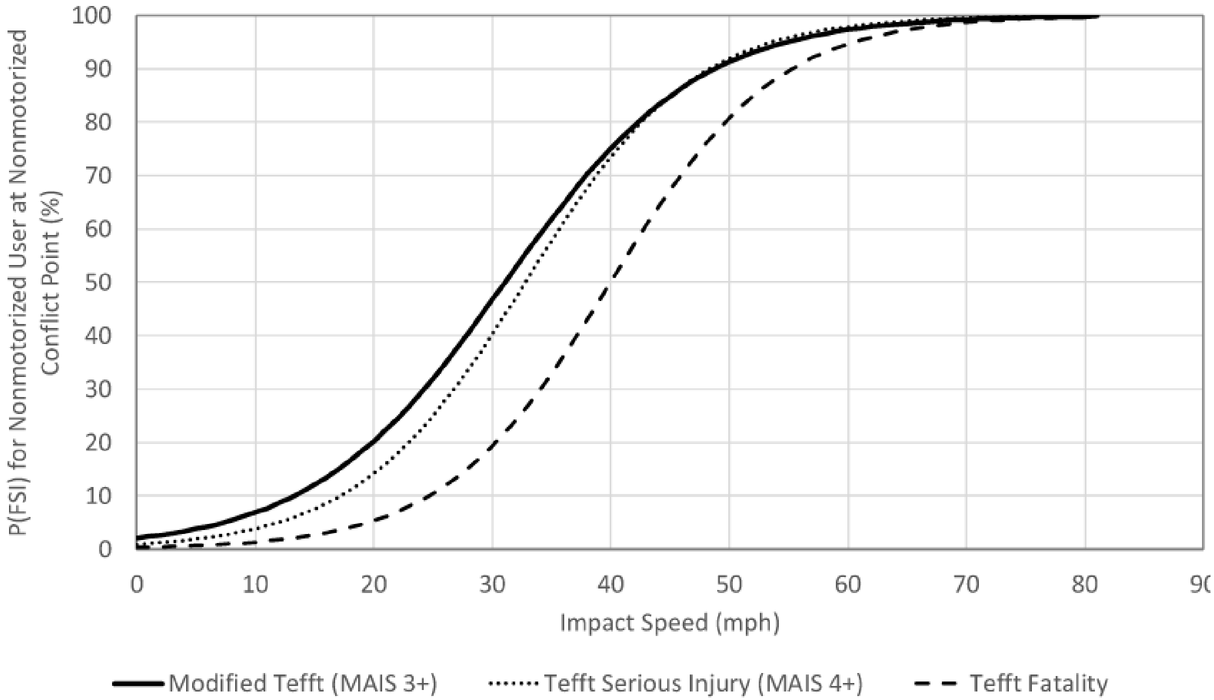

Figure 2.4 Risks of severe injury and death in relation to impact speed (Porter et al., 2021; Tefft, 2013).

<u>2.5.4 Safe Roads</u>

Safe Roads encompass creating safe designs that prioritize the safety of both vehicles and active transportation modes. The purpose of Safe Roads is to prevent crashes among all users and to keep impacts on the human body at a tolerable level. Designing roads in a way that prevents crashes can be done by separating roadway users in space, separating roadway users in time, and increasing attentiveness and awareness. To manage the kinetic energy of a crash, speeds, crash angles, and crash energy distribution must be properly managed. It is important to note that this element is best thought of as a continuum, not an absolute, with the goal of continuously designing and operating roads that adhere to the Safe System Approach.

Designing transportation infrastructure to accommodate human mistakes and injury tolerances can greatly reduce the severity of crashes that do occur. Reaching zero fatalities will require that road users, especially the most vulnerable, such as pedestrians and bicyclists, are protected from the energy of faster moving vehicles. This can be done by separating vulnerable road users from traffic. An example of this includes separating bike lanes from vehicle travel lanes and reducing vehicle speeds where pedestrians and bicyclists share the road with vehicles (Michael et al., 2023). Countermeasures can be installed that alert drivers to pedestrians and hazards, as well as reduce crash forces. Roadway countermeasures that notify drivers of pedestrians include pedestrian hybrid beacons. Roadway countermeasures that reduce crash forces so that they are tolerable by humans include roundabouts and separated bike lanes (Michael et al., 2023).

One application of the Safe Roads element of the Safe System Approach is an Intersection Control Evaluation (ICE) study. An ICE study is an analytical framework designed to assess and analyze traffic intersections. The primary goal of such a study is to evaluate the performance and safety of intersections, helping traffic engineers and planners make informed decisions about traffic control measures and improvements.

The objective of the UDOT ICE program is to be proactive regarding safety. A UDOT intersection becomes a candidate for an ICE review when one of the following conditions occurs:

- A new signal is warranted;
- There is a high number of crashes at the intersection; or
- The intersection layout changes.

When one of these conditions is met, both the Capacity Analysis for Planning of Junctions (Cap-X) and Safety Performance for Intersection Control Evaluation (SPICE) analyses are performed. These analyses are completed with spreadsheets from the FHWA website that have been adjusted so that they are more specific for Utah intersections. The results from these studies are presented at UDOT region field reviews. Based on the results of these studies, the UDOT region may decide to proceed with a full ICE study. In a full ICE study, operation, safety, and maintenance costs are evaluated between intersection alternatives. The benefit-cost ratio for each alternative is also calculated. Currently, the benefit-cost ratio does not account for active transportation. The findings from the alternatives are presented to UDOT and they determine how to proceed.

ICE fits within the Safe Roads element of the Safe System Approach as it has allowed UDOT to move toward being proactive regarding safety at intersections. The current tools and procedures can be improved to better adhere to Safe System principles by accounting for active transportation, as the Safe System Approach is concerned about all road users, not just vehicles.

2.5.5 Post-Crash Care

When severe crashes occur, it is important that first responders can arrive at the crash scene as quickly as possible. Doing so can prevent injuries from becoming fatal and increases the chances of saving lives. “People who are injured in collisions rely on emergency first responders to quickly locate and stabilize their injuries and transport them to medical facilities. Post-Crash Care also includes forensic analysis at the crash site, traffic incident management, and other activities” (Doctor and Ngo, 2022). Faster cleanup reduces the chance of subsequent crashes happening at the same location. Therefore, effective incident management not only increases the potential to save lives, but also is proactive in reducing subsequent crashes at the same location immediately after a crash has taken place. Research done by Brigham Young University (BYU) found that increasing the number of Incident Management Teams from 13 to 25 decreased response time by 7 percent (Schultz et al., 2023). Although not explicitly discussed in that research, lowering the response time may result in an increased chance of survival for those who are injured as they are able to receive medical treatment sooner.

2.6 The Safe System Pyramid

It is important to recognize that the Safe System elements described in Section 2.5 are not equivalent in their impact to reducing kinetic energy. Additionally, each of these elements require different levels of individual commitment. Recognizing that each of these elements apply to different levels of the population helps to determine interventions that can protect as many people as possible. To understand this, traffic safety should be viewed through the lens of public health. When public health practitioners understand causes of disease and injury, they can prioritize interventions at different population levels to decrease exposure and risk to as many people as possible. The Health Impact Pyramid developed by Thomas Friedman relates the effectiveness of a public health intervention to the amount of individual effort required (Mitman et al., 2024). The more individual effort for an intervention means little impact on the population level. The reverse is also true. The Safe System Pyramid helps to bridge the gap between traffic safety, kinetic energy reduction, the Safe System Approach, and public health.

The Safe System Pyramid is like the Health Impact Pyramid in that it relates roadway safety interventions to the amount of individual effort required. The Safe System Pyramid, shown in Figure 2.5, helps transportation engineers and planners apply public health concepts in traffic safety and allows them to focus safety interventions at different levels, reducing the cause of injury (Ederer et al., 2023). The Safe System Pyramid consists of the following levels from top to bottom:

- Education;
- Active measures;
- Latent safety measures;
- Built environment; and
- Socioeconomic factors

Figure 2.5 The Safe System Pyramid (Mitman et al., 2024).

The following subsections describe each of these levels with examples of programs, interventions, and policies for each tier.

2.6.1 Education

At the top of the Safe System Pyramid is Education. This tier focuses on changing individual behavior. If constant reminders are needed to slow down, yield to pedestrians, and wear seatbelts, then it should be worth observing if the physical environment encourages higher speeds or the local traffic safety culture does not promote seatbelt usage (Ederer et al., 2023). Regardless of the culture or environment, education can improve individual driving behaviors, promote alternate travel modes, and reinforce traffic laws. However, the effectiveness of these measures is dependent on individual behavior. Transportation professionals can incorporate education in the application of the Safe System Approach by having driver's education requirements prior to obtaining a license. "Slow Down" campaigns are another program that can be used that requires individuals to educate themselves on the dangers of higher speeds.

2.6.2 Active Measures

Active Measures refers to safety features that are effective but require individual effort to be used. Examples of active measures include seat belts, bicycle and motorcycle helmets, turn signals, and stop signs. These measures have prevented many injuries in the past but require individual effort to be effective (Ederer et al., 2023). If a driver chooses to ignore them, then they are not as effective in preventing injuries or fatalities. Speed enforcement by a police officer is another example of an active measure, since the officer chooses the offenders that will receive a ticket.

2.6.3 Latent Safety Measures

Latent Safety Measures are highly effective in decreasing the level of risk and do not require human intervention. Examples of latent safety measures include airbags, automated vehicle braking systems, lane guidance systems, and other automatic vehicle technologies. Many latent safety measures are vehicle technology measures that are active regardless of human intervention (Ederer et al., 2023). It is important to note that many of these vehicle technologies are exclusive to more expensive vehicles, and do not benefit those with lower income (Metzger et al., 2020). Transportation professionals can incorporate latent safety measures into their designs by engineering signal timing that encourages lower speeds, leading pedestrian intervals

(LPIs), and automated speed enforcement such as speed safety cameras. Speed safety cameras enforce speeds uniformly, contrary to a police officer who chooses which offenders to issue a ticket. Standards on signal placement and cycle length and vehicle standards that require the installation of safety measures are other latent safety measures that can be incorporated.

2.6.4 Built Environment

The Built Environment level consists of physical infrastructure. On a city scale, this includes land use, population density, and access to destinations. These elements influence mode choice and the distance traveled (Stevenson et al., 2016). On a roadway scale, the built environment consists of the physical right-of-way, including sidewalks and bike paths. Signal timing, raised crossings, roadside barriers, and lane narrowing are also examples of the built environment. Changes to the built environment will affect everyone on the roadway, not just those who are speeding. For example, a roundabout will require all roadway users to modify their path to continue through the intersection, regardless of their speed (Ederer et al., 2023). The built environment can also be modified to discourage driving and promote other modes of transportation, decreasing the number of vehicles on the roadway. In this way, the built environment can serve as a form of transportation demand management. Transportation professionals can modify the built environment to adhere to the Safe System Approach by emphasizing safety over capacity, adding traffic calming measures to reduce speed, and installing additional measures to help make pedestrians and bicyclists more noticeable to drivers.

2.6.5 Socioeconomic Factors

At the base of the Safe System Pyramid is Socioeconomic Factors. This is the base level because factors such as income, community safety, and social and institutional support set the context for traffic safety. Socioeconomic factors influence the need to travel, as well as where to travel and when. For example, people may need to commute for night shifts and truck drivers are regularly on the roadway for work (Ederer et al., 2023). These factors have an influence on driving behavior such as whether it is acceptable to wear a seatbelt or not. Additionally, those with lower income and people of color tend to live near more dangerous intersections (Morency et al., 2012). Socioeconomic factors are rarely included in traffic models, and the changes required to address these issues are beyond traffic safety policy, despite their influence on traffic safety. Transportation professionals can account for socioeconomic factors in their work by aligning the functional classification of roadways with adjacent land uses, prioritizing safety in their designs, placing transit near affordable housing, and rezoning land uses to reduce Vehicle Miles Traveled (VMT). In Salt Lake City, street typologies consider land use context and citywide and neighborhood goals to allocate space with person mobility as the top priority (Salt Lake City, 2023). Socioeconomic factors may not seem relevant to transportation professionals but can alter the need to travel in the first place or reduce the distance needed to travel.

2.7 The Safe System at Intersections Methodology

The FHWA has developed an analytical methodology to help characterize how an intersection aligns with the principles of kinetic energy management and a Safe System Approach. This method is called the Safe System for Intersections (SSI) methodology (Porter et al., 2021). The SSI methodology was developed in a way that it can be used with data that is easy to acquire, including the posted speed limit, annual average daily traffic (AADT), and number of through lanes on intersecting roads. “The goal [behind this methodology] is to provide a technical basis by which intersection planners and designers can apply kinetic energy principles to common intersection projects” (Porter et al., 2021). The SSI methodology includes the following steps:

- Conflict point identification and classification;
- Conflict point exposure;
- Conflict point severity;
- Movement complexity; and
- SSI measures of effectiveness and SSI score.

The following subsections provide additional details on each of these steps.

2.7.1 Conflict Point Identification and Classification

A conflict point refers to locations where the paths of road users intersect. Intersections contain concentrated groupings of conflict points. It is important to understand the different types of conflict points and how the number of conflict points can be reduced at intersections. The SSI methodology classifies conflict points into the following categories (Porter et al., 2021):

- Crossing conflict point – two input traffic streams and two output traffic streams.
- Merging conflict point – two input traffic streams and one output traffic stream.
- Diverging conflict point – one input traffic stream and two output traffic streams.
- Nonmotorized conflict point – vehicle path crosses a pedestrian or cyclist path.

One weakness in current conflict-point identification strategies is that bicycles are assumed to follow the same path as pedestrians in intersections. Another weakness is that rear-end crashes resulting from differential speeds or traffic congestion due to traffic control devices are not accounted for. The SSI methodology can identify conflict points on a movement basis or a lane-by-lane basis. When exact configurations are not known, conflict points can be determined on a movement basis. When the intersection layout is determined, the analysis may need to be done again to account for additional conflicts due to a higher number of lanes (Porter et al., 2021).

A conventional four-leg intersection with one lane in each direction has up to 32 points at which vehicle-vehicle conflicts can occur and 24 points at which vehicle-pedestrian conflicts can occur as shown in Figure 2.6. Having more lanes for each movement can increase the number of conflict points at an intersection. The movement-based conflict points for a roundabout are shown in Figure 2.7. As shown, there are only 8 of each type of conflict point. Additionally, the design of a roundabout arranges the conflicts between vehicles at flat angles instead of right angles, potentially reducing crash severity. Due to these factors, roundabouts generally experience both lower crash frequencies and severities than traditional intersections. Harwood et al. (2017) reports that “the Highway Safety Manual (HSM) indicates that converting a stop-controlled intersection to a roundabout can reduce injury crashes by 82 percent, while converting a signalized intersection to a roundabout can reduce injury crashes by 78 percent” (Harwood et al., 2017).

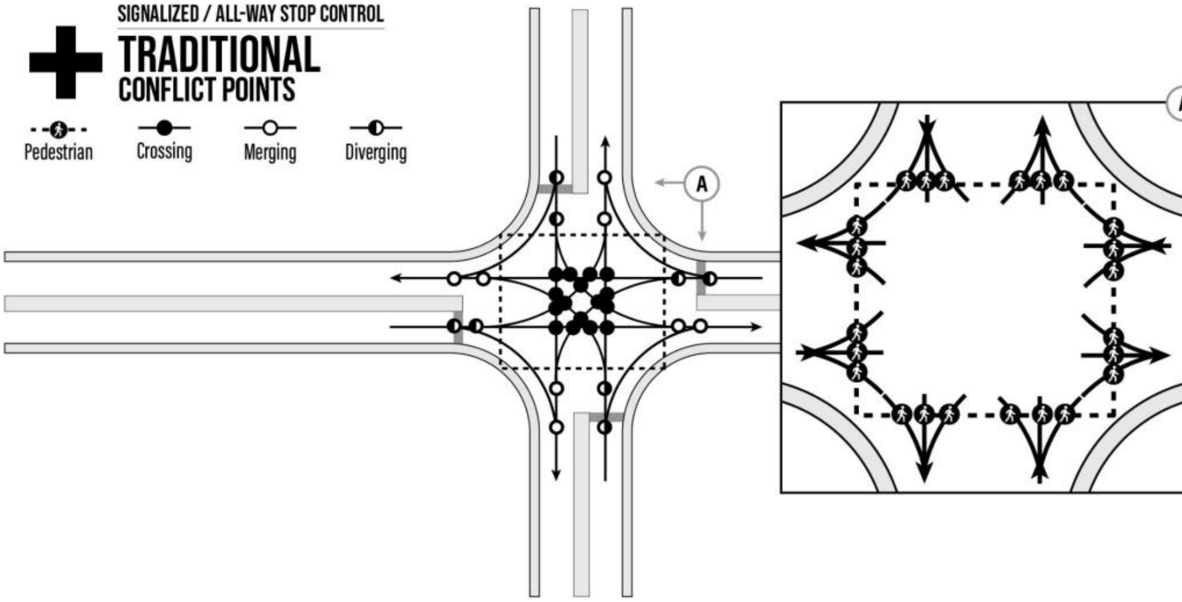

Figure 2.6 Conflict points at a traditional intersection (Porter et al., 2021).

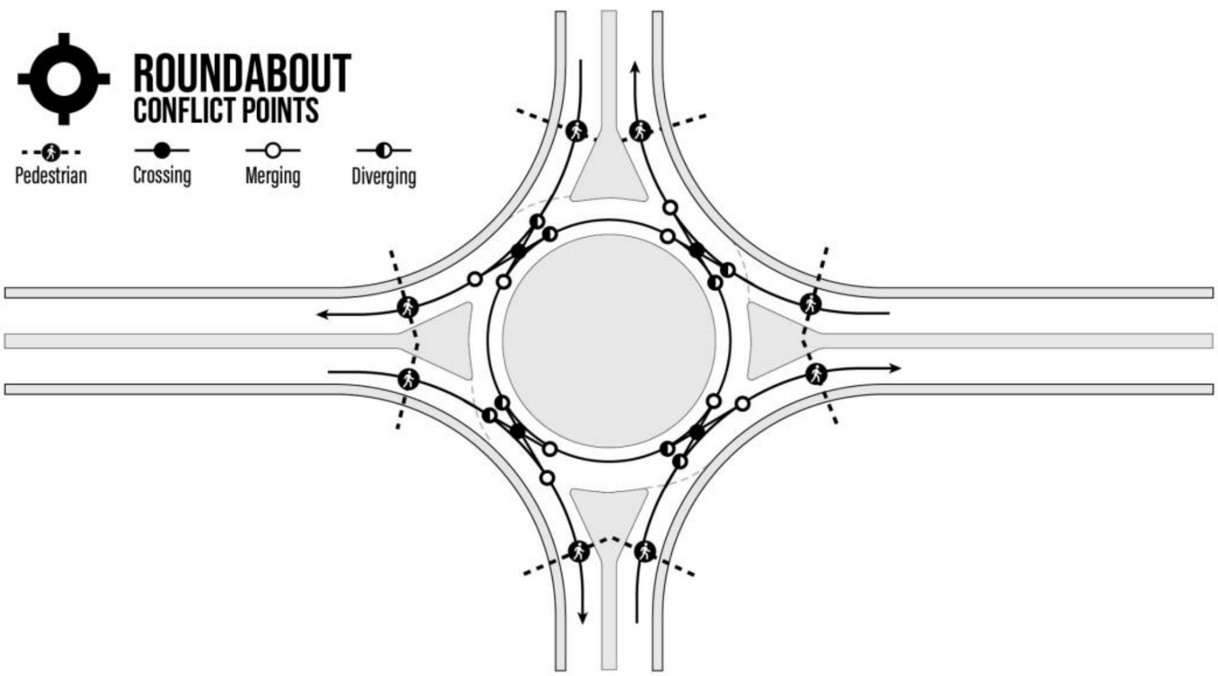

Figure 2.7 Conflict points at a roundabout intersection (Porter et al., 2021).

2.7.2 Conflict Point Exposure

Conflict point exposure refers to the vehicle and pedestrian volumes that pass through a conflict point. Since it is more likely that a crash will occur at a conflict point when more vehicles and nonmotorized users move through it, higher volumes indicate higher exposure. The exposure index is calculated by taking the product of vehicle or nonmotorized daily volumes that pass through the conflict point. The total exposure for each type of conflict point is determined by summing the exposure index across the intersection for that specific type of conflict point (Porter et al., 2021). The exposure step of the SSI methodology allows planners and engineers to see what types of crashes are most likely to occur at an intersection alternative. Knowing the crash that is most likely to occur allows planners and engineers to be proactive in what type of countermeasure to implement.

2.7.3 Conflict Point Severity

Conflict point severity refers to the estimated probability of at least one fatal or serious injury crash (Porter et al., 2021). The SSI methodology uses the MAIS based on information provided by trained medical professionals (Burch et al., 2014). This scale is more consistently coded with probability of survival within and across states than police reports. The SSI methodology defines fatal and serious injuries as those with a MAIS score of 3 or higher (Porter et al., 2021).

The SSI methodology incorporates analytical models to estimate the probability of a severe or fatal injury crash. These models require vehicle speeds and impact angles (Porter et al., 2021). The conflict-point severity step of the SSI methodology allows planners to see which conflict points have a higher likelihood of being severe or fatal. This step in combination with the exposure step can help to identify which countermeasures should be installed at an intersection to prevent fatal and serious injury crashes.

2.7.4 Movement Complexity

Human errors are addressed within movement complexity. This factor of the FHWA methodology focuses on intersection features that make specific movements more complex for road users (Porter et al., 2021). Currently, the following features are accounted for in the complexity factors:

- Traffic control type;
- The number of conflicting lanes the road user crosses or merges with;
- The speed of conflicting traffic; and
- Indirect crossing paths.

The first three elements are applicable to motorized and nonmotorized users. The last element is applicable to only nonmotorized users. Regarding traffic control, movements are less complex when they are separated in time. For example, left turns onto busy roads are less complex when they are signalized versus stop controlled. As the number of conflicting lanes increases, movements get more complex. This is also true for the speed of conflicting traffic. Road users must judge the speed of conflicting traffic before making a movement. Indirect paths refer to pedestrians or cyclists crossing where there is not a designated crosswalk or crossing path. For example, some nonmotorized users may cross an intersection diagonally if there is a pedestrian phase or if traffic volumes are low. If this is the case, then indirect crossing paths are accounted for in analysis. "The SSI methodology assumes intersection attributes with lower levels of complexity for all users will eventually bring it into closer alignment with a Safe System" (Porter et al., 2021). This step of the SSI methodology can help planners and engineers to recognize when their designs may be too complex and help them to recognize that their designs may need to be simplified to increase safety.

2.7.5 Safe System at Intersection Measures of Effectiveness and Scores

Sections 2.7.1 to 2.7.4 present steps to identify and classify conflict points, and determine exposure, conflict point severity, and movement complexity. These steps can serve as measures of effectiveness that can help planners identify how an intersection alternative aligns with Safe System principles. Planners and engineers can design intersections that lower the number of conflict points or conflict point severity. Alternatively, they can look for ways to reduce movement complexity or reduce exposure by reducing the number of vehicles moving through a conflict point.

Within the FHWA methodology, the above steps can be combined to create an SSI score. The SSI score provides designers with an overall indication of how the intersection adheres to Safe System Approach principles. The SSI score ranges from 0 to 100. The higher the score, the lower the chances of a fatal and serious injury. Knowing the SSI score for an intersection alternative allows planners and engineers to be proactive and choose an alternative that is safer before it is installed. This methodology can also be used on existing intersections and can allow for potential changes or mitigation before a crash occurs. The measures of effectiveness and SSI score can be used to complement existing crash-based metrics from predictive approaches like the HSM or SPICE (Porter et al., 2021).

2.8 Safe System Alignment Frameworks

To promote the implementation of the Safe System Approach, the FHWA developed the Safe System Project-Based and Policy-Based Alignment Frameworks. The goal of these frameworks is to quantify alignment or integration of Safe System Approach principles and elements into roadway projects and policies. The frameworks also work to integrate equity to address disproportional fatal and serious injury crashes impacting lower income communities and vulnerable road users (FHWA, 2024b). In addition to these frameworks, New Zealand has a Safe System Audit that is used to assess how roadway projects adhere to the Safe System Approach. This section will discuss both the FHWA Safe System Frameworks, and then the New Zealand Safe System Audit.

2.8.1 Safe System Project-Based Alignment Framework

The Safe System Project-Based Alignment Framework can be used to assess roadway projects through the lens of the Safe System Approach. This framework provides a scoring matrix, which can be used to assess existing conditions, or to evaluate and compare project alternatives. The scoring matrix focuses on exposure, likelihood, and severity for both motor vehicles and vulnerable road users. The framework is like the FHWA SSI method in that it presents a scoring system to evaluate how closely a project aligns with Safe System principles. However, while the SSI method is limited to intersections, the framework can be used on a wider variety of projects. For this framework, a lower final score indicates closer alignment to Safe

System principles. Note that the SSI method uses similar steps to determine a Safe System score. However, according to the SSI method, a higher score indicates closer alignment to a Safe System, while the opposite is true for the Safe System Alignment Framework. Additionally, the framework provides prompts based on the Safe Road Users, Safe Vehicles, and Post-Crash Care elements of the Safe System Approach. Equity is also considered. These prompts do not influence the final score but provide an opportunity to note information that should be considered in a comprehensive safety analysis.

The framework is available through a Microsoft Excel spreadsheet. Tabs are provided for the exposure, likelihood, and severity steps as described below:

- Exposure – The inputs on the exposure tab include vehicle and vulnerable road user volumes, roadway width, and crossing distance. The exposure subtotal score is based on thresholds for volumes, the number of lanes, and crossing distance.
- Likelihood – Inputs on the likelihood tab are based on risk factors. Users input risk factors on separate tabs for motorists and vulnerable road users. Risk factors include roadway and intersection geometry such as the existence of a shared use path, bike lanes, crosswalks available at intersections, and the presence of fixed objects. Each risk factor is given a value. The values are summed, then divided by three. For intersection analysis, the value is also divided by the number of intersection legs. This quotient is then compared to a threshold value, which provides a corresponding likelihood score.
- Severity – Inputs on the severity tab include operating speeds. The severity score is based on speed thresholds.

When determining an overall score, the subtotals for exposure, likelihood, and severity are multiplied together. This is done separately for motorists and vulnerable road users. These subtotals are then added together to give a final score. This final score can be used to assess how the existing infrastructure adheres to Safe System principles and can be compared to potential alternatives to determine if those changes would align closer to the Safe System Approach.

2.8.2 Safe System Policy-Based Alignment Framework

The Safe System Policy-Based Alignment Framework is used to help agencies assess their policies, programs, practices, and to document language through a Safe System lens. This framework includes seven criteria, which are the six principles of the Safe System Approach and equity. Users provide a score that reflects how they feel their agency addresses each of the seven criteria. It may be completed individually or as a group. However, it provides the most benefit when completed by a team with as many safety stakeholders as possible. The framework is available through a Microsoft Excel spreadsheet. Users score each criterion on a scale from 0 to 15, based on the following guidelines:

- Initiation (0-3) – The agency has begun to address the principle. If no action has been taken or is not addressed in the policy, the score should be reported as 0.
- Development (4-6) – The agency has developed a plan to address the principle.
- Execution (7-9) – The agency has executed a plan to address the principle.
- Evaluation (10-12) – The agency has evaluated a plan's performance and it has been in effect for some time.
- Integration (12-15) – The agency has integrated the principle into its culture.

After completing the framework, a facilitator with a strong understanding of the Safe System Approach can review results with participants, discussing scores and comparing results. This provides opportunities to observe where the agency has strengths and weaknesses. The Safe System Policy-Based Alignment Framework helps agencies to track how their policies are aligning with the Safe System Approach, raise awareness, identify gaps, generate strategies, and influence changes.

2.8.3 New Zealand Safe System Audit

The Waka Kotahi New Zealand Transport Agency has a Safe System audit to assist in identifying a project's alignment with Safe System principles. The Safe System audit is an assessment of transportation improvement and renewal projects. These audits are completed by qualified audit teams, consider the safety of all people, and seek to eliminate the potential for fatal and serious injury crashes. The Safe System audit is like the FHWA Safe System Project-

Based Alignment Framework in that it presents a scoring system to evaluate how closely a project aligns with Safe System principles. The Safe System audit is not limited to intersections and can be used on a wider variety of projects. New Zealand based this audit on the Austroads Safe System assessment framework, which provides technical notes on the scoring system in this audit (Turner et al., 2016). Waka Kotahi investment policy states that Safe System audits should be completed at key stages of a project's development, including the concept, preliminary design, detailed design, and pre-opening and/or post-construction stages (NZTA, 2022). The following subsections discuss how projects are scored and safety risks are assessed according to the audit.

2.8.3.1 Safe System Assessment Score

The Safe System audit includes a scoring system that assesses how closely a project aligns with the Safe System principles. This scoring system considers the exposure, likelihood, and severity associated with seven different crash types. The scoring matrix is shown in Figure 2.8. Each combination is given a maximum score out of four. The exposure, likelihood, and severity scores for each crash type are multiplied, resulting in a maximum product of 64. These products are then summed to obtain the total safe system assessment score, with a maximum possible score of 448. A lower score indicates a high level of alignment with the Safe System. This is consistent with the Safe System Project-Based Alignment Framework, but different from the SSI method.

	Run-off-road	Head-on	Intersection	Other	Pedestrian	Cyclist	Motorcyclist
Exposure	/ 4	/ 4	/ 4	/ 4	/ 4	/ 4	/ 4
Likelihood	/ 4	/ 4	/ 4	/ 4	/ 4	/ 4	/ 4
Severity	/ 4	/ 4	/ 4	/ 4	/ 4	/ 4	/ 4
Product	**/ 64**	**/ 64**	**/ 64**	**/ 64**	**/ 64**	**/ 64**	**/ 64**
Total Safe System assessment score						**/ 448**	

Figure 2.8 Safe System Audit Assessment Table (NZTA, 2022).

The Safe System audit guidelines provide guidance on scoring each category. It is understood that there will be a level of subjectivity when completing this audit. Therefore, it is necessary that the same audit team performs the audits throughout the project's development. The Austroads Safe System Assessment Framework on which this is based states that due to the subjectivity, these scores should not be used to compare different sites but instead compare options at a single site and identify sources of risk. The Austroads Safe System Assessment Framework also states that if a more quantitative result is desired, the Extended Kinetic Energy Management Model could be used to determine the probability of a severe crash, or the Australian National Risk Assessment Model could be used to identify the likelihood and severity of different crash types (Turner et al., 2016). Within the New Zealand Safe System audit, guidelines for scoring the categories are summarized below:

- Exposure – A lower score indicates a lower volume of vehicles and other road users. Volume thresholds are provided to help determine what score a crash type should receive for exposure.
- Crash likelihood – A lower score indicates that this crash type is less likely to occur. A higher score indicates that the likelihood of this crash type is high given the existing infrastructure. Factors that should be considered for crash likelihood include road curvature, speeds, and number of conflict points.
- Crash severity – A lower score indicates that if a crash should occur, the probability of a fatality or serious injury is minimal. A higher score indicates higher kinetic energy, resulting in a higher likelihood of a fatal or serious injury. Factors to be considered for crash severity include speeds, impact angles, and roadside hazards or barriers.

2.8.3.2 Safety Concern Risk Assessment

As mentioned in Section 2.8.3.1, there is a level of subjectivity in completing these audits. However, key questions are provided to help determine the risk of a severe crash (NZTA, 2022):

- Is it possible to have a head-on crash at a speed greater than 70 kilometers per hour (approximately 45 MPH)?
- Is it possible to have an intersection (right-angle) crash at a speed greater than 50 kilometers per hour (approximately 30 MPH)?
- Is it possible to have a run-off-road (side impact with a rigid object) crash at a speed greater than 40 kilometers per hour (approximately 25 MPH)?
- Is it possible to have a vulnerable road user – for example, pedestrian, cyclist or motorcyclist, crash at a speed greater than 30 kilometers per hour (approximately 20 MPH)?

In addition to these questions, a safety concern risk-rating matrix is provided. This matrix helps auditors to determine the safety concerns associated with a project and the appropriate actions that should be taken. The safety concern risk-rating matrix is shown in Figure 2.9. As shown in the matrix, any crashes that result in a serious injury are at a minimum a significant safety concern. If serious injury crashes are likely, then the safety concern is serious. On the contrary, if it is very likely that property-damage-only crashes will occur, the safety concern is minor. The audit provides the following suggested actions based on the safety-concern risk rating (NZTA, 2022):

- Serious – Concern that must be addressed and requires changes to avoid serious safety consequences.
- Significant – Concern that should be addressed and requires changes to avoid serious safety consequences.
- Moderate – Concern that should be addressed to improve safety.
- Minor – Concern that could be addressed where practical to improve safety.

		Severity outcome				
		Non-injury	Minor		Serious	Fatal
		Property damage only (PDO)	Injury which is not 'serious' but requires first aid, or which causes discomfort or pain to the person injured.	Safe System injury threshold	Injury (fracture, concussion, severe cuts or other injury) requiring medical treatment or removal to and retention in hospital.	A death occurring as the result of injuries sustained in a road crash within 30 days of the crash.
Probability of a crash	Very likely	Minor	Moderate		Serious	Serious
	Likely	Minor	Moderate		Serious	Serious
	Unlikely	Minor	Minor		Significant	Serious
	Very unlikely	Minor	Minor		Significant	Significant

Figure 2.9 Safety-concern risk-rating matrix (NZTA, 2022).

While not included in the New Zealand Safe System audit guidelines, the Austroads Safe System Assessment Framework provides treatment suggestions for all seven crash types. The treatments are sorted into the following hierarchy (Turner et al., 2016):

- Safe System options or primary treatments;
- Supporting treatments that are compatible with future Safe System options;
- Supporting treatments that do not affect future Safe System options; and
- Other considerations.

The influence of each treatment is also listed, whether it impacts the exposure, likelihood, or severity of crashes. For example, primary treatments for intersection crashes include grade separation or a roundabout. These options reduce the likelihood and severity of an intersection crash. Supporting treatments include turning lanes, improved sight distance, and street lighting. These solutions influence the likelihood of a crash at an intersection.

While this Safe System audit is currently used in New Zealand, it is important to note that National Cooperative Highway Research Program (NCHRP) project 17-125, titled “Guide for Applying Safe System Principles in the Road Safety Audit Process” is currently in progress to help state DOTs incorporate the Safe System Approach into their road safety audits. This project is expected to be completed in October 2026.

2.9 Summary

The purpose of this chapter was to provide background information regarding the Safe System Approach and its guiding principles and elements. The Safe System Approach originates from Sweden through Vision Zero and recognizes that crashes will occur, but steps can be taken to prevent them from being severe or fatal. The objective of the Safe System Approach is to reduce crash severity, adjust travel speeds to align with roadway conditions, and mitigate impact forces. The principles that guide the Safe System Approach include:

- Death/Serious Injury is Unacceptable;
- Humans Make Mistakes;
- Humans are Vulnerable;
- Responsibility is Shared;
- Safety is Proactive; and
- Redundancy is Crucial.

The elements of the Safe System Approach include:

- Safe Road Users;
- Safe Vehicles;
- Safe Speeds;
- Safe Roads; and
- Post-Crash Care.

Traffic safety should be viewed through the lens of public health. When public health practitioners understand causes of disease and injury, they can prioritize interventions at different population levels to decrease exposure and risk to as many people as possible (Mitman et al., 2024). The Health Impact Pyramid relates the effectiveness of a public health intervention to the amount of individual effort required (Mitman et al., 2024). The Safe System Pyramid relates roadway safety to the amount of individual effort required. The Safe System Pyramid helps transportation engineers and planners apply public health concepts in traffic safety and allows them to focus safety interventions on reducing the cause of injury.

The FHWA created the Safe System Project-Based and Policy-Based Alignment Frameworks to help quantify how projects and policies integrate the principles and elements of the Safe System Approach. Additionally, the Waka Kotahi New Zealand Transport Agency has a Safe System audit to assist in identifying a project's alignment with Safe System principles. The Austroads Safe System Assessment Framework offers treatment measures and describes how they will influence safety.

The FHWA has created the SSI methodology to assess intersections. This methodology characterizes conflict points, exposure, severity, and movement complexity. These steps can serve as measures of effectiveness in planning and can be used to calculate an SSI score. A higher SSI score indicates the intersection is closer to a safe system. Although this methodology is in its early stages, variations of it have already been implemented by DOTs in states such as Georgia and Florida. These applications will be explored in the next chapter.

3.0 STATE OF THE PRACTICE

3.1 Overview

This chapter contains programs, policies, and practices that are recommended by ITE and FHWA and/or are currently being used by jurisdictions to implement the Safe System Approach. Some of the practices presented in this chapter are specific to intersections, while others discuss how the Safe System Approach is being implemented generally. The first topic discussed is the current programs UDOT has that fit within the Safe System Approach. Following this is a discussion on Vision Zero, including case studies of jurisdictions that have become Vision Zero communities. Next, case studies regarding the Safe System Approach at intersections are provided, followed by discussion on the how Florida and Georgia DOTs are implementing the FHWA SSI methodology in their ICE programs. This is followed by how several DOTs have institutionalized the Safe System Approach, and how the FHWA recommends incorporating the Safe System Approach into the Highway Safety Improvement Program (HSIP). A discussion on the Safe System Framework and Safe System Roadway Design Hierarchy developed by ITE and the FHWA is then provided. This chapter ends with a presentation of several physical countermeasures recommended by the FHWA, and/or that have been used outside of the United States to reduce vehicle speeds and kinetic energy at intersections.

3.2 Existing UDOT Policies and Programs

Many generally adopted policies and practices at UDOT already fit within principles and elements of the Safe System Approach. UDOT has policies, programs, and groups that address different elements of the Safe System Approach including:

- Zero Fatalities;
- Utah’s Strategic Highway Safety Plan (SHSP);
- Speed limit policy;
- ICE Program;

- AASHTOWare Safety; and
- UDOT groups and departments.

The following subsections summarize these policies, programs, and groups.

3.2.1 Zero Fatalities

Zero Fatalities is an initiative within the state aimed at reducing traffic-related fatalities and serious injuries on Utah's roadways. The program focuses on the following strategies and campaigns to promote safe driving behaviors and raise awareness about the importance of road safety (Zero Fatalities, 2024):

- Education and outreach – The Zero Fatalities program emphasizes educating the public about safe driving practices through various outreach efforts. These include public service announcements, school programs, community events, and partnerships with local organizations to spread awareness about road safety.
- Behavioral change campaigns – The program runs campaigns designed to change driver behavior and promote safer habits on the road. These campaigns often target specific behaviors such as distracted driving, speeding, impaired driving, and not wearing seat belts. By highlighting the consequences of risky behaviors and promoting alternatives, the aim is to encourage safer driving practices among motorists.
- Partnerships and collaboration – The success of the Zero Fatalities program relies on collaboration with various stakeholders, including government agencies, law enforcement, community organizations, schools, businesses, and the public. By working together, these partners can amplify the program's message, share resources, and implement coordinated efforts to improve road safety.

Overall, the Zero Fatalities program combines education, outreach, and collaboration to achieve its goal of eliminating traffic-related fatalities and serious injuries on Utah's roadways. The goals of Zero Fatalities are consistent with Vision Zero and the Safe System Approach. By continuing to develop Zero Fatalities, UDOT stands by the principles and elements of the Safe System Approach.

3.2.2 Utah's Strategic Highway Safety Plan

Formed in 2003, the Utah Safety Leadership Executive Committee is formed of several Utah agencies. This committee created a comprehensive plan to reduce serious and fatal crashes on Utah's roadways. The most recent version of the plan was created in 2020 and seeks to coordinate safety efforts for the next five years, starting in 2021. Utah's SHSP is focused on the following aspects (UDOT, 2020):

- Engineering – According to the SHSP, safety in engineering starts with planning, designing, constructing, and maintaining safe transportation systems. Transportation professionals apply proven safe and reliable design principles, adhering to national standards to ensure consistency for all travelers. They also continually seek new and innovative methods to enhance roadway safety.
- Education – The SHSP states that education is crucial in informing the public about proper and improper driving behaviors. Enhanced education fosters behavioral change and, over time, shifts cultural attitudes, resulting in fewer road fatalities. These educational efforts target all age groups and address various safety issues.
- Enforcement – UDOT's SHSP states that enforcement is essential to remind people of the laws governing its roadways. State, county, and municipal law enforcement agencies collaborate with highway safety partners across Utah to enforce traffic laws through regular patrols and specialized mobilization efforts.
- Emergency medical services – This aspect refers to emergency medical services such as trained dispatchers and medical personnel. First responders are responsible for ensuring patients are treated and transported to hospitals as quickly as possible. Additionally, dispatchers ensure the right resources arrive at the crash site, and incident management works to reduce the risk of secondary crashes.
- Everyone – According to the SHSP, road safety begins with everyone. As everyone using Utah's roads does their part to travel safely, 'zero fatalities' becomes a more achievable goal.

Each of these aspects are used to address areas that UDOT has put an emphasis on. Some emphasis areas include aggressive driving, motorcycle safety, and intersection safety. Regarding each emphasis area, the SHSP identifies challenges associated with that area and priority strategies that can be used by each element to address those challenges. The aspects of the SHSP are like the elements of the Safe System Approach discussed in Section 2.5. For example, Emergency Medical Services is similar to Post-Crash Care, and Engineering is similar to Safe Roads. The SHSP will continue to update over time. As it is updated, it can be further aligned with the Safe System Approach.

3.2.3 Speed Limit Policy

UDOT has made changes to how speed limits are set on their roadways. In November of 2023, UDOT updated internal policy 06C-25 "Establishment of Speed Limits on State Highways" (UDOT, 2023a). This policy states that speed limits will be established on state highways based on an engineering study in accordance with the Manual on Uniform Traffic Control Devices (MUTCD) and Utah Code. The policy states that the speed limit will be determined based on the access category of the UDOT roadway. A range of acceptable speed limits is provided for each access category. Other factors to consider include the 85th percentile speed, pedestrian and bicycle activity, on-street parking, and crash history. This policy was updated to meet UDOT's goal of zero fatalities and adds consideration of roadway context to protect all users when establishing a speed limit (UDOT, 2023a).

Determining the speed limit by using the 85th percentile speed exclusively means that vehicle drivers determine the speed limit on the roadway, with no consideration for other modes of transportation. This updated UDOT speed policy accounts for other roadway users, making speed limits safer for other forms of transportation. UDOT will continue to update this policy over time. The next scheduled review is in November 2026.

3.2.4 Intersection Control Evaluation Program

As discussed in Section 2.5.4, UDOT currently has an ICE program. The primary goal of the ICE program is to evaluate the performance and safety of different intersection alternatives, helping traffic engineers and planners make informed decisions about traffic control measures and improvements. In a full ICE study, operation, safety, and maintenance costs are evaluated between intersection alternatives. The benefit-cost ratio for each alternative is also calculated. Currently, the benefit-cost ratio does not account for active transportation. The findings from the alternatives are presented at UDOT region field reviews. The UDOT region then determines how to proceed. ICE fits within the Safe System Approach as it has allowed UDOT to move toward being proactive regarding safety at intersections. The current tools and procedures can be improved to better adhere to the Safe System principles by accounting for active transportation, as the Safe System Approach is concerned about all road users, not just vehicles.

3.2.5 AASHTOWare Safety

UDOT's AASHTOWare Safety web tool (Numetric, 2024) is a product developed by Numetric and the American Association of State Highway and Transportation Officials (AASHTO) and used by UDOT to manage and analyze crash data. AASHTOWare Safety provides tools for collecting, storing, and analyzing crash data, as well as for conducting safety evaluations. The tool helps UDOT to identify high-crash locations, develop patterns according to crash severity, prioritize safety investments, and track the effectiveness of safety initiatives over time. Overall, AASHTOWare Safety plays a crucial role in supporting UDOT's efforts to enhance road safety and reduce severe injury and fatal crashes. The Safe System Approach and Vision Zero are data driven. Using a program like AASHTOWare Safety allows UDOT to use crash data effectively and holistically in safety analysis and roadway projects. Using crash data allows UDOT to be proactive, focus on severe injury and fatal crashes, and adhere to the principles of the Safe System Approach.

3.2.6 UDOT Groups and Departments

UDOT has several departments, groups, and practices that work to improve safety on the roadway. One of these is the Transportation Technology Group. UDOT's Transportation Technology Group focuses on the implementation and management of transportation-related technologies. This group is responsible for overseeing various technological solutions aimed at improving the efficiency, safety, and effectiveness of Utah's transportation system. Their responsibilities may include the deployment of intelligent transportation systems such as connected vehicles, traffic management systems, real-time traveler information systems, and other innovative technologies designed to enhance the state's transportation infrastructure and operations.

UDOT also has incident management teams that work to ensure post-crash care is provided swiftly and adequately. They work closely with first responders to manage and provide traffic control for crash scenes. Their responsiveness is key to survival rates after a crash has occurred. UDOT has also continued to research the benefits of increasing the number of incident management teams, strengthening this element of the Safe System Approach in their practice.

3.3 Vision Zero Communities and Action Plans

As discussed in Section 2.2, the Safe System Approach is the method by which Vision Zero is achieved. As of February 2024, a total of 59 communities in the United States have been recognized as Vision Zero communities (Vision Zero Network, 2024). Vision Zero communities work to shift traditional views of safety to the Safe System Approach. The following sections discuss how to become a Vision Zero community, what should be included in a Vision Zero Action Plan, and case studies of Vision Zero communities and their Vision Zero Action Plans. Note that Vision Zero communities and Action Plans are used to apply the Safe System Approach generally, not just at intersections.

3.3.1 Becoming a Vision Zero Community

A Vision Zero community is more than a community that has adopted Vision Zero as a slogan. It is a community that has established the goal of zero traffic fatalities and serious injuries, with multiple departments and elected official support. Additionally, a Vision Zero Action Plan or strategy is put in place to measure the community's progress toward zero deaths and serious injuries. According to Vision Zero Network, a Vision Zero city has met the following minimum standards (Shahum and Vanderkooy, 2017):

- Sets clear goal of eliminating traffic fatalities and severe injuries;
- Mayor (or top official) has officially committed to Vision Zero publicly;

- Vision Zero strategy or plan is in place or Mayor (or top official) has committed to doing so in a clear time frame; and
- Key city departments (police, transportation, public health) are engaged.

Many of these standards are addressed in a community's Vision Zero Action Plan. The Vision Zero Network has established guidelines for creating a Vision Zero Action Plan (Vision Zero Network, 2017). These fundamentals are described in the following section.

3.3.2 Foundational Elements of a Vision Zero Action Plan

To become a Vision Zero community, a Vision Zero Action Plan is required. A Vision Zero Action Plan helps communities committed to Vision Zero to set goals, timelines, and priorities for eliminating traffic fatalities and serious injuries. This plan should also include broader community and stakeholder input (Vision Zero Network, 2017). This ties into the principle of the Safe System Approach that Responsibility is Shared. The following subsections discuss the foundational elements of a Vision Zero Action Plan, as established by Vision Zero Network.

3.3.2.1 Build a Robust Data Framework

Collecting crash data allows communities to develop a High Injury Network (HIN). This HIN can be used to identify locations where safety projects should be prioritized, both proactively and reactively. It is important to note that crash data alone often does not provide a complete story. Marginalized communities might be less likely to report traffic crashes. Additionally, certain areas may feel unwelcoming or dangerous, deterring pedestrians and cyclists. As a result, these locations may not be highlighted as high-injury problem areas, but still may warrant attention. Therefore, demographic data and community input should be used when creating a data framework (Vision Zero Network, 2017). Creating a robust data framework allows communities to be proactive in safety projects, which is one of the principles behind the Safe System Approach.

3.3.2.2 Set Measurable Goals with a Clear Timeline for Implementation

Clear goals with an established timeline and ownership create a framework that is easier to evaluate. Communities are recommended to determine a target year to reach zero roadway fatalities and injuries. Many cities use a 10-year timeframe. Action Plans are then recommended to have short-term and long-term goals within that timeframe, establishing Vision Zero and the Safe System Approach as a long-term strategy. As mentioned previously in Section 2.6.5, people of color tend to live closer to dangerous intersections and are disproportionately impacted by traffic crashes. Therefore, goals that seek to improve intersection safety will begin to close this gap in addition to reducing the number of serious crashes (Vision Zero Network, 2017).

3.3.2.3 Be Accountable

One of the principles of the Safe System Approach is that Responsibility is Shared. Therefore, every strategy and countermeasure presented in the Vision Zero Action Plan should be identified with the leading and supporting agencies. This helps to strengthen partnerships across departments, increasing redundancy in planning and engineering (Vision Zero Network, 2017). This in turn supports the principle in the Safe System Approach that Redundancy is Crucial.

3.3.2.4 Ensure Transparency

Transparency of successes, challenges, and community progress toward zero serious injuries and fatalities is key to keeping the community and stakeholders engaged in the process. This can be done by creating a public website that shares crash data and progress on Action Plan strategies. This can also give residents an opportunity to provide feedback. Creating a Vision Zero Task Force with key stakeholders helps to assess successes and challenges to a community's Vision Zero progress. Finally, having a third party assess Vision Zero goals helps to provide another perspective on how the community is performing (Vision Zero Network, 2017). This reinforces the Responsibility is Shared principle of the Safe System Approach.

3.3.3 Vision Zero Community Case Studies

As mentioned in Section 3.3, a total of 59 communities in the United States have been recognized as Vision Zero communities as of February 2024. Four case studies are presented in this section. Each case study includes a brief description of the community's Vision Zero Action Plan, actions that were taken, and outcomes. Note that while not all case studies are exclusively intersection related, it is how communities are implementing the Safe System Approach.

3.3.3.1 Portland, Oregon

Portland, Oregon adopted Vision Zero in 2015 and adopted a Vision Zero Action Plan in 2016. Their goal is to eliminate traffic deaths and serious injuries by 2025. As part of their Vision Zero Action Plan, Portland has implemented the following strategies (PBOT, 2016):

- Develop a high crash network for motor vehicles, bicyclists, and pedestrians, overlayed with equity data to identify "communities of concern;"
- Develop installation criteria guidelines for marked pedestrian and bicycle crossings based on vehicle speeds, volumes, transit stops, and other factors;
- Develop installation criteria guidelines for protected bike lanes;
- Work with rideshare and taxi services to provide intoxicated drivers a ride home, as discussed in Section 2.5.1; and
- Implement pilot speed safety cameras on four high crash corridors.

Other actions are being taken to address street design, impairment, speed, and dangerous behaviors. As a result of these actions, Portland has seen the following safety outcomes (PBOT, 2023):

- Decrease in traffic deaths by 25 percent from 2017 to 2018 (PBOT, 2019);
- Reduction in intersection turning radius to reduce speeds (also known as turn calming, discussed further in Section 3.9.19), which has reduced median turning speeds by 13 percent;
- Speed safety camera installations resulting in 71 percent fewer speeding events and 92 percent fewer speeding events of 10 MPH or more over the speed limit; and
- Lane reconfigurations resulting in 72 percent fewer speeding events of 10 MPH or more over the speed limit.

It is important to note that Portland saw an increase in traffic fatalities from 2018 to 2021 (PBOT, 2023). However, using the data from these crashes, Portland has found new trends and has pivoted their strategies to prevent fatal and serious injury crashes moving forward. In their November 2023 Vision Zero Action Plan update, Portland will implement the following:

- Launch a “no turn on red” pilot;
- Launch a “rest on red” pilot (this is also known as a dwell on red and is discussed further in Section 3.9.4);
- Update signal timing to promote lower speeds;
- Install more speed safety cameras; and
- Adopt a policy to rebuild safer intersections on the high crash network.

Other enforcement and public outreach campaigns will still be implemented. Portland is still committed to its goal of eliminating traffic fatalities in 2025, despite setbacks in recent years.

3.3.3.2 Austin, Texas

In Austin, Texas, the city council adopted Vision Zero as a policy goal in 2015. Their first Vision Zero Action Plan was adopted in 2019. As part of their Vision Zero plan, Austin has implemented the following practices (Abel et al., 2023; Austin, Texas, 2021):

- Created a GIS crash database and high injury network to determine the highest concentration of severe crashes to prioritize safety strategies and complement systemic safety analysis;
- Systemic countermeasures were installed at high-risk locations with similar roadway characteristics;
- Created a Vision Zero leadership council that meets every six weeks to give direction and guidance on Vision Zero programs and priorities; and
- Applied systemic changes to road design, including LPIs at 110 intersections, signal timing improvements, more prominent signal heads, lowering speed limits to 35 MPH or less on urban core arterials, and improved lighting.

As a result of these efforts, Austin has seen the following safety benefits (Abel et al., 2023; Austin, Texas, 2021):

- A 17 percent decrease in fatal and serious injury crashes in 2021 compared to the previous three-year average on high injury roadways that received low-cost countermeasures;

- An additional 18 percent reduction in annual pedestrian crashes involving left-turn vehicles at intersections that implemented an LPI compared with those that did not;
- A 36 percent reduction in annual pedestrian crashes involving right-turning vehicles at intersections that implemented an LPI; and
- A 64 percent reduction in annual number of opposing left-turn crashes at intersections where signal timing adjustments were made.

Like Portland, Austin also saw an increase in fatal and serious injury crashes from 2020 to 2022. As a result, they are adopting the following strategies (Austin, Texas; 2023):

- Increase in low-cost systematic countermeasures such as signals with retroreflective backplates, left-turn calming treatments, and signal timing changes;
- Development of Austin-specific policies and guidelines for when to install a roundabout with conceptual designs in development for six intersections; and
- New messaging campaigns regarding speeding and dangerous driving.

3.3.3.3 Boulder, Colorado

Boulder, Colorado began reporting data on Vision Zero in 2009 and adopted it as part of their Transportation Master Plan in 2014. As part of their Vision Zero Plan, Boulder has made changes to their arterial streets as they are where most fatal and serious injury crashes were happening. Some intersection countermeasures that Boulder has implemented include (Abel et al., 2023):

- LPIs;
- Flashing yellow arrows;
- No right turn on red;
- Longer pedestrian clearance times; and
- Converting permitted/protected left-turn phasing to protected-only during peak travel times or permanently.

Several roadside improvements were also made. As a result of these measures, Boulder has seen the following safety benefits on the city network (Abel et al., 2023):

- Zero traffic fatalities in 2015 and 2017;
- Decrease in total crashes by 13 percent between 2015 and 2019; and
- Support to implement large-scale roadway redesigns.

3.3.3.4 Fremont, California

Fremont, California adopted Vision Zero in 2015 and established a Vision Zero Action Plan in 2016. As part of their Vision Zero Action Plan, Fremont has implemented the following (Abel et al., 2023):

- Transportation engineers and police departments meet monthly to share information and ensure narrow roads do not increase emergency response times;
- Created a map of high-crash roads to focus infrastructure projects and provide systemic responses to locations with similar infrastructure;
- The 2016 city theme at the city's outreach booth at community events was "safety;" and
- The vice mayor started a speaker series to discuss Vision Zero.

Each of the measures listed above demonstrates how Fremont institutionalized Vision Zero and the Safe System Approach into their policymaking. The above efforts worked to change the system and culture surrounding roadway safety. The following physical measures were also implemented (Abel et al., 2023):

- Pedestrian countdown signals at all signalized intersections;
- A total of 16,000 streetlights converted to brighter LED lights;
- Narrowed travel lanes (to 10 feet) and enhancement of bicycle facilities;
- Smaller turning radii at intersections;
- Protected intersections, including improved sight lines and the elimination of weaving maneuvers between bicycles and vehicles;

- Installation of 40 midblock crosswalks with measures such as enhanced striping, signage, markings, rectangular rapid-flashing beacons (RRFBs), and refuge islands; and
- Improvements made along safe routes to schools for all 40 public schools.

As a result of these measures, Fremont has seen the following safety benefits when comparing crash data between 2013 and 2015 to crash data from 2018 to 2020 (Abel et al., 2023):

- Reduction of pedestrian fatal and serious injury crashes by 32 percent;
- Reduction of bicycle fatal and serious injury crashes by 23 percent;
- Reduction of fatal and serious injury crashes in dark conditions by 36 percent; and
- Reduction of youth fatal and serious injury crashes in dark conditions by 67 percent.

In 2021 and 2022, Fremont saw an increase in fatal and serious injury crashes. However, the crash rates are still lower than they were before adopting Vision Zero. Fremont recognizes that COVID-19 has resulted in new driving behaviors that have not been targeted by previous Vision Zero efforts, primarily excessive speeding, and homeless walking in the street at night. As a result, Fremont has adopted the following strategies (City of Fremont, California; 2024):

- The police, public works, and human services departments distributed traffic safety kits to the homeless including lights and reflective clothing;
- A total of 77 driver feedback signs have been installed along major corridors, and traffic signal timing is being updated to promote lower speeds; and
- Fremont is also constructing a protected intersection and pedestrian flashing beacons.

3.3.3.5 Philadelphia, Pennsylvania

Philadelphia adopted Vision Zero in 2016. A Vision Zero three-year Action Plan was released in 2017. The Action Plan priorities included equity, evaluation, engineering, education, and enforcement (City of Philadelphia, 2017). Between 2017 and 2020, Philadelphia implemented the following safety measures (City of Philadelphia, 2020; 2023):

- Development of an HIN, which is used to determine where safety projects should be implemented;
- Speed camera legislation and installation;
- Over 100 LPIs and speed cushions; and
- Emphasis on complete streets projects, including separated bike lanes and road diets.

Despite these actions, the number of fatalities increased from 78 to 92 from 2017 to 2018, and then decreased to 83 in 2019 (City of Philadelphia, 2020). The plan was updated in 2020 and the most recent version of the Vision Zero Action Plan has incorporated the Safe System Approach. The Action Plan priorities have been changed to be equity, safe speeds, safe streets, safe people, safe vehicles, safety data, and vision zero for youth. Action items are established for each priority to decrease the number of roadway fatalities by 2025 (City of Philadelphia, 2020).

It is important to note that traffic fatalities in 2020 were higher than in the previous eight years with 152 fatalities. Fatalities decreased in 2021 to 123 fatalities, and in 2022, there were 124 fatalities. Traffic fatalities are still higher than pre-pandemic levels. However, Philadelphia has also seen the following safety benefits (City of Philadelphia, 2023):

- Reduction of speed on roadways with a road diet by 25 percent;
- No fatal or serious injury crashes and reduction of crashes in neighborhood slow zones (20 MPH speed limit) by 75 percent; and
- Reduction of speeding violations by 95 percent on roads with automated speed enforcement, resulting in 21 percent fewer fatal and serious injury crashes and 50 percent fewer crashes involving pedestrians.

3.4 Safe System Approach to Intersections Case Studies

In 2021, ITE published a summary of case studies of locations that had implemented the Safe System Approach. This summary included how certain jurisdictions applied the Safe System Approach to major thoroughfares, intersections, and pedestrian safety. This section summarizes the case studies that discussed implementing the Safe System Approach to intersections in the following locations:

- Roundabout Program – Carmel, Indiana.
- Turn Hardening Program – New York City and Washington, D.C.
- Daylighting Intersections – San Francisco, California.
- Near-Miss Metrics – Bellevue, Washington.

Additionally, the Capital Region Intersection Safety Partnership (CRISP) carried out a pilot project on engineering applications of the Safe System Approach. This included the development of a Safe System Intersection Assessment Path. This assessment path will also be discussed in this section. It is important to note that in some of these case studies, the application of the Safe System Approach is a result of a Vision Zero Action Plan.

3.4.1 Roundabout Program

The city of Carmel, Indiana has been implementing the Safe System Approach by prioritizing the installation of roundabouts at intersections wherever possible. As a result, more than 125 intersections have been converted to roundabouts across the city. The benefits of roundabouts are discussed further in Section 3.9.15. As a result of this roundabout program, Carmel has experienced an 80 percent reduction in serious injury crashes in locations where roundabouts replaced traditional signalized intersections (ITE, 2021). In addition to increasing the number of roundabouts in the city, Carmel added further safety measures by changing the 15 MPH warning speed limit signs at these roundabouts to regulatory signs. They are also creating an ordinance that will require vehicles to stop at all crosswalks for pedestrians who are about to cross, rather than only if there is already a pedestrian in the crosswalk (ITE, 2021).

3.4.2 Turn Hardening Program

As part of their Vision Zero programs, New York City and Washington, D.C. have adopted turn hardening measures to reduce the turning radius at intersections using flex posts and pavement markings. Turn hardening is also referred to as turn calming. Reducing the turning radius in the intersection reduces the turning speed, which reduces the kinetic energy. This increases a pedestrian's chance of survival should a crash occur. In New York City, traffic data revealed that death and serious injury crashes for pedestrians and bicyclists were three times more likely to occur at left turns than at right turns. Left-turn hardening measurements were shown to reduce median speeds by 24 percent and the number of drivers crossing the double yellow line by 98 percent. Similarly, Washington, D.C. identified intersections with high rates of serious crashes involving turning movements. As a result, left-turn hardening posts were installed, no right-turn-on-red movements were implemented, turning radii were reduced, and slip lanes were removed (ITE, 2021). Portland, Oregon also implemented a turn calming program as part of their Vision Zero Program. Turn calming is discussed further in Section 3.9.19.

3.4.3 Daylighting Intersections

In 2019, the city of San Francisco, California implemented the Safe System Approach by passing a resolution to remove on-street parking spaces near intersections where they restrict visibility, particularly along high-injury corridors. This safety practice is often referred to as "daylighting intersections." By anticipating the human error that is associated with restricted visibility, San Francisco decided that the simplest solution was to increase visibility through this process of daylighting (ITE, 2021). In 2014, daylighting was implemented on 80 intersections in the Tenderloin neighborhood of San Francisco. This resulted in 14 percent fewer reported collisions at the treated intersections (City and County of San Francisco, 2019). Similarly, the California legislature has recently made it illegal to park within 20 feet of the approach of any crosswalk, which should increase safety statewide (California Legislature, 2023).

3.4.4 Near-Miss Metrics

The city of Bellevue, Washington has used artificial intelligence to process traffic footage to determine near-crash event data. This data helps transportation engineers make safety improvements to prevent crashes before they occur, rather than as reactive measures (ITE, 2021). The video footage provides engineers with more specific data than a crash report, allowing them to observe characteristics of near misses in addition to actual crashes. This program found that bicycle users were 10 times more likely to be involved in a conflict than a motorist (Intelligent Transportation Systems Joint Program Office, 2022). With this information, safety measures focusing on bicycle safety can be implemented before a bicycle crash occurs. The data-driven, proactive nature of this program is consistent with the Safe System principle that Safety is Proactive.

3.4.5 Safe System Intersection Application Pilot Project

CRISP conducted a pilot project on engineering applications of the Safe System Approach. The pilot project consisted of applying a kinetic energy management model to 16 problematic intersections in the Capital Region. The model evaluated the transfer of kinetic energy on a human body during a crash based on the impact speed and angle. The probability of fatal and serious injury crashes with existing layouts was compared with other intersection layouts such as roundabouts, turbo-roundabouts, and interchanges. The following Safe System design principles developed by the Monash University Accident Research Centre were considered when presenting alternatives (Corben et al., 2010):

- Fewer vehicles – Reducing the number of vehicles lowers risk of collision.
- Fewer intersections – Reducing the number of intersections reduces high-risk conflict opportunities.
- Fewer conflict points per intersection – Simplifying intersections and reducing conflict points reduces crash opportunities.
- Impact speeds and impact angles constrained to biomechanically tolerable levels. In the event of a crash, designing optimal speed and angle combinations results in lower severity and injury risk.

As part of this pilot project, road safety audits were discussed, and the Safe System Assessment Path was developed, which incorporates the design principles listed above. The Safe System Intersection Assessment Path is a two-stage approach to help align intersections with the Safe System Approach. First, it encourages designers to reduce the risk of crashes as much as possible. Second, any crashes that remain should be within an acceptable tolerance level for the human body. The Safe System Intersection Assessment Path is shown in Figure 3.1 (Huculak, 2014).

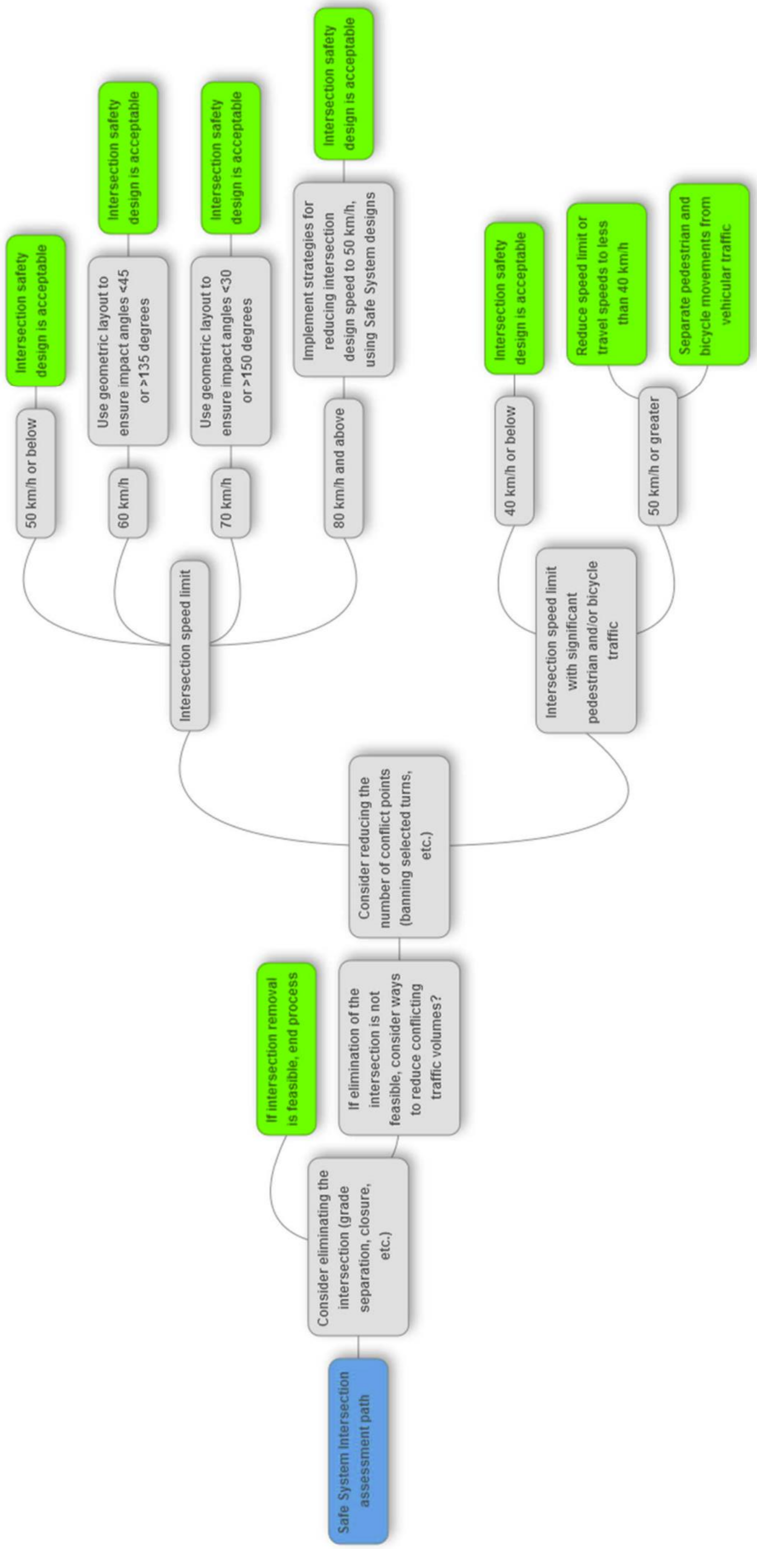

Figure 3.1 Safe System Intersection Assessment Path (Huculak, 2014).

According to Assessment Path, the first step to consider is eliminating the intersection altogether, such as through grade separation or closure. If it is not possible, then the next step is to find ways to reduce traffic volumes, as lower volumes result in lower exposure. The next step is to reduce the number of conflict points. After the number of conflict points has been reduced, the desired speed limit at the intersection must be determined. The Assessment Path provides a variety of acceptable speed limits based on impact angles and the level of vulnerable road user traffic.

One key finding from the pilot project is that tolerance for traveling over the speed limit should be much less than speeds 15 kilometers per hour (approximately 10 MPH). Speeds 10 MPH or higher over the speed limit drastically increase the probability of a crash resulting in a fatality or serious injury. Conclusions from the pilot project consist of including road safety audits as part of the planning and design process and adopting the Safe System Intersection Assessment Path.

3.5 The Safe System at Intersections Methodology in Intersection Control Evaluation Programs

A summary of the FHWA SSI methodology was discussed previously in Section 2.7. This section will provide a brief description of how the SSI scores are calculated. This section will also discuss how both the Florida Department of Transportation (FDOT) and the Georgia Department of Transportation (GDOT) have implemented this methodology into their ICE programs.

3.5.1 Federal Highway Administration Methodology

As discussed previously in Section 2.7, the FHWA has created a methodology that evaluates how closely an intersection alternative adheres to the Safe System principles. The goal of this methodology is to provide planners and designers with a technical basis for kinetic energy management principles that rely on readily available data. The data required for this analysis includes (Porter et al., 2021):

- Posted speed limit;
- AADT volumes; and
- Number of through lanes on intersecting roads.

A summary of each step is provided in the following subsections, while the details, including equations and detailed calculations, can be found in the literature (Porter et al., 2021; Dunn et al., 2023). A flowchart of the steps and their outputs is shown in Figure 3.2.

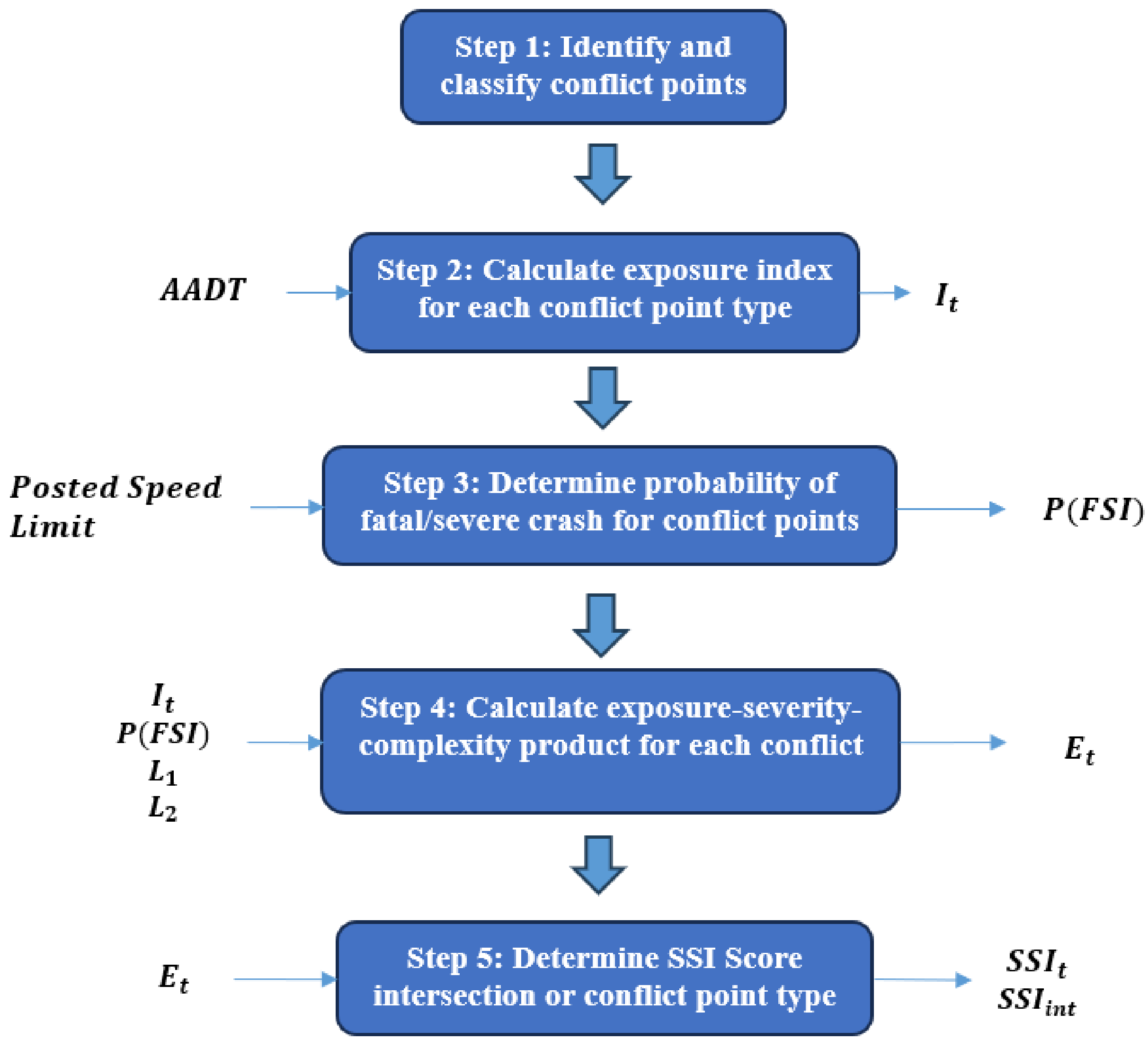

Figure 3.2 FHWA SSI Methodology Flowchart

3.5.1.1 Step 1 – Conflict Point Identification and Classification

The first step in the SSI methodology is to identify the conflict points at an intersection. This is done on a movement basis, and not a lane-by-lane basis. Each conflict point is identified and then classified as a crossing, merging, diverging, or nonmotorized conflict point.

3.5.1.2 Step 2 – Calculating Conflict Point Exposure

After each conflict point is identified and classified, the next step is to determine the exposure index (I_c) for each individual conflict point. The exposure index is the product of vehicle or nonmotorized daily volumes passing through the conflict point. The exposure indices for individual conflict points are then summed together for all conflict points of a specific type at an intersection (I_t). This allows for the calculation of the overall exposure for each type of conflict point, such as the total exposure for all crossing conflict points or all merging conflict points.

3.5.1.3 Step 3 – Calculating Fatal and Serious Injury Crash Probability for Each Conflict Point

Following the calculation of the exposure index, the next step is to determine the conflict point severity. SSI defines this as the probability of a fatal or severe injury crash at a conflict point ($P(FSI)$). The MAIS scale is used to define whether an injury is severe or fatal. Conflict point severity is determined using ($P(FSI)$) models. These models use movement speeds and collision angles as inputs. The SSI method has default values for these inputs, but specific values can be used.

3.5.1.4 Step 4 – Determining Exposure-Severity-Complexity Product Conflict Point Types

The next step is to determine the exposure-severity-complexity product for each conflict point type (E_t). The SSI method identifies two primary factors of intersection complexity. The first factor (L_1) assesses the complexity arising from conflicting traffic characteristics and how traffic control moderates this complexity. This factor applies to both vehicle and nonmotorized movements, including vehicle-vehicle and vehicle-nonmotorized movement conflict points. The second factor (L_2) focuses specifically on additional complexity related to nonmotorized traffic, considering indirect and nonintuitive movements that may challenge pedestrians and cyclists. The SSI method assumes that intersection attributes linked to lower complexity levels for all users contribute to aligning it with a Safe System Approach. The exposure index (I_c), probability of fatal and severe injury crashes ($P(FSI)$), and complexity factors (L_1 and L_2) are used to calculate an exposure-severity-complexity product for each conflict point type (E_t).

3.5.1.5 Step 5 – Determine SSI Scores for Conflict Point Types and Intersection Alternatives

After the exposure-severity-complexity product (E_t) for each conflict point type is determined, an SSI score can be calculated for each conflict point type (SSI_t) and for the intersection (SSI_{int}). The SSI score for a conflict point type only uses the exposure-severity-complexity product for that type of conflict point, whereas the SSI score for the intersection uses the exposure-severity-complexity product for all conflict point types. Both calculations use a calibration factor that ensures the final score is between zero and 100. The higher the score, the lower the chances of a fatal and serious injury.

It is important to note that several measures of effectiveness result from this analysis, including the SSI score for the intersection, the SSI score for a conflict point type, the probability of a fatal or serious injury crash associated with a specific conflict point, and the exposure index.

3.5.2 Florida Department of Transportation

FDOT integrated the SSI methodology into their ICE program in 2022. A Microsoft Excel spreadsheet was created to compute the SSI scores of intersection alternatives that could be considered at study locations. The spreadsheet also calculates the SSI scores for each conflict point type for each intersection alternative. This spreadsheet was developed internally by the consultant support team and was later integrated into FDOT's SPICE spreadsheet. FDOT currently uses the same assumptions as the FHWA methodology regarding turning speeds and collision angles for each type of conflict point. According to FDOT, it took approximately 900 hours (23 weeks) to explore the FHWA methodology, develop the spreadsheet, integrate it into the SPICE tool, update the ICE forms and manuals, and test and demonstrate the spreadsheet. This number of hours also includes meetings held throughout the process. In addition to this, several hundred hours have been completed for updates to the SSI worksheet since it was originally developed (Saha, 2024).

The use of the ICE program in Florida is decentralized, relying on districts to be responsible for the implementation of the SSI tool. The SSI tool is used in addition to Safety Performance Function (SPF) analysis outlined in the HSM. FDOT uses SSI as an additional lens in safety analysis and is not using it to replace SPF analysis. Regardless of the results, the engineer ultimately decides which alternative is chosen, considering additional factors such as cost and right-of-way acquisition. As of April 2024, the program has been received positively, with little to no pushback from the districts. However, FDOT has found that the basic framework of the SSI methodology, as developed by the FHWA, has certain limitations, particularly regarding intersection type. As part of the improvements FDOT is making to their SSI tool, they are adding a more comprehensive selection of intersection options. Additionally, the default assumptions for intersections regarding collision angles and turning speeds are the same as the FHWA, and therefore may not be entirely accurate in every situation (Saha, 2024).

The SSI tool is used during Stage I of ICE. When comparing SSI scores between alternatives, FDOT does not have a specific threshold to measure significant differences between SSI scores. Therefore, the process of choosing an alternative based on the SSI section of the SPICE tool is subjective. In Florida, this issue often surfaces as engineers tend to favor signalized control as the preferred option, even when alternative choices may have higher SSI scores. Lastly, the SSI tool has no formal tutorial or training for it, which can make it a difficult process to understand and implement uniformly across districts (Saha 2024).

3.5.3 Georgia Department of Transportation

GDOT has been using SSI in their ICE program since 2022. The Microsoft Excel spreadsheet computing the SSI scores was developed internally with consultant assistance. Currently, the SSI spreadsheet and calculations are embedded into the ICE spreadsheet. Like the FDOT spreadsheet, the GDOT spreadsheet calculates the SSI score for intersection alternatives and the SSI score for conflict point types for each alternative. According to GDOT, the spreadsheet took approximately 5 weeks to create and complete. However, GDOT is still updating calculations to ensure that they are accurate (Harris, 2024).

When first implementing SSI into their ICE tool, GDOT did so with the results from the SSI score locked and inaccessible for the duration of a year. After one year of collecting data, they re-opened the SSI portion of the tool to determine its effectiveness compared to typical ICE results. From this they determined that roundabouts were more accurately identified as a viable alternative when compared to other alternatives. When comparing SSI scores between alternatives, GDOT has determined that a difference of less than 5 percent (5 points) in the SSI score is insignificant. Differences in SSI score greater than 5 percent are considered more seriously. This 5 percent rule is consistent with how differences are measured between alternatives in SPF analysis (Harris, 2024).

Like FDOT, the final alternative decision is based on engineering judgment. GDOT currently uses the same assumptions as the FHWA methodology regarding turning speeds and collision angles. GDOT is currently working to make improvements to their SSI tool. The main improvement that they are focusing on is calibrating their SSI scoring to better reflect typical ICE results, since currently roundabouts are skewed more heavily. The long-term goals that they have for their SSI tool include making the SSI calculations more transparent to the average user, bringing in actual speed measurements based on historical speed data, and converting their entire ICE tool to a web-based application, as opposed to a Microsoft Excel spreadsheet, to make it easier to code (Harris, 2024).

3.6 Departments of Transportation Institutionalizing the Safe System Approach

While FDOT and GDOT have implemented the SSI methodology into their ICE programs, other DOTs have applied the Safe System Approach beyond just intersections. Additionally, NCHRP has set aside funding for research project 17-132 titled, "Tools to Support State DOT Implementation of the Safe System Approach." According to the problem statement, "The objective of this research is to develop resources such as tools, methods, and process models to support consideration of safety throughout the transportation project lifecycle and across state DOT programs using the framework and principles of the Safe System approach." This research project will develop tools to support state DOT implementation of the Safe System Approach. This project will begin in fiscal year 2025 and is not discussed in this section. However, it is important to be aware of when this research project is completed.

Currently, some state DOTs have made steps to implement the Safe System Approach ahead of this research. California, Washington, and Massachusetts are examples of DOTs that have issued policies or orders that have institutionalized the Safe System Approach into their practices. Additionally, the FHWA has published recommendations for how a state DOT can incorporate the Safe System Approach into their HSIP. This section will discuss the policies of these three DOTs and how they are applying the Safe System Approach into their work as well as the recommendations from the FHWA.

3.6.1 California Department of Transportation

In 2022, the California Department of Transportation (Caltrans) issued Director's Policy 36. This policy committed Caltrans to prioritizing safety by eliminating fatal and serious injury crashes by 2050 and eliminating race-, age-, ability-, and mode-based disparities in road safety. This policy mandated that all divisions within Caltrans align their programs, plans, policies, procedures, and practices with the Safe System Approach (Caltrans, 2022a). This policy has institutionalized the Safe System Approach into Caltrans' daily activities.

In the same year, Caltrans created District Chief Safety Officer positions and District and headquarters Safe System Lead positions. The Safe System Leads are the points of contact for all safety strategies. They also lead the Road Safety Action Plan (RSAP), which was published in 2023 (Caltrans, 2022b). As part of this RSAP, Caltrans is completing the following (Caltrans, 2022c):

- Reviewing and updating statewide planning guidelines to incorporate the Safe System Approach;
- Updating the safety project prioritization to focus on crash severity;
- Updating safety countermeasures in the HSIP Guidelines to be more consistent with proven safety countermeasures;
- Delegating approval for proactive safety projects in addition to reactive projects;
- Enhancing safety review process to incorporate the Safe System Approach; and
- Developing a statewide inventory of safety measures to support proactive safety initiatives.

Other tasks in the RSAP are related to public outreach and database management. The completion date for the RSAP is December 2024. It is also important to note that Caltrans updated its SHSP in May of 2024 to align the plan with the Safe System Approach. One of the actions assigned to the steering committee is to develop a Safe System Proclamation and guidebook for implementation (Caltrans, 2024). Institutionalizing the Safe System Approach with DP-36 has resulted in Caltrans prioritizing safety at every level of its organization. While the findings are currently unknown, Caltrans' commitment to the Safe System Approach demonstrates how it has shifted its view beyond traditional safety practices.

3.6.2 Washington State Department of Transportation

In 2023, the Washington State Department of Transportation (WSDOT) issued secretary's executive order E 1085.01, Advancing the Safe System Approach for All Users (WSDOT, 2023). This order reiterates WSDOT's goal to eliminate fatal and serious crashes on their roadways by 2030, as established in WSDOT's SHSP, also known as Target Zero (WSDOT, 2023). It also directs WSDOT executives and employees to revise agency policies and reallocate resources to align with the Safe System Approach. Some direction from the executive order includes:

- Work with internal and external stakeholders to analyze safety performances and develop strategies consistent with the Safe System Approach that lead to zero fatalities and serious injuries;
- Maintain a quantitative analytical approach across program areas, complying with AASHTO HSM guidelines where applicable, spanning program, planning, project development, operations, and maintenance functions;
- Conduct equity analyses based on modal crash data and Healthy Environment for All Act environmental justice requirements;
- Prioritize safety-oriented design and operational decisions tailored to specific road contexts, especially in areas impacted by legacy state transportation facilities and lacking walking and biking infrastructure, as outlined in the Active Transportation Plan;

- Explicitly identify and address a project's expected effects on network connectivity and crash exposure for vulnerable road users;
- Update methods for determining safety projects to incorporate the Safe System Approach;
- Revise manuals, policies, processes, procedures, and plans to embed the Safe System Approach into WSDOT's capital programs framework, aligning with Complete Streets implementation; and
- Submit annual reports to the Office of the Secretary on highway and roadway safety status, along with proposed actions to achieve Target Zero goals using the Safe System Approach.

Executive order E 1085.01 assigns responsibilities to employees at every level of WSDOT and helps the DOT to connect with local agencies. After Seattle installed LPIs, they saw a 48 percent reduction in pedestrian turning crashes and a 34 percent reduction in serious injury and fatal pedestrian crashes from 2009 to 2018. Bellevue saw a 42 percent reduction in vehicle-pedestrian crashes after LPIs were installed (Abel et al,. 2023).

As a result of executive order E 1085.01, all WSDOT employees are to ensure that their practices are consistent with the Safe System Approach. Higher level employees should hold discussions and training courses to make sure all employees understand and are implementing the Safe System Approach. Like Caltrans' DP-36, WSDOT's executive order 1085.01 has institutionalized the Safe System Approach into WSDOT's daily activities.

3.6.3 Massachusetts Department of Transportation

The Massachusetts Department of Transportation (MassDOT) has applied the Safe System Approach in policies and practices systemically across its jurisdiction. MassDOT has added a new module of safety analysis tools in its crash data portal. This module can be used to identify intersections with high crash rates and high risks of crashes (Abel et al., 2023). MassDOT has also provided local jurisdictions with the MassDOT Safety Alternatives Analysis Guide which supports planners and engineers in the development and selection of safety-focused and cost-effective alternatives. This guide supplements traditional ICE alternatives and provides a method for calculating crash frequency where national and state SPFs are not available. The guide also includes an economic analysis step in which alternative costs are compared to the estimated system-wide benefit using Massachusetts comprehensive crash costs (Abel et al., 2023).

In November 2016, the Massachusetts State Legislature passed legislation permitting municipalities to decrease speed limits from 30 MPH to 25 MPH in areas with higher business or residential density. Municipalities can independently choose to adopt this measure through local ordinances, or by notifying MassDOT of the adjusted speed limit and posting it at jurisdictional boundaries. Additionally, the law allows for the establishment of safety zones where speed limits can be further reduced to 20 MPH. Since its inception, 58 municipalities statewide have opted to lower speed limits in their densely settled areas. Major cities like Boston and Springfield implemented similar local laws within a year of the state law's passage. Smaller urban areas like Amesbury and Winthrop enacted their own speed limit adjustments through local ordinances in 2021 (Abel et al., 2023).

Nationally, there is limited data on the effectiveness of solely reducing posted speed limits. MassDOT acknowledges that speed limit reductions are most impactful when paired with changes to roadway geometry that support those speeds. Recognizing the element of Safe Speeds within the Safe System Approach and the cumulative effect of speed limit changes combined with roadway geometry changes, MassDOT has developed an informative speed management webpage. This webpage provides guidance on implementing safer speeds in Massachusetts communities, including a roadway treatment toolkit designed for municipalities and local stakeholders. The toolkit aims to educate on the integration of speed management treatments that regulate speeds and create separation through roadway treatments (Abel et al., 2023).

Additionally, as part of their 2023 SHSP, MassDOT incorporated the Safe System Approach. The SHSP includes the following six core initiatives (MassDOT, 2023):

- Implement Speed Management to Realize Safer Speeds;
- Address Top-Risk Locations and Populations;
- Take an Active Role to Affect Change in Vehicle Design, Features, and Use;
- Accelerate Research and Adoption of Technology;

- Double Down on What Works; and
- Implement New Approaches to Public Education and Awareness.

These core initiatives include 31 actions aligned with the Safe System Approach, including setting safer speed limits, installing safety projects systemically, championing safe vehicle technology, increasing road safety audits, improving post-crash care, and continuing to improve driver education. The 31 action items tie into a principle or element of the Safe System Approach, further institutionalizing it as a part of MassDOT's culture.

By incorporating elements of the Safe System Approach into its safety policies and practices, MassDOT has observed a decline in severe injury collisions annually from 2012 to 2019. This trend has led to an overall reduction in severe injury collisions of 23 percent over these 7 years, even as VMT has risen over the same period (Abel et al., 2023).

3.6.4 Integrating the Safe System Approach with the Highway Safety Improvement Program

The HSIP is a federal-aid highway program with the purpose of reducing roadway fatalities and serious injuries through safety projects. Recognizing that this goal is like that of the Safe System Approach, the FHWA has explored the relationship between the two to determine how they can be better integrated together (Finkel et al., 2020). Two major components of the HSIP are the SHSP and highway safety improvement projects. Guidance provided by the FHWA on how to incorporate the Safe System Approach into these two components is described in the following subsections.

3.6.4.1 States' Strategic Highway Safety Plans

SHSPs provide guidance on which safety projects to prioritize through emphasis areas. It is an opportunity for states to incorporate and adopt the Safe System Approach in their organizations. The FHWA recognizes the following opportunities for holistically integrating the Safe System Approach into state SHSPs (Finkel et al., 2020):

- Organize the SHSP around the Safe System six core principles and five elements – Replacing emphasis areas with the five elements of the Safe System Approach establishes that it is the path forward in roadway safety. Another option is to change the strategies from the Safety Es to the Safe System Approach elements.

- Commit to "zero" goal and establish performance management strategies – Setting a goal of zero deaths and serious injuries reinforces the principle that Death and Serious Injury is Unacceptable. The focus of this goal should be a reduction to zero, as in achieving zero deaths or serious injuries by a target year. This further establishes urgency and should be present throughout the SHSP.
- Refocus speeding emphasis area on speed management and roadway design – Instead of solely relying on education and enforcement to address the speeding emphasis area, SHSPs should refocus on speed management and roadway design changes. This includes setting speed limits that are consistent with adjacent land uses and designing the roadway so that when speed-related crashes occur, they do not result in a fatality or serious injury.
- Institutionalize equity in road safety work – Equity in transportation safety includes protecting traditionally underserved populations. Equity refers to the fair distribution of safety projects and proactively working against inequities that currently exist in the transportation system.
- Use proactive data collection and analysis approaches to address equity considerations – Shifting data collection and analysis methods from relying solely on historic crash data can identify new risk factors and safety projects. This approach is more proactive and can rely on other data sources such as crowdsourcing or near-miss data.

These opportunities are first steps that organizations can take to strengthen commitment to the Safe System Approach, with an emphasis on the principle that Death and Serious Injury is Unacceptable through an equitable approach and the element of Safe Speeds.

3.6.4.2 States' Highway Safety Improvement Projects

The FHWA recognizes the following opportunities for holistically integrating the Safe System Approach into state Highway Safety Improvement Projects (Finkel et al., 2020):

- Research, prioritize, and fund engineering countermeasures that address Safe System elements and principles – States can prioritize countermeasures that align with Safe System principles. Several aspects to consider when prioritizing countermeasures include:
    - Hierarchy of Controls – This framework, shown in Figure 3.3, conveys that countermeasures most aligned with the Safe System Approach would be within the Elimination category, physically removing the safety hazard from the roadways. These countermeasures should be prioritized first, and then moving on to countermeasures in subsequent categories. This Hierarchy of Controls framework is similar to the Safe System Intersections Assessment Path discussed in Section 3.4.5, as well as the Safe System Roadway Design Hierarchy discussed in Section 3.8.1.
    - Primary and supporting countermeasures – Within the Hierarchy of Controls framework, primary and supporting treatments are defined. They are consistent with the primary and supporting treatments defined by Austroads briefly discussed in Section 2.8.3.2. Primary treatments are larger steps toward a Safe System, while supporting countermeasures are incremental steps.
    - Beyond traditional countermeasures – State highway safety improvement projects should address Safe System principles and elements in a coordinated manner. This can be done by broadening the focus of engineering countermeasures to include components that address each Safe System element. If a countermeasure only addresses the Safe Roads element, it should be lower on a priority list compared to countermeasures that address multiple elements. Additionally, countermeasures selection should be focused on preventing death and serious injury. This approach may change how countermeasures are prioritized.
    - Prioritize research for countermeasures focused on bicycle and pedestrian safety – Crashes involving vulnerable road users have been increasing and are disproportionate in lower income areas. Prioritizing countermeasures to protect vulnerable road users ensures they do not get forgotten and

helps agencies to ensure an equitable approach is being taken when determining roadway projects.

    - Doubling down on countermeasures to address fatal and serious injury crashes – States can prioritize strategies that counter fatal and serious injury crashes. Crash modification factor and SPF research can be done focusing on fatal and serious injury crashes. HINs can be calibrated to only show fatal or serious injury crashes to identify safety issues or patterns. Shifting focus to fatal and serious injury crashes accepts that humans will make mistakes and crashes will occur, but the objective is to ensure no one gets killed or seriously injured on the roadway.
    - Other project prioritization considerations – It is important to note that under traditional safety approaches, a benefit-cost ratio and available budget is a large component when determining safety measures to install. Under a Safe System, agencies should first determine the amount of funding required to create a Safe System and then determine how to obtain funding. States and the FHWA can work together to determine how to prioritize projects with a Safe System Approach. An example of this could be using equity considerations in prioritization or using kinetic energy management models in combination with crash modification factors to identify and prioritize projects.
- Assess crash severity risk using level of kinetic energy transfer and speed – Roadway operating speeds and roadway features can be used to proactively estimate the risk of serious injury crashes. Combining this proactive approach with data on historic crashes, agencies can move toward estimating the likelihood of future severe crashes on their road networks. It is also important to recognize how kinetic energy transfers differently between different modes and crash types.
- Identify opportunities to encourage local planning efforts that align with the Safe System Approach – State DOTs can encourage and provide funding for local jurisdictions to implement their own safety planning to align with the Safe System Approach. This can help cities and counties to obtain grants. Additionally, an

SHSP that aligns with the Safe System Approach can act as a resource for local jurisdictions. This opportunity ties into the principle that Responsibility is Shared.

- Establish Safe System working groups and pilot projects – The International Transport Forum (ITF) states that "demonstrations and pilot projects can also be helpful to raise awareness among road users, system designers and politicians that a Safe System improves road safety" (ITF, 2016). To establish and generate support for demonstration projects and the Safe System Approach, a Safe System working group can be established. This improves collaboration between stakeholders in committing to the Safe System Approach.

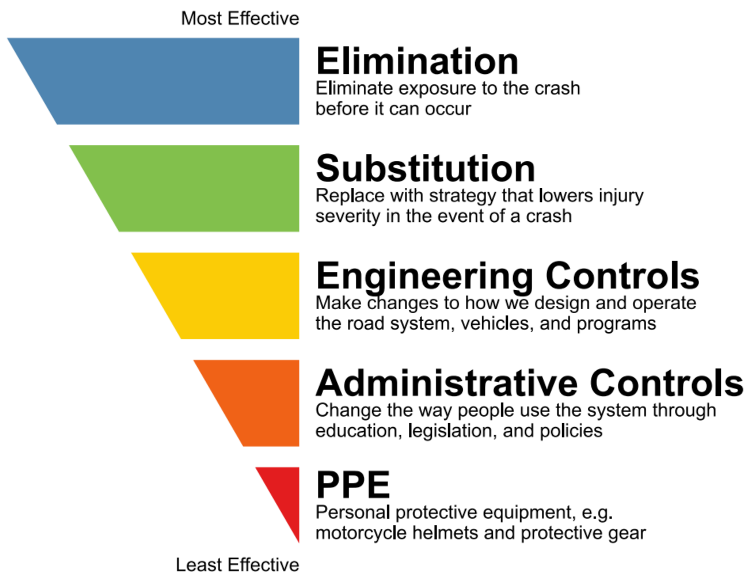

Figure 3.3 Hierarchy of Controls for Traffic Safety (Finkel et al., 2020).

3.7 Organizational Safety Culture Self-Assessment

As mentioned in Section 2.2, the Safe System Approach is a multifaceted strategy that seeks to improve safety beyond exclusively installing physical countermeasures to reduce crashes. The Safe System Approach includes changing mindset and perspectives surrounding traffic safety. To help organizations understand their traffic safety culture, the FHWA has published the Organizational Safety Culture Self-Assessment for Transportation Agencies

Toolkit (Otto et al., 2024). This Toolkit focuses on an agency's assessment of their internal safety culture and programmatic safety integration. The Self-Assessment includes the following components for both areas:

- Questionnaires;
- Improvement strategies; and
- Improvement plan template.

The following subsection summarizes each of these components.

3.7.1 Questionnaires

There are two questionnaires included in the Toolkit. One is regarding safety culture, while the other is about programmatic safety integration. It is recommended that these questionnaires be completed in workshops, with participants from different levels of the organization. Participants rate their organization's level of maturity regarding road safety culture or programmatic safety integration on a level from 0 to 4, with 0 being no engagement and 4 being optimized engagement. If participants have different answers to a question, the answers should not be averaged. The purpose of the questionnaires is to identify opportunities for improvement; therefore, the lowest score should be used (Otto et al., 2024).

3.7.2 Improvement Strategies

After the questionnaires are completed, results can be used to determine opportunities for improvement and potential strategies to improve the organization's maturity level. This step should be done in the same workshop as when the questionnaires are completed. Questions with the lowest scores may highlight the best improvement opportunities. With respect to strategies, participants can discuss possible opportunities, what will lead to greatest safety improvements, how prepared the organization is to address changes, and the likelihood of success. The Toolkit provides some example improvement strategies. The next step is to develop a detailed plan of how to implement the strategies. This may occur after the workshop when more data are collected, and stakeholders and technical knowledge is involved (Otto et al., 2024).

3.7.3 Improvement Plan

Once participants agree on improvement strategies, the organization can identify staff to establish an improvement plan. This may be done outside of the workshop. The improvement plan should include the selected strategies, what is needed to implement them, a timeline for implementation, and a way to measure success. Staff members assigned to the improvement plan can involve workshop participants (Otto et al., 2024).

Changing a culture can take a long time. The FHWA Organizational Safety Culture Self-Assessment for Transportation Agencies Toolkit can be used to make an agency aware of their existing traffic culture and set goals to improve weaker maturity levels. Organizations can also repeat the workshop to evaluate the effectiveness of the improvement plan and strategies. Evaluating an organization's safety culture can help to identify how they can implement the Safe System Approach in their policies and practices most effectively.

3.8 Safe System Approach Framework and Roadway Design Hierarchy

The FHWA has developed the Safe System Approach Framework and Safe System Roadway Design Hierarchy to help identify and prioritize countermeasures in roadway projects. This section will summarize these two resources and how they interact.

3.8.1 Safe System Roadway Design Hierarchy

The Safe System Roadway Design Hierarchy characterizes physical countermeasures based on their alignment with the Safe System Approach. The Safe System Roadway Design Hierarchy is shown in Figure 3.4. It has four tiers organized from most to least aligned with Safe System principles. These tiers are discussed further in the following subsections.

3.8.1.1 Tier 1 – Remove Severe Conflicts

Removing severe conflicts refers to separating road users traveling at different speeds or in different directions. This minimizes conflicts between road users. When determining roadway projects, emphasis should be placed on solutions in this tier as they align closest with the Safe System Approach. Countermeasures in this tier remove conflict points at intersections or provide physical separation between motorists and vulnerable road users. Countermeasures in this tier apply to the Safe Roads and Safe Road Users elements of the Safe System Approach (Gaines et al., 2024).

3.8.1.2 Tier 2 – Reduce Vehicle Speeds

Reducing vehicle speeds reduces the kinetic energy in a crash. Jurisdictions should set appropriate speed limits to lower the risk that motorists have on vulnerable road users. Additionally, the roadway should incorporate design elements that enforce lower speed limits such as speed management measures. Countermeasures in this tier support the Safe Roads, Safe Speeds, and Safe Road Users elements of the Safe System Approach (Gaines et al., 2024).

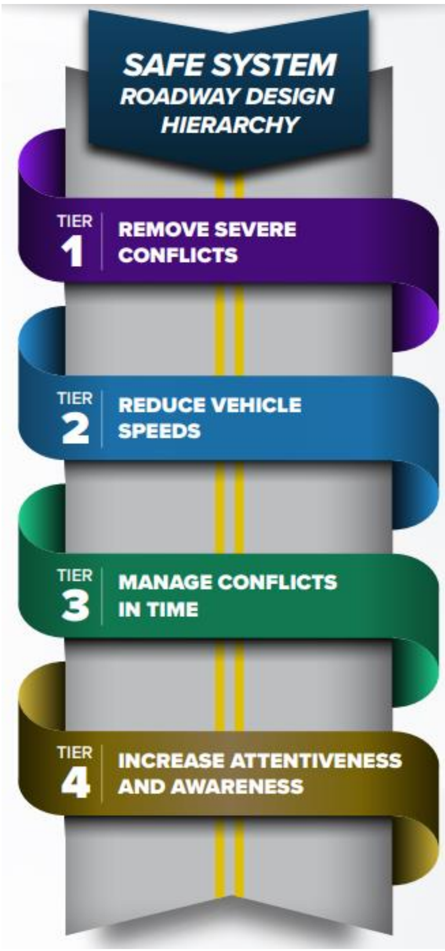

Figure 3.4 The Safe System Roadway Design Hierarchy (Gaines et al., 2024).

3.8.1.3 Tier 3 – Manage Conflicts in Time

At some locations, road users will need to occupy the same physical space on the roadway. This is especially true at intersections, where vehicles on conflicting paths need to occupy the same space to pass through the intersection. When vehicles need to occupy the same space, they should do so at different times. Separating users in time, particularly vulnerable road users, is proactive in anticipating human error so that if an error occurs, it is less likely the users are in the same space at the same time. Countermeasures in this tier support the Safe Roads, Safe Speeds, and Safe Road Users elements of the Safe System Approach (Gaines et al., 2024).

3.8.1.4 Tier 4 – Increase Attentiveness and Awareness

Increasing attentiveness and awareness includes alerting road users to conflict types so that they can act safely. Note that while the first three tiers remove conflicts or reduce kinetic energy, strategies in this tier rely on the road user to make safe decisions. Therefore, greater emphasis should be put on the first three tiers before solutions from this tier are considered. Countermeasures in this tier can also be used to supplement solutions from higher tiers. Solutions in this tier support the Safe Roads, Safe Speeds, and Safe Road Users elements of the Safe System Approach (Gaines et al., 2024).

3.8.2 The Safe System Approach Framework

The Safe System Approach framework, shown in Figure 3.5, focuses on the principles of the Safe System Approach that state Humans Make Mistakes and Humans are Vulnerable (Abel et al., 2023). This framework does not prioritize countermeasures like the Safe System Roadway Design Hierarchy, but it does provide guidance on actions that should be taken in roadway projects to closer align with Safe System principles. According to the framework, human errors can be anticipated by implementing the following strategies:

- Separating users in space;
- Separating users in time; and
- Increasing attentiveness and awareness.

Accommodating human injury tolerances can be addressed by implementing the following strategies:

- Reducing speeds; and
- Reducing impact forces.

The following subsections summarize each of the Safe System Approach framework strategies.

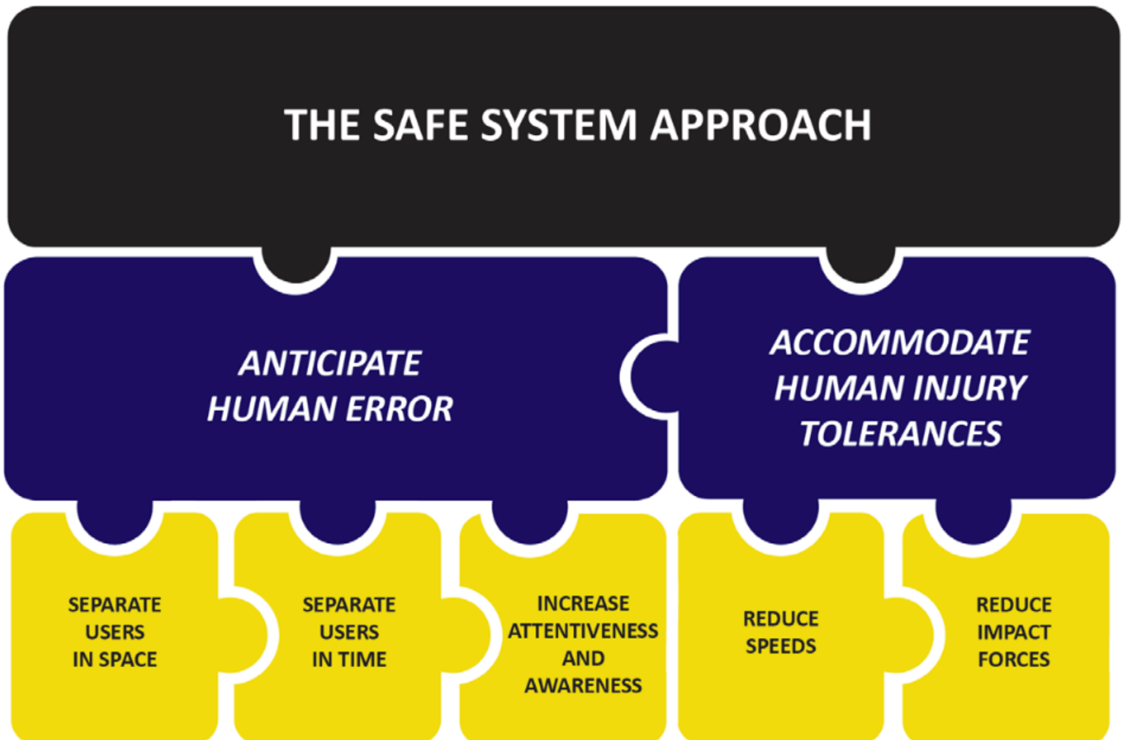

Figure 3.5 The Safe System Approach framework (Abel et al., 2023).

3.8.2.1 Separating Users in Space

Separating users in space refers to the physical separation of different road users. This provides travelers with a dedicated right-of-way, which minimizes conflicts with other road users. The amount of separation is usually dependent on vehicle speeds, vehicle volumes, and volumes of other road users. An example of separation between bicycles and vehicles includes marked bike lanes on the roadway. This gives bicyclists a dedicated space on the roadway so they are less likely to travel in the same space as vehicles, which can minimize conflicts (Abel et al., 2023). Separation can be taken one step further by providing a physical barrier between bike lanes and the vehicle travel lanes. A physical barrier provides an additional layer of safety since if a vehicle departs from its travel lane, it will hit a barrier instead of a bicyclist. Increasing the level of separation between roadway users provides better protection for when a roadway user makes a mistake. According to the FHWA, removing severe conflicts is the highest tier in the hierarchy of Safe System roadway design (Gaines et al., 2024). This indicates that when designing roadways, conflict separation is the first safety solution that should be implemented. The fewer conflict points, the simpler the roadway for users.

3.8.2.2 Separating Users in Time

As mentioned in Section 3.8.1.3, road users will need to occupy the same physical space on the roadway at some locations, particularly intersections. Separating users in time can be achieved through traffic control devices that help to ensure that these road users will not occupy the same space on the roadway at the same time (Abel et al., 2023). California reported an average reduction in total crashes by 35 percent when left-turn lanes were constructed and left-turn phases were used. When left-turn lanes were built but no left-turn phase was used, crashes were only reduced by 15 percent (Antonucci et al., 2004). Regarding vulnerable road users, bicyclists can be separated in time from motorized vehicles with a bicycle signal face or a leading bicycle interval. Pedestrians can be separated in time from vehicles via exclusive pedestrian phasing, split phasing, or left-turn phasing. Separating users in time is the third tier in the hierarchy of Safe System roadway design, after removing severe conflicts and reducing vehicle speeds (Gaines et al., 2024). This means that roadway designs should first look to remove conflict points and then reduce vehicle speeds before seeking safety solutions by managing conflicts in time.

3.8.2.3 Increasing Attentiveness and Awareness

In addition to separating users in time and space, increasing attentiveness and awareness of vulnerable road users increases safety as these users will become more easily perceived by drivers. Crosswalk visibility enhancements such as additional lighting, RRFBs, and signal backplates with reflective borders can increase the noticeability of pedestrians to motorized vehicles more than a marked crosswalk or a pedestrian warning sign (Abel et al., 2023). Making vulnerable road users more noticeable to drivers reduces the risk of them being overlooked. Increasing attentiveness and awareness is the fourth tier in the hierarchy of Safe System roadway design (Gaines et al., 2024). Therefore, roadway designers should install measures that increase attentiveness and awareness after having already implemented measures in a higher tier of the hierarchy of design.

3.8.2.4 Reduce Speeds

As discussed in Section 2.5.3, speeds are a determining factor in kinetic energy. Reducing speeds reduces kinetic energy in crashes, increasing the chances of survival. Speeds can be reduced in the following ways:

- Considering design speed and target speed – Design speed is the speed used to determine geometric design features of the roadway (Abel et al., 2023). Target speed is defined as the highest speed at which vehicles should operate on a roadway considering the surroundings and context of the roadway. Target speed aims to balance efficient mobility for vehicles while creating a safe and accommodating environment for other roadway users such as pedestrians, cyclists, and public transit users. A lower target speed may be more appropriate for roadways in urban areas with higher levels of multi-modal use (FHWA, 2017). Having a lower target speed in turn reduces the kinetic energy of a vehicle. This means less energy will be transferred to the human body should a crash occur.
- Reducing the speed limit – Speed limits can be reduced statutorily to encourage lower speeds. City and state transportation agencies committed to Vision Zero and the Safe System Approach have been exploring new methodologies to determine speed limits (Abel et al., 2023). As discussed in Section 3.2.2, UDOT's current speed policy is moving away from the using the 85^{th} percentile speed to set speed limits and is instead basing speed limits on the context and access category of the roadway. Establishing lower speed limits alone may not reduce speeds, but it allows for the legal enforcement of lower speeds. As discussed, lower speeds result in less kinetic energy that is inflicted on the human body should a crash occur.
- Reducing speed through engineering – When lowering speed limits does not result in the desired operating speed, engineering efforts can be made to reduce higher speeds. Retrofits to roadways and intersections can be done to change

roadway configuration to create self-enforcing roadways. Self-enforcing roadways implement measures that induce lower travel speeds and change driver perception so that drivers feel uncomfortable traveling at higher speeds (Gaines et al., 2024). Traffic calming and signal timing can be used to lower speeds along corridors. At intersections, reducing vehicle turning speeds is critical for the safety of non-motorized road users (Abel et al., 2023). This can be done by minimizing the turn radius at intersections. Many cities use corner radii as small as 2 feet (NACTO, 2013). Protected intersections can reduce turning speeds and add a physical layer of protection for non-motorized users. Protected intersections add median islands, reducing the width of roadway that non-motorized users need to cross (NACTO, 2019). A diagram of a protected intersection is shown in Figure 3.6.

- Reducing speed through education and enforcement – Education and high visibility enforcement and/or speed safety cameras can also be used to reduce speeds. It is important to remember that education requires a higher level of individual commitment. When enforcement and/or speed safety cameras are used, equity should also be considered when implementing these measures (Abel et al., 2023). Speed safety cameras tend to be a more equitable countermeasure in that they do not choose which offenders to cite. Instead, all offenders are cited equally.

Reducing vehicle speeds is the second tier in Safe System roadway design, after removing severe conflicts (Gaines et al., 2024). This means that roadway designs should first look to remove conflict points and then look to reduce vehicle speeds.

3.8.2.5 Reduce Impact Forces

In addition to speed reduction, engineering and vehicle technology can be used to reduce impact forces so they do not exceed human tolerance for crash forces. Engineering can be used to reduce impact forces at intersections by altering vehicle paths, such as with a roundabout. Altering vehicle paths can reduce the angle of impact and lowers speed. Additionally, vehicle technology such as airbags, seatbelts, automatic braking, and exterior vehicle design can be used to reduce the transfer of kinetic energy (Broshears and Tobias, 2022).

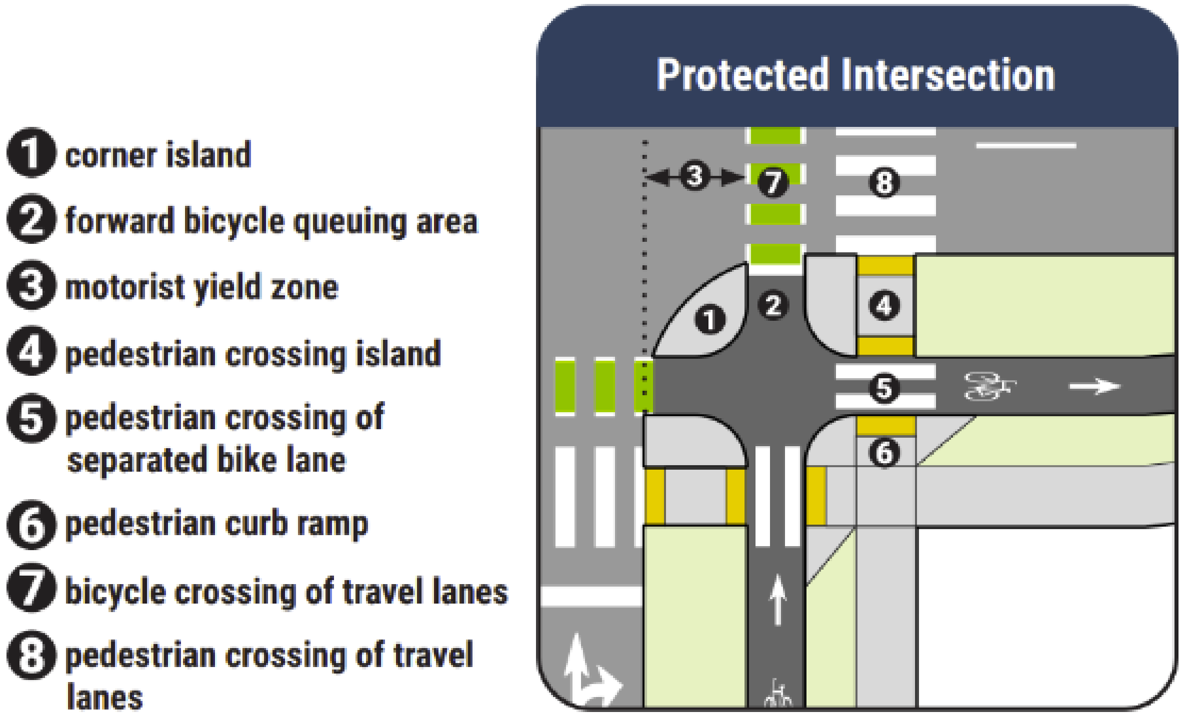

Figure 3.6 Protected intersection diagram (Abel et al., 2023).

3.9 Physical Countermeasures

In addition to the practices recommended in the Safe System Framework discussed in Section 3.8, and the case studies mentioned in Sections 3.3.3 and 3.4, there are other physical countermeasures that several jurisdictions both inside and outside of the United States have used to implement the Safe System Approach at their intersections. This section will discuss these countermeasures and their effectiveness. A summary table of each countermeasure, the safety benefits, and source is provided in Table 3.1. More details on each of the countermeasures are provided in the following subsections.

Table 3.1 Summary Table of Physical Countermeasures

Physical Countermeasure	Safety Impact	Source
Channelized Right Turns	• Between 4% and 26% crash reduction depending on intersection control and approaches used	Antonucci et al. (2004)
Corridor Access Management	• Between 5% and 23% reduction in total crashes on two-lane rural roads • Between 25% and 31% reduction in fatal and injury crashes along urban and suburban arterials	Albee and Bobitz (2021)

Table 3.1 Continued

Physical Countermeasure	Safety Impact	Source

Dedicated Left- and Right-Turn Lanes at Intersections	• Left-turn lanes:
	  ○ Between 28% to 48% reduction in total crashes
	• Positive offset left-turn lanes:
	  ○ 36% reduction in fatal and injury left-turn crashes.
	• Right-turn lanes:
	  ○ Between 14% to 26% reduction in total crashes
		Albee and Bobitz (2021)

Dwell-on-Red	• 7 MPH reduction in 85th percentile Speed • 45% crash reduction	Hillier et al. (2016)
Hash Marks on Intersection Approaches	• 5 MPH reduction in 85th percentile speed • 0 to 3 MPH speed reduction	Hillier et al. (2016) UDOT (2021)
Intersection Conflict Warning System (ICWS)	• 25% to 32% reduction in crashes when installed on both major and minor road • 20% to 30% reduction in all crashes at rural stop-controlled intersections when combined with overhead and advanced post-mounted signs • Drivers are more than one-and-a-half times more likely to come to a complete stop • Some sources report no clear reduction in crash rates	Hallmark et al. (2017) Himes et al. (2016) INDOT (2024) Maranatha and Derek (2019)
Leading Pedestrian Interval (LPI)	• 13% reduction in pedestrian and vehicle crashes at intersections • 13% reduction in vehicle-to-vehicle crashes	Goughnour et al. (2021)
Lighting	• 42% reduction in nighttime injury pedestrian crashes • Between 33% and 38% reduction in nighttime rural and urban intersection crashes	Albee and Bobitz (2021)
Pedestrian Scramble	• 51% reduction in pedestrian fatal and serious injury crashes	Gaines et al. (2024)
Protected Intersection	• 25% reduction in injury crashes	New York City Department of Transportation (2013)
Protected Left-Turn Phasing	• 87% reduction in fatal and serious injury crashes • 84% reduction in left-turn head-on collisions • 59% reduction in injury crashes • 32% reduction in total crashes	Gaines et al. (2024) FHWA (2010)
Raised Crosswalks	• 45% reduction in pedestrian crashes • 46% reduction in fatal and serious injury crashes in urban and suburban areas • 4 MPH reduction in 85th percentile speed when combined with other traffic calming measures	FHWA (2024c) FHWA (2024d) Gaines et al. (2024)
Raised Intersection	• 5 MPH reduction in 85th percentile speed • 40% reduction in fatal and injury crashes	Hillier et al. (2016)

Restricted Crossing U-turn (RCUT)	• Two-way stop control to RCUT:
	  ○ 54% reduction in fatal and injury crashes
	• Signalized intersection to signalized RCUT:
	  ○ 22% reduction in fatal and injury crashes
	• Unsignalized intersection to unsignalized RCUT:
	  ○ 63% reduction in fatal and injury crashes
		Albee and Bobitz (2021)

Table 3.1 Continued

Physical Countermeasure	Safety Impact	Source
Median U-Turn (MUT)	• 30% reduction in intersection injury crash rate	Albee and Bobitz (2021)

Roundabouts	• Converting a two-way stop control to roundabout:
	  ○ 82% reduction in fatal and serious injury crashes
	• Converting a signalized intersection to a roundabout:
	  ○ 78% reduction in fatal and serious injury crashes
		Albee and Bobitz (2021)

Signal Backplates with Retroreflective Border	• 15% reduction in total crashes	Albee and Bobitz (2021)

Speed Safety Cameras	• Fixed units on urban principal arterials:
	  ○ 54% reduction in all crashes
	  ○ 48% reduction in injury crashes
	• Point-to-point (P2P) units on principal arterials, urban expressways, and freeways:
	  ○ 37% reduction in fatal and injury crashes
	• Mobile units on urban principal arterials:
	  ○ 20% reduction in fatal and injury crashes
	• 71% reduction in overall speeding
	• 94% reduction of speeding 10 MPH or more over the speed limit
		Albee and Bobitz (2021)
		PBOT (2023)

Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections	• 10% reduction of fatal and serious injury crashes • 15% reduction of nighttime crashes at all locations • 27% reduction of fatal and serious injury crashes at rural intersections • 19% reduction of fatal and injury crashes at two-lane-by-two-lane intersections	Albee and Bobitz (2021)
Turn Calming	• 13% reduction in median speed • Hardened centerlines that extend into the intersection are 50% more effective at reducing speeds relative to centerlines that do not • Left-turn calming treatments nearly eliminate sharp turns where drivers cross the centerline • 3 MPH speed reduction in right turn 85th percentile speed	Lindley and Wunderlich (2023) PBOT (2020)
Variable Speed Limits on Intersection Approaches	• 11 MPH reduction in 85th percentile speed • 8% rural area crash reduction	Hillier et al. (2016)
Vehicle Activated Signs at Intersections	• 3 MPH reduction in 85th percentile speed • 70% rural area crash reduction	Hillier et al. (2016)
Yellow Change Intervals	• Between 36% and 50% reduction in red-light running • Between 8% and 14% reduction in total crashes • 12% reduction in injury crashes • 9% reduction in multivehicle crashes • 37% reduction in crashes involving pedestrians and bicycles	Albee and Bobitz (2021) Antonucci et al. (2004)

3.9.1 Channelized Right Turns

A channelized right turn is a traffic engineering design that involves the use of physical barriers or markings to guide vehicles making right turns along a designated path. These channels typically separate turning vehicles from through traffic, improving safety by reducing conflicts and enhancing traffic flow efficiency at intersections. Adding a raised crosswalk or RRFB to the channelized right-turn lane increases safety for pedestrians (Lindley and Wunderlich, 2023). Research has found that channelized right-turn lanes can reduce crashes between 4 percent and 26 percent, depending on the number of approaches they are installed on and the intersection control (Antonucci et al., 2004). For guidance in design of channelized right turns, NCHRP has developed a design guide for channelized right-turn lanes (NASEM, 2014).

3.9.2 Corridor Access Management

Access management involves the planning, implementation, and regulation of entry and exit points along a roadway, encompassing intersections with other roads and driveways serving neighboring properties. Strategic access management along a corridor can improve safety for all modes of transportation, promote walking and biking, and alleviate trip delays and congestion. Safety benefits of reducing driveway density include the following (Albee and Bobitz, 2021):

- Reduction in total crashes on two-lane rural roads by 5 to 23 percent; and
- Reduction in fatal and injury crashes along urban and suburban arterials by 25 to 31 percent.

Access management can provide operational benefits in addition to safety benefits. Detailed guidance and instruction regarding access management can be found in the Access Management Manual (Williams et al., 2014). Additionally, UDOT has Administrative Rule R930-6 which provides guidance on intersection spacing based on the access category of the roadway (UDOT, 2019).

3.9.3 Dedicated Left- and Right-Turn Lanes at Intersections

Auxiliary turn lanes, whether for left or right turns, offer a physical separation between turning vehicles, which are either slowing down or stopped, and the adjacent through traffic at intersection approaches. These lanes are designed to facilitate deceleration before a turn and provide space for vehicles to wait until they can safely complete their turn. Implementing an offset for left- and right-turn lanes to enhance visibility can offer additional safety advantages, especially in locations with higher speeds or where unrestricted or free-flowing movements are possible. In situations where turn lanes have zero or negative offset, turning vehicles may obstruct sightlines. For left-turn lanes, this often occurs when opposing left-turning vehicles occupy the same space simultaneously. In the case of right-turn lanes, it typically involves vehicles turning right from the main road and those entering the intersection from the minor road. Introducing positive offset to turn lanes improves the sight distance to oncoming vehicles that intersect with the turning movement. Offset turn lanes should be considered in areas prone to frequent conflicts of this nature to diminish the risk of severe crashes. A diagram comparing turn lanes with and without offset is shown in Figure 3.7. Safety benefits of dedicated turn lanes include the following (Albee and Bobitz, 2021):

- Left-turn lanes reduce total crashes between 28 and 48 percent;
- Positive offset left-turn lanes result in a 36 percent reduction in fatal and injury left-turn crashes; and
- Right-turn lanes result in a 14 to 26 percent reduction in total crashes.

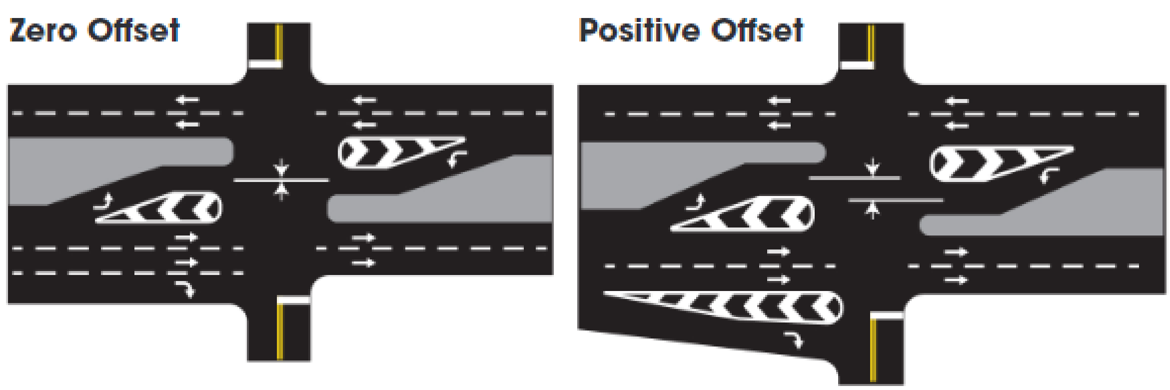

Figure 3.7 Zero offset versus positive offset of auxiliary turn lanes (Albee and Bobitz, 2021).

UDOT has Administrative Rule R930-6 which provides guidance on turn lanes based on the access category of the roadway (UDOT, 2019).

3.9.4 Dwell-on-Red

The dwell-on-red countermeasure entails integrating an additional phase into signalized intersections and pedestrian crossings. This phase involves displaying an all-red signal when there is no traffic or pedestrian demand present. The signals transition to green only when actuated by a vehicle or pedestrian. This treatment is typically implemented in areas with high nighttime pedestrian activity, including those where pedestrians may be under the influence of alcohol. The primary objective of dwell-on-red signals is to lower vehicle speeds and reduce the proportion of vehicles traveling at speeds that pose a severe threat of pedestrian injury. Researchers in Australia found that implementing these measures resulted in the following safety benefits (Hillier et al., 2016):

- A 7 MPH reduction in the 85th percentile speed; and
- A crash reduction of 45 percent.

3.9.5 Hash Marks on Intersection Approaches

Hash marks on intersection approaches refer to transverse markings on the roadway that convey a sense of speed to the driver. The spacing between markings is continually reduced, giving the illusion that vehicles are traveling faster than their actual speed. This encourages drivers to reduce their speed. These hash marks are also known as optical speed bars. Safety benefits of hash marks on intersection approaches include the following:

- Australia has applied these markings to intersection approaches and found that this resulted in a 5 MPH reduction in the 85th percentile speed (Hillier et al., 2016); and
- UDOT has found that optical speed bars result in a speed reduction of 0 to 3 MPH (UDOT, 2021).

The Utah MUTCD refers to hash marks as speed reduction markings and provides guidance on how they should be installed (UDOT, 2011).

3.9.6 Intersection Conflict Warning Systems

ICWS signs are activated when a vehicle approaches an intersecting roadway. Warning messages such as "Vehicle Entering When Flashing" or "Crossing Traffic When Flashing" may be displayed. These are often installed at stop-controlled intersections in rural areas (Gaines et al., 2024). Studies have found a variety of results regarding the effectiveness of an ICWS:

- The FHWA found that installing ICWS on the major road in combination with the minor road to be most effective, with crashes reducing by 25 percent to 32 percent (Himes et al., 2016);
- The Minnesota Department of Transportation (MnDOT) found that stopping behavior appeared to improve when the system was active, with drivers more than one-and-a-half times more likely to come to a complete stop (Hallmark et al., 2017);
- MnDOT compared crash rates before and after a rural ICWS was installed and findings determined that there was not a clear reduction in crash rates, even after the system was installed (Maranatha and Derek, 2019); and
- The Indiana Department of Transportation (INDOT) reports that the safety benefits of an ICWS include a reduction in all crashes and severities by 20 to 30 percent in rural stop-controlled intersections when combined with overhead and advanced post-mounted signs (INDOT, 2024). This finding is stated to be according to the FHWA.

These studies report different findings, ranging from beneficial to inconsequential. None of these studies report negative outcomes of installing an ICWS.

3.9.7 Leading Pedestrian Interval

An LPI allows pedestrians to enter the crosswalk at an intersection 3 to 7 seconds prior to vehicles receiving a green light. This enables pedestrians to establish their presence in the crosswalk before vehicles are granted priority to make right or left turns. This can separate pedestrians and vehicles in time as they pass through the intersection. However, it is important to note that if vehicles are permitted to turn right on red, then conflicts between roadway users are not fully separated in time. Potential benefits of an LPI include the following (Goughnour et al., 2021):

- Reduction of vehicle-to-pedestrian crashes by 13 percent; and
- Reduction in vehicle-to-vehicle crashes by 13 percent.

According to the research by Goughnour et al. (2021), these results are similar between New York City and Chicago, where New York prohibits right turn on red while Chicago permits it. It is also worth noting that New York City generally had higher pedestrian volumes, with the factor sometimes being as large as three to four. The Utah MUTCD provides guidance on how an LPI can be incorporated into the signal timing (UDOT, 2011).

3.9.8 Lighting

The number of fatal crashes during daylight hours is roughly equivalent to those happening in darkness. However, the rate of fatalities at night is three times higher than during the day due to only 25 percent of VMT occurring after dark. During nighttime travel, vehicles moving at higher speeds may be unable to stop when a change or hazard in the roadway becomes visible by headlights. Implementing continuous lighting along road segments and specific areas like intersections and pedestrian crossings can mitigate the risk of crashes (Albee and Bobitz, 2021). Safety benefits of lighting include:

- Nighttime injury pedestrian crashes reduced by 42 percent; and
- Nighttime rural and urban intersection crashes reduced by 33 to 38 percent.

The UDOT Lighting Design Manual states that there is not a formal process for warranting lighting projects, but engineers can support new lighting systems with the warrant analysis established in AASHTO's Roadway Lighting Design Guide (UDOT, 2023b).

3.9.9 Pedestrian Scramble

A pedestrian scramble is a signal phase where all vehicular traffic is stopped, allowing pedestrians to cross in any direction, including diagonally. A pedestrian scramble can also be paired with "no turn on red." This separates pedestrians and vehicles so that they are not in the intersection at the same time. Implementing a pedestrian scramble on urban roadways can result in the following safety benefits:

- New York City reduced pedestrian fatal and serious injury crashes by 51 percent on urban roadways (Gaines et al., 2024); and
- In Oakland, California, a pedestrian scramble implemented at the 8th and Webster Street intersection reduced the number of conflicts from 77 to 35. It is important to note that a large public outreach effort was implemented prior to the installation of the pedestrian scramble (Bechtel et al., 2003).

3.9.10 Protected Intersections

Briefly discussed in Section 3.8.2.4, protected intersections increase visibility between motor vehicles and active transportation users. Protected intersections may include features such as pedestrian refuge islands, intersection crossing markings, and bicycle queuing areas. Protected intersections help to separate users in space, increase attentiveness and awareness, and lower speeds as they reduce the turn radii of vehicles. Medians with marked crosswalks can decrease pedestrian crashes by 26 percent, and pedestrian refuge islands can result in a 56 percent reduction of pedestrian crashes (Albee and Bobitz, 2021). Protected intersections combine both of those safety measures. The New York City DOT installed several protected intersection features along Columbus Avenue, resulting in a 25 percent reduction in injury crashes (New York City Department of Transportation, 2013).

3.9.11 Protected Left-Turn Phasing

Protected left-turn phasing provides a dedicated phase for vehicles to make left turns without conflicting with oncoming traffic or pedestrians. During this phase, left-turning vehicles have a green arrow, ensuring they can turn safely while other movements are stopped. This separates users in time as they travel through the intersection. Utah has found that changing permissive left turns to protected left turns results in a reduction of fatal and serious injury crashes by 87 percent (Gaines et al., 2024). In Detroit and Grand Rapids, Michigan, changing permissive left turns to protected left turns at three locations resulted in the following (FHWA, 2010):

- Reduction of left-turn head-on collisions by 84 percent;
- Reduction of injury crashes by 59 percent; and
- Reduction in total crashes by 32 percent.

3.9.12 Raised Crosswalks

Raised crosswalks are like raised intersections in that they are elevated above the street level. They alter the roadway vertically, resulting in vehicles traveling at lower speeds while crossing them. Raised crosswalks also increase the visibility of pedestrians. Safety benefits of raised crosswalks include:

- Reduction in pedestrian crashes by up to 45 percent (FHWA, 2024c); and
- Reduction in fatal and serious injury crashes by 46 percent in urban and suburban areas (Gaines et al., 2024).

Cambridge, Massachusetts installed raised crosswalks and used concrete pavers to increase contrast with asphalt. These were combined with other traffic calming improvements. As a result, the 85th percentile speed on the roadway decreased from 28 MPH to 24 MPH (FHWA, 2024d).

3.9.13 Raised Intersections

A raised intersection is a type of traffic calming measure where the entire intersection is elevated slightly above the surrounding road level. This elevation creates a gentle ramp for vehicles to traverse, often slowing them down as they approach the intersection. Raised intersections prioritize pedestrian safety by providing a level surface for pedestrians to cross, effectively reducing vehicle speeds and increasing visibility at the intersection. Safety benefits of raised intersections include (Hillier et al., 2016):

- A 40 percent reduction in fatal and injury crashes; and
- A reduction in 5 MPH of the 85th percentile speed.

The Urban Street Design Guide provides guidance for installing a raised crosswalk (NACTO, 2013).

3.9.14 Reduced Left-Turn Conflict Intersections

Intersections with reduced left-turn conflicts feature geometric designs that modify the way left-turn movements are executed. These intersections simplify decision making for drivers and decrease the likelihood of more severe crash types such as head-on and angle crashes (Albee and Bobitz, 2021). Two designs that incorporate U-turns to facilitate specific left-turn movements are the RCUT and the MUT (Albee and Bobitz, 2021) as discussed in the following subsections.

3.9.14.1 Restricted Crossing U-Turn

RCUT intersections, alternatively referred to as a J-turn, Superstreet, or Reduced Conflict Intersection, alter the direct left-turn and through movements from the minor street approaches. To make a left turn from a minor street, traffic makes a right turn followed by a U-turn at a designated location. The RCUT can be adapted to various scenarios, from remote rural areas with high-speed traffic to urban and suburban corridors with heavy traffic and multiple modes of transportation. RCUTs present a competitive and cost-effective alternative to building interchanges and function optimally when implemented consistently along a corridor but can also be effectively utilized at individual intersections. Some of the safety benefits of an RCUT include the following (Albee and Bobitz, 2021):

- Two-way stop control to RCUT results in a 54 percent reduction in fatal and injury crashes;
- Signalized intersection to signalized RCUT results in a 22 percent reduction in fatal and injury crashes; and
- Unsignalized intersection to unsignalized RCUT results in a 63 percent reduction in fatal and injury crashes.

The FHWA has an informational guide for RCUTs, including geometric designs, multimodal consideration, and operational characteristics (Hummer et al., 2014).

3.9.14.2 Median U-Turn

MUT intersections modify direct left turns from the major approaches. Vehicles on the major road travel through the main intersection, make a U-turn shortly downstream, and then make a right turn at the main intersection. The U-turns can also serve to alter left turns from the minor street, like the RCUT. Some of the safety benefits of an MUT include a 30 percent reduction in intersection injury crash rate (Albee and Bobitz, 2021). The FHWA has an informational guide for RCUTs, including geometric designs, multimodal consideration, and operational characteristics (Reid et al., 2014).

3.9.15 Roundabouts

A roundabout is an intersection where traffic flows continuously in one direction around a central island. Vehicles entering a roundabout yield to the circulating traffic and wait for a safe gap before entering. Roundabouts are designed to improve traffic flow, reduce congestion, and enhance safety compared to traditional intersections, as they eliminate the need for vehicles to come to a complete stop in most cases. Roundabouts have been referred to as the “trifecta of safety” (Lindley and Wunderlich, 2023) since they reduce speeds, minimize crash angles, and reduce the number of conflict points. Safety benefits of a roundabout include the following (Albee and Bobitz, 2021):

- Converting a two-way stop control to roundabout results in an 82 percent reduction in fatal and serious injury crashes; and
- Converting a signalized intersection to roundabout results in a 78 percent reduction in fatal and serious injury crashes.

3.9.16 Signal Backplates with Retroreflective Borders

Retroreflective backplates on signal heads improve the visibility of the signal head by making them contrast more against the background. Signal heads with retroreflective backgrounds are more visible in both daytime and nighttime conditions. An example of a signal head with a retroreflective backplate is shown in Figure 3.8. The safety benefits of adding a retroreflective backplate to signal heads include a 15 percent reduction in the total number of crashes (Albee and Bobitz, 2021). According to UDOT’s Signalized Intersection Design

Manual, retroreflective tape should always be used on signals that are constantly illuminated and always in use. Signal heads that are not always in use such as freeway ramp meters and reduced speed school zones should not have retroreflective tape, so they do not attract driver attention when they are not activated (UDOT, 2023c).

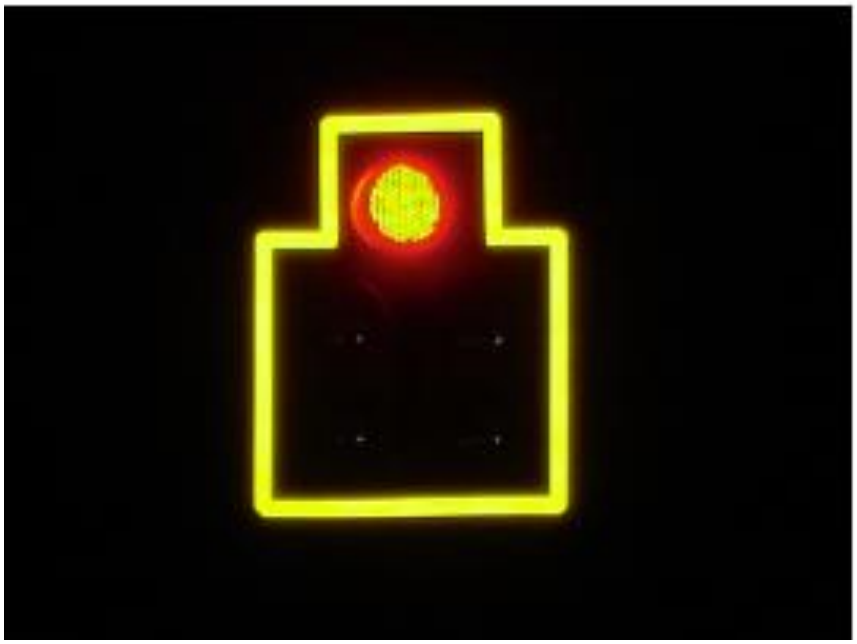

Figure 3.8 Signal head with retroreflective backplate (Albee and Bobitz, 2021).

3.9.17 Speed Safety Cameras

Speed safety cameras use speed measurement devices to detect speeding and capture photographic or video evidence of vehicles exceeding a specified speed limit. They can be deployed as fixed units, P2P units, or a mobile unit. Speed safety cameras can ensure fair and impartial enforcement of speeding laws, regardless of the driver's age, race, gender, or socioeconomic status. When installing speed safety cameras, community input and equity impacts should be considered. The safety benefits of speed safety cameras include (Albee and Bobitz, 2021):

- A reduction of all crashes by 54 percent and injury crashes by 48 percent with a fixed unit on urban principal arterials;

- A reduction of fatal and injury crashes by 37 percent with a P2P unit on freeways, principal arterials, and urban expressways; and
- A reduction of fatal and injury crashes by 20 percent with a mobile unit on urban principal arterials.

As discussed previously in Section 3.3.3.1, Portland, Oregon found that speed safety cameras have provided the following benefits (PBOT, 2023):

- A reduction of speeding overall by 71 percent; and
- A reduction of 94 percent of instances of speeding 10 MPH or more over the speed limit.

3.9.18 Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections

This systemic approach to intersection safety involves implementing a combination of low-cost measures across numerous stop-controlled intersections. These countermeasures, such as improved signage and pavement markings, aim to heighten driver awareness and recognition of intersections and potential hazards. Examples of countermeasures include the following (Albee and Bobitz, 2021):

- Oversized advance intersection warning signs with supplemental street name plaques on both sides of the approach roadway (flashing beacons can be added to these signs);
- Oversized advance “Stop Ahead” intersection warning signs (flashing beacons can be added to these signs);
- Reflective sheeting on signposts;
- Enhanced pavement markings delineating edge lines of through lanes;
- Removal of sight distance obstructions; and
- Double arrow warning sign at the stem of three leg intersections.

Each of these treatments are relatively low cost, with an average benefit-cost ratio of 12:1. Safety benefits of systemically applying low-cost countermeasures includes the following (Albee and Bobitz, 2021):

- Reduction of fatal and serious injury crashes by 10 percent;
- Reduction of nighttime crashes at all locations by 15 percent;
- Reduction of fatal and serious injury crashes at rural intersections by 27 percent; and
- Reduction of fatal and injury crashes at two-lane by two-lane intersections by 19 percent.

3.9.19 Turn Calming

Briefly discussed in Section 3.4.2, the goal of turn hardening or turn calming is to reduce turning speeds at intersections. Reducing turning speeds at intersections reduces the amount of kinetic energy a vehicle may have, which increases a pedestrian's chance of survival should a crash occur. Speeds are reduced by reducing the turning radius in the intersection. This can be done with delineator posts, striping, or speed bumps. A diagram with an example of a turn-calming measure is shown in Figure 3.9. In 2020, the city of Portland, Oregon completed a left-turn calming pilot project to evaluate the effectiveness of left-turn calming. The project included an evaluation of 42 intersections. The pilot project resulted in the following findings (PBOT, 2020):

- Median speed reduction of 13 percent (from average median speed of 14.0 to 12.1 MPH);
- Hardened centerlines that extend into the intersection are 50 percent more effective at reducing speeds relative to centerlines that do not;
- Left-turn calming treatments nearly eliminate sharp turns where drivers cross the centerline;
- Hardened centerlines with speed bumps are about equally effective as those with delineators; and

- Installation and maintenance costs are lower with bumps than delineators. However, it is unknown how durable bumps are in weather that requires snow plowing.

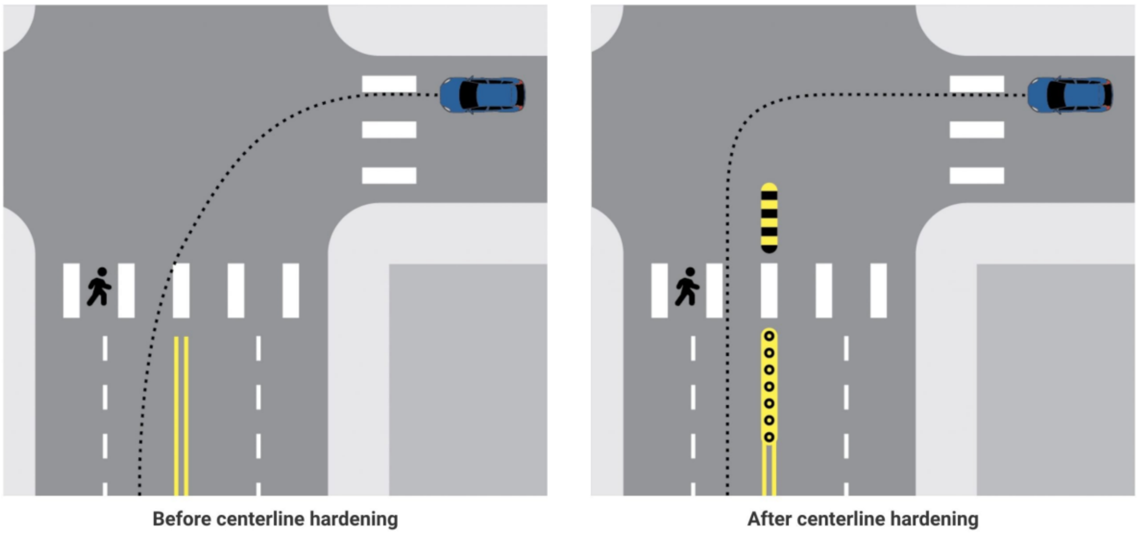

Figure 3.9 Bumps used for left-turn calming in Portland, Oregon (Maus, 2020).

Portland has also implemented right-turn wedges, which are used to slow the speed of right-turning vehicles. These are placed in the path of right-turning vehicles in the corners of intersections. An example is shown in Figure 3.10 where a 3 MPH speed reduction in the 85th percentile speed was reported (Lindley and Wunderlich, 2023).

Figure 3.10 Bumps used for right-turn calming in Portland, Oregon (Lindley and Wunderlich, 2023).

3.9.20 Variable Speed Limits on Intersection Approaches

Variable speed limit signs are dynamic road signs that display varying statutory speed limits based on current traffic, weather, and road conditions. Variable speed limits use data such as traffic speed, volume, weather conditions, road surface, and approaching traffic to calculate suitable speed limits. In New Zealand, variable speed limit signs were placed at six high-risk intersections. The signs were placed on major streets and were activated based on the presence of vehicles on the minor street. Preliminary findings from this research determined that variable speed limit signs result in a speed reduction at intersections, but it is noted that the safety effects will take time to emerge (Mackie et al., 2014).

Researchers in Australia found that this measure results in the following safety benefits (Hillier et al., 2016):

- A reduction of 11 MPH in the 85th percentile speed in rural areas (the typical posted speed limit in rural Australia is 110 kilometers per hour (approximately 70 MPH)); and
- A crash reduction of 8 percent in rural areas.

3.9.21 Vehicle Activated Signs at Intersections

Vehicle-activated signs are electronic warning signs installed alongside roads. They activate when road users surpass a predetermined speed threshold. When not activated, the signs remain blank. Once triggered, they illuminate to indicate relevant hazards ahead and may display messages prompting drivers to slow down or indicate a safe travel speed. These signs serve to alert drivers to upcoming intersections, aiming to enhance their alertness and encourage them to reduce speed for safer navigation through the intersection. Researchers in Australia found that this measure results in the following safety benefits (Hillier et al., 2016):

- A reduction of 3 MPH reduction in the 85th percentile speed; and
- A crash reduction of 70 percent in rural areas.

These activated signs can also increase safety for drivers of vehicles on the minor street who may be expecting vehicles on the major street to travel at a certain speed. If conflicting traffic is traveling too fast, then drivers from the minor road may misjudge an acceptable gap.

3.9.22 Yellow Change Intervals

Given that red-light running is a leading cause of severe crashes at signalized intersections, it is crucial to ensure appropriate timing of the yellow change interval to avoid a dilemma zone. Too brief of a yellow change interval might lead to drivers being unable to stop safely, inadvertently resulting in red-light running. Conversely, an excessively long interval may prompt drivers to perceive the yellow as an extension of the green phase, potentially encouraging intentional red-light running (Albee and Bobitz, 2021). Various factors, including the speeds of approaching and turning vehicles, driver perception-reaction time, vehicle deceleration, and intersection geometry, should all factor into the timing calculation. Appropriate yellow change interval timing can result in the following safety benefits (Albee and Bobitz, 2021):

- Reduction in red-light running by 36 to 50 percent;
- Reduction in total crashes by 8 to 14 percent; and
- Reduction in injury crashes by 12 percent.

New York state also determined that appropriately timed clearance intervals resulted in the following safety benefits (Antonucci et al., 2004):

- Reduction in injury crashes at intersections by 12 percent (same as Albee and Bobitz, 2021);
- Reduction in multivehicle crashes by 9 percent; and
- Reduction in crashes involving pedestrians and bicycles by 37 percent.

It should be noted that the timing changes implemented by New York state included both the yellow and all red phases. The change intervals were lengthened to meet ITE recommendations. UDOT also has the Guidelines for Traffic Signal Timing in Utah manual which provides guidance for the length of a yellow change interval (UDOT, 2017).

3.10 Summary

The purpose of this chapter was to present how the Safe System Approach is being implemented at intersections by other jurisdictions, as well as best practices established by the FHWA and ITE. UDOT has several existing programs that fit within the Safe System Approach. Communities can implement the Safe System Approach by becoming Vision Zero communities and creating Vision Zero Action Plans. Both Florida and Georgia DOTs have included the SSI methodology in their ICE tools, specifically during the SPICE process. Other state DOTs have institutionalized the Safe System Approach generally with director’s policies and executive orders. Guidance from the FHWA on how to incorporate the Safe System Approach into the HSIP was discussed. The FHWA has also recently published the Organizational Safety Culture Self-Assessment for Transportation Agencies which allows organizations to evaluate their safety culture and set goals to make improvements. Additionally, the Safe System Roadway Design Hierarchy and Safe System Framework provides guidance for countermeasures that can be implemented to improve safety. Several jurisdictions have also implemented a variety of physical countermeasures at or near intersections. This state of the practice is considered when recommending how UDOT can implement the Safe System Approach at intersections, which is the focus of the next chapter.

4.0 EVALUATION AND SUMMARY

4.1 Overview

This chapter evaluates the existing Safe System Approach policies and practices recommended by ITE, FHWA, and other organizations, as well as those implemented by other jurisdictions and begins to offer recommendations for how UDOT can implement these policies and physical countermeasures. The original scope of work stated that locations in Utah where specific approaches could be implemented would be identified. In conversation with UDOT leaders, it was determined that how a measure is implemented is more important than where it should be implemented. Therefore, this chapter establishes the different categories used to organize the strategies and countermeasures. Each category includes a table summarizing how each of the different strategies and countermeasures can be used to implement the Safe System Approach at intersections in Utah.

4.2 Countermeasure Categories

The countermeasures and strategies were sorted into the following categories based on where they could be implemented or the type of safety benefit they provide:

- Policies, programs, and practices;
- Universal physical measures;
- Signalized intersections;
- Unsignalized intersections;
- Geometric features;
- Vulnerable road user-focused;
- Quick build; and
- Further research safety benefits or implement pilot program.

The following subsections contain a description of these categories and the relevant strategies and countermeasures. Note that some countermeasures fit within multiple categories. All categories include a table that presents the strategy or countermeasure, applicable elements of the Safe System Approach Framework, the corresponding tier in the Safe System Roadway Design Hierarchy, relevant principles and elements of the Safe System Approach, how they can be implemented, and where they were discussed earlier in the document. The Safe System Roadway Design Hierarchy and the Safe System Framework are not referenced in the policies, programs, and practices category as they only apply to physical countermeasures and roadway design. Instead, the table in the policies, programs, and practices subsection explains why and how a strategy can be implemented.

The research team used a subjective methodology when assigning applicable elements of the Safe System Framework, tiers of the Safe System Roadway Design Hierarchy, and the principles and elements of the Safe System Approach. All tiers, principles, and elements were considered, and those deemed most appropriate by the research team for a particular countermeasure or strategy were included in the table. Note that some tables do not include solutions within every tier of the Safe System Roadway Design Hierarchy. Other or additional principles and elements may also be relevant to a strategy or countermeasure and could be considered by UDOT.

It is important to recognize that there is no single solution to implementing the Safe System Approach. Rather, several countermeasures, policies, and practices need to be enacted to ensure that this shift is a systemic change, impacting all levels of the Safe System Pyramid.

4.2.1 Policies, Programs, and Practices

The policies, programs, and practices category refers to strategies that are used to change perceptions surrounding traffic safety and adopting the Safe System Approach. These are not physical measures that are installed on the roadway, but rather programs or best practices that seek to institutionalize the Safe System Approach and make it part of an organization's culture. Note that many of these strategies are focused on adopting the Safe System Approach generally rather than intersections specifically. A list of policies, programs, and practices for implementing the Safe System Approach is shown in Table 4.1.

Table 4.1 Policies, Programs, and Practices for Implementing the Safe System Approach

Strategy	Why	How	Safe System Approach Principles and Elements	Section(s) Discussed
Vision Zero Action Plans	Change mindset surrounding traffic crashes and promote a traffic safety culture	Invite municipalities in Utah to become Vision Zero communities	**Principles** • Death/Serious Injury is Unacceptable • Responsibility is Shared • Safety is Proactive • Redundancy is Crucial	3.3
FHWA SSI Methodology	Evaluate how different intersection configurations adhere to the Safe System Approach	Implement SSI methodology into SPICE Spreadsheet	**Principles** • Safety is Proactive • Humans are Vulnerable **Elements** • Safe Roads	2.7 3.5
DOT Executive Order	Establish the Safe System Approach as a priority for UDOT	Mandate the Safe System Approach be considered in all projects	**Principles** • Death/Serious Injury is Unacceptable • Responsibility is Shared • Safety is Proactive • Redundancy is Crucial	3.6
Safe System Alignment Frameworks	Evaluate how roadway projects, policies, and programs adhere to the Safe System Approach	Implement the Safe System Alignment Frameworks as part of intersection projects and policy reviews	**Principles** • Death/Serious Injury is Unacceptable • Responsibility is Shared • Safety is Proactive • Redundancy is Crucial	2.8.1 2.8.2
Safe System Audit	Evaluate how roadway projects adhere to the Safe System Approach	Include Safe System audit in road safety audit	**Principles** • Safety is Proactive **Elements** • Safe Roads	2.8.3
Organizational Safety Culture Self-Assessment	Assess UDOT's traffic safety culture and set goals to make improvements where necessary	Administer the FHWA Self-Assessment	**Principles** • Death/Serious Injury is Unacceptable • Responsibility is Shared • Safety is Proactive • Redundancy is Crucial	3.7
SHSP	Establish clear goals for stakeholders to implement the Safe System Approach	Update UDOT's SHSP to incorporate Safe System principles and elements	**Principles** • Death/Serious Injury is Unacceptable • Responsibility is Shared • Safety is Proactive • Redundancy is Crucial	3.2.2
Near-Miss Metrics	Identify locations where near miss conflicts occur, but not necessarily crashes	Research near-miss metrics; potentially implement a pilot program	**Principles** • Humans Make Mistakes • Safety is Proactive	3.4.4

Table 4.1 Continued

Strategy	Why	How	Safe System Approach Principles and Elements	Section(s) Discussed
Roundabout Program	Increase the number of roundabouts—the safest intersection layout—in Utah	Make roundabouts a priority in Utah; emphasize roundabouts in ICE program	**Principles** • Death/Serious Injury is Unacceptable • Humans are Vulnerable • Safety is Proactive **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.4.1 3.9.15
Speed Safety Camera Legislation	Reduce vehicle speeds	Research speed safety cameras; potentially implement a pilot program	**Principles** • Safety is Proactive **Elements** • Safe Road Users • Safe Speeds	3.3.3.1 3.8.2.4 3.9.17

4.2.2 Universal Physical Measures

Universal physical measures are changes to the roadway that can be implemented at both signalized and unsignalized intersections. These measures are shown in Table 4.2, organized by tiers according to the Safe System Roadway Design Hierarchy.

Table 4.2 Physical Measures to Implement the Safe System Approach at All Intersections

Countermeasure	Safe System Approach Framework	How	Safe System Approach Principles and Elements	Section(s) Discussed
Tier 1: Remove Severe Conflicts				
Channelized Right Turns	• Separate users in space	Channelize right turns; guidance provided by NCHRP	**Elements** • Safe Roads	3.9.1
Corridor Access Management	• Reduce impact forces	Review UDOT access management standards in Administrative Rule R930-6; only approve variances when necessary	**Principles** • Redundancy is Crucial **Elements** • Safe Roads	3.9.2
Dedicated Left- and Right-Turn Lanes at Intersections	• Separate users in space	Review UDOT turn lane standards; guidance provided by Administrative Rule R930-6; revise as necessary	**Elements** • Safe Roads	3.9.3

Table 4.2 Continued

Countermeasure	Safe System Approach Framework	How	Safe System Approach Principles and Elements	Section(s) Discussed
Tier 1: Remove Severe Conflicts				
Roundabouts[2,4]	• Separate users in space • Increase attentiveness and awareness • Reduce speeds • Reduce impact forces	Implement roundabout program; emphasize roundabouts in ICE program	**Principles** • Death/Serious Injury is Unacceptable • Humans are Vulnerable • Redundancy is Crucial **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.4.1 3.9.15
RCUT[2,3,4]	• Separate users in space • Increase attentiveness and awareness • Reduce speeds • Reduce impact forces	Install RCUTs; guidance provided in FHWA informational guide	**Principles** • Humans are Vulnerable • Redundancy is Crucial **Elements** • Safe Speeds • Safe Roads	3.9.14.1
MUT[2,3,4]	• Separate users in space • Increase attentiveness and awareness • Reduce speeds • Reduce impact forces	Install MUTs; guidance provided in FHWA informational guide	**Principles** • Humans are Vulnerable • Redundancy is Crucial **Elements** • Safe Speeds • Safe Roads	3.9.14.2
Tier 2: Reduce Vehicle Speeds				
Hash Marks on Intersection Approaches[4]	• Increase attentiveness and awareness • Reduce speeds	Implement hash marks near intersections; guidance provided by the MUTCD	**Elements** • Safe Speeds • Safe Roads	3.9.5
Protected Intersections[4]	• Increase attentiveness and awareness • Reduce speeds • Reduce impact forces	Install protected intersections; guidance provided in Urban Street Design Guide	**Principles** • Humans Make Mistakes • Humans are Vulnerable • Safety is Proactive • Redundancy is Crucial **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.8.2.4 3.9.10
Raised Intersections[4]	• Increase attentiveness and awareness • Reduce speeds	Install raised intersections; guidance provided in Urban Street Design Guide	**Principles** • Humans are Vulnerable **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.9.13
Speed Safety Cameras	• Reduce speeds	Research speed safety cameras	**Principles** • Safety is Proactive **Elements** • Safe Road Users • Safe Speeds	3.9.17

Table 4.2 Continued

Countermeasure	Safe System Approach Framework	How	Safe System Approach Principles and Elements	Section(s) Discussed
Tier 4: Increase Attentiveness and Awareness				
Lighting	• Increase attentiveness and awareness	Review lighting standards; improve lighting at rural intersections and pedestrian crossings	**Elements** • Safe Road Users • Safe Roads	3.9.8
Variable Speed Limits on Intersection Approaches	• Increase attentiveness and awareness • Reduce impact forces	Install variable speed limits at intersection approaches; guidance provided by Austroads	**Principles** • Humans are Vulnerable **Elements** • Safe Road Users • Safe Speeds	3.9.20

[2]Countermeasure also applies to Tier 2: Reduce Vehicle Speeds
[3]Countermeasure also applies to Tier 3: Manage Conflicts in Time
[4]Countermeasure also applies to Tier 4: Increase Attentiveness and Awareness

4.2.3 Signalized Intersections

The signalized intersection category refers to countermeasures and strategies that can be implemented at signalized intersections. A list of strategies that can be used to apply the Safe System Approach at signalized intersections is shown in Table 4.3. The measures are organized by tiers according to the Safe System Roadway Design Hierarchy.

Table 4.3 Measures to Implement the Safe System Approach at Signalized Intersections

Countermeasure	Safe System Approach Framework	How	Safe System Approach Principles and Elements	Section(s) Discussed
Tier 2: Reduce Vehicle Speeds				
Dwell-on-Red	• Reduce speeds	Research dwell-on-red; potentially implement a pilot program	**Principles** • Safety is Proactive **Elements** • Safe Speeds • Safe Roads	3.9.4
Turn Calming	• Reduce speeds	Install countermeasures that reduce vehicle turn radius or speeds at intersections	**Principles** • Humans Make Mistakes • Humans are Vulnerable **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.4.2 3.9.19
Yellow Change Intervals	• Reduce speeds	Research current yellow interval timings; guidance provided in Guidelines for Traffic Signal Timing in Utah	**Principles** • Humans Make Mistakes **Elements** • Safe Speeds • Safe Roads	3.9.22

Table 4.3 Continued

Countermeasure	Safe System Approach Framework	How	Safe System Approach Principles and Elements	Section(s) Discussed
Tier 3: Manage Conflicts in Time				
LPI or Similar Treatments[4]	• Separate users in time • Increase attentiveness and awareness	Research LPIs and RTOR restrictions; potentially implement a pilot program	**Principles** • Humans are Vulnerable **Elements** • Safe Road Users • Safe Roads	3.3.3.2 3.3.3.3 3.3.3.5 3.6.2 3.9.7
Pedestrian Scramble[4]	• Separate users in time • Increase attentiveness and awareness	Research pedestrian scramble; potentially implement a pilot program	**Principles** • Humans are Vulnerable **Elements** • Safe Road Users • Safe Roads	3.9.9
Protected Left-Turn Phasing	• Separate users in time	Review UDOT protected left-turn standards	**Principles** • Death/Serious Injury is Unacceptable • Humans Make Mistakes • Humans are Vulnerable **Elements** • Safe Roads	3.9.11
Tier 4: Increase Attentiveness and Awareness				
Signal Backplates with Retroreflective Borders	• Increase attentiveness and awareness	Use retroreflective borders on all UDOT signal heads; guidance provided in Signalized Intersections Design Manual	**Principles** • Humans Make Mistakes • Safety is Proactive • Redundancy is Crucial **Elements** • Safe Roads	3.9.16

[4]Countermeasure also applies to Tier 4: Increase Attentiveness and Awareness

4.2.4 Unsignalized Intersections

This category is for countermeasures that can be installed at unsignalized intersections. Often, the countermeasures have been used at unsignalized intersections in a rural context, but they can also be used in an urban context. A list of strategies that can be used to apply the Safe System Approach at unsignalized intersections is shown in Table 4.4. The measures are organized by tiers according to the Safe System Roadway Design Hierarchy.

Table 4.4 Measures to Implement the Safe System Approach at Unsignalized Intersections

Countermeasure	Safe System Approach Framework	How	Safe System Approach Principles and Elements	Section(s) Discussed
Tier 2: Reduce Vehicle Speeds				
Vehicle-Activated Signs at Intersections[4]	• Increase attentiveness and awareness • Reduce speeds	Research vehicle-activated signs at intersections; potentially implement a pilot program	**Principles** • Humans Make Mistakes • Humans are Vulnerable • Responsibility is Shared • Safety is Proactive **Elements** • Safe Road Users • Safe Roads	3.9.21
Tier 4: Increase Attentiveness and Awareness				
Daylighting Intersections	• Increase attentiveness and awareness	Restrict on-street parking near crosswalks and intersections	**Principles** • Humans Make Mistakes • Humans are Vulnerable • Safety is Proactive **Elements** • Safe Road Users • Safe Roads	3.4.3
ICWS	• Increase attentiveness and awareness	Install ICWS on both major and minor intersection approaches	**Principles** • Responsibility is Shared • Safety is Proactive **Elements** • Safe Road Users • Safe Roads	3.9.6
Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections	• Increase attentiveness and awareness	Create program for implementing low-cost countermeasures at intersections	**Principles** • Humans Make Mistakes • Redundancy is Crucial **Elements** • Safe Roads	3.9.18

[4]Countermeasure also applies to Tier 4: Increase Attentiveness and Awareness

4.2.5 Geometric Measures

Geometric measures alter the physical geometry of the roadway. They require drivers to actively engage in maneuvering their vehicle when navigating around these measures. As a result, these measures will result in decreased speeds at intersections. A list of geometric measures is shown in Table 4.5. The measures are organized by tiers according to the Safe System Roadway Design Hierarchy.

Table 4.5 Geometric Measures

Countermeasure	Safe System Approach Framework	How	Safe System Approach Principles and Elements	Section(s) Discussed
Tier 1: Remove Severe Conflicts				
Channelized Right Turns	• Separate users in space	Channelize right turns; guidance provided by NCHRP	**Elements** • Safe Roads	3.9.1
Corridor Access Management	• Reduce impact forces	Review UDOT access management standards in Administrative Rule R930-6; only approve variances when necessary	**Principles** • Redundancy is Crucial **Elements** • Safe Roads	3.9.2
Dedicated Left- and Right-Turn Lanes at Intersections	• Separate users in space	Review UDOT turn lane standards; guidance provided by Administrative Rule R930-6; revise as necessary	**Elements** • Safe Roads	3.9.3
Roundabouts[2,4]	• Separate users in space • Increase attentiveness and awareness • Reduce speeds • Reduce impact forces	Implement roundabout program; emphasize roundabouts in ICE program	**Principles** • Death/Serious Injury is Unacceptable • Humans are Vulnerable • Redundancy is Crucial **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.4.1 3.9.15
RCUT[2,3,4]	• Separate users in space • Increase attentiveness and awareness • Reduce speeds • Reduce impact forces	Install RCUTs; guidance provided in FHWA informational guide	**Principles** • Humans are Vulnerable • Redundancy is Crucial **Elements** • Safe Speeds • Safe Roads	3.9.14.1
MUT[2,3,4]	• Separate users in space • Increase attentiveness and awareness • Reduce speeds • Reduce impact forces	Install MUTs; guidance provided in FHWA informational guide	**Principles** • Humans are Vulnerable • Redundancy is Crucial **Elements** • Safe Speeds • Safe Roads	3.9.14.2
Tier 2: Reduce Vehicle Speeds				
Protected Intersections[4]	• Increase attentiveness and awareness • Reduce speeds • Reduce impact forces	Install protected intersections; guidance provided in Urban Street Design Guide	**Principles** • Humans Make Mistakes • Humans are Vulnerable • Safety is Proactive • Redundancy is Crucial **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.8.2.4 3.9.10

Table 4.5 Continued

Countermeasure	Safe System Approach Framework	How	Safe System Approach Principles and Elements	Section(s) Discussed
Tier 2: Reduce Vehicle Speeds				
Raised Crosswalks[4]	• Increase attentiveness and awareness • Reduce speeds	Install raised crosswalks	**Principles** • Humans are Vulnerable **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.9.12
Raised Intersections[4]	• Increase attentiveness and awareness • Reduce speeds	Install raised intersections; guidance provided in Urban Street Design Guide	**Principles** • Humans are Vulnerable **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.9.13
Turn Calming	• Reduce speeds	Install countermeasures that reduce vehicle turn radius or speeds at intersections	**Principles** • Humans Make Mistakes • Humans are Vulnerable **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.4.2 3.9.19

[2]Countermeasure also applies to Tier 2: Reduce Vehicle Speeds
[3]Countermeasure also applies to Tier 3: Manage Conflicts in Time
[4]Countermeasure also applies to Tier 4: Increase Attentiveness and Awareness

4.2.6 Vulnerable Road User-Focused

This category refers to countermeasures that emphasize safety for vulnerable road users. These countermeasures either increase awareness of pedestrians and bicycles or decrease vehicle speeds so that if a crash does occur, kinetic energy is lower. A list of measures that increase safety for vulnerable road users is shown in Table 4.6. The measures are organized by tiers according to the Safe System Roadway Design Hierarchy.

Table 4.6 Vulnerable Road User-Focused Measures

Countermeasure	Safe System Approach Framework	How	Safe System Approach Principles and Elements	Section(s) Discussed
Tier 1: Remove Severe Conflicts				
Roundabouts[2,4]	• Separate users in space • Increase attentiveness and awareness • Reduce speeds • Reduce impact forces	Implement roundabout program; emphasize roundabouts in ICE program	**Principles** • Death/Serious Injury is Unacceptable • Humans are Vulnerable • Redundancy is Crucial **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.4.1 3.9.15
Tier 2: Reduce Vehicle Speeds				
Protected Intersections[4]	• Increase attentiveness and awareness • Reduce speeds • Reduce impact forces	Install protected intersections; guidance provided in Urban Street Design Guide	**Principles** • Humans Make Mistakes • Humans are Vulnerable • Safety is Proactive • Redundancy is Crucial **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.8.2.4 3.9.10
Raised Crosswalks[4]	• Increase attentiveness and awareness • Reduce speeds	Install raised crosswalks	**Principles** • Humans are Vulnerable **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.9.12
Raised Intersections[4]	• Increase attentiveness and awareness • Reduce speeds	Install raised intersections; guidance provided in Urban Street Design Guide	**Principles** • Humans are Vulnerable **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.9.13
Turn Calming	• Reduce speeds	Install countermeasures that reduce vehicle turn radius or speeds at intersections	**Principles** • Humans Make Mistakes • Humans are Vulnerable **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.4.2 3.9.19
Tier 3: Manage Conflicts in Time				
LPI or Similar Treatments[4]	• Separate users in time • Increase attentiveness and awareness	Research LPIs and RTOR restrictions; potentially implement a pilot program	**Principles** • Humans are Vulnerable **Elements** • Safe road users • Safe roads	3.3.3.2 3.3.3.3 3.3.3.5 3.6.2 3.9.7

Table 4.6 Continued

Countermeasure	Safe System Approach Framework	How	Safe System Approach Principles and Elements	Section(s) Discussed
Tier 3: Manage Conflicts in Time				
Pedestrian Scramble[4]	• Separate users in time • Increase attentiveness and awareness	Research pedestrian scramble; potentially implement a pilot program	**Principles** • Humans are Vulnerable **Elements** • Safe Road Users • Safe Roads	3.9.9
Tier 4: Increase Attentiveness and Awareness				
Daylighting Intersections	• Increase attentiveness and awareness	Restrict on-street parking near crosswalks and intersections	**Principles** • Humans Make Mistakes • Humans are Vulnerable • Safety is Proactive **Elements** • Safe Road Users • Safe Roads	3.4.3
Lighting	• Increase attentiveness and awareness	Review lighting standards; improve lighting at rural intersections and pedestrian crossings	**Elements** • Safe Road Users • Safe Roads	3.9.8

[2]Countermeasure also applies to Tier 2: Reduce Vehicle Speeds
[4]Countermeasure also applies to Tier 4: Increase Attentiveness and Awareness

4.2.7 Quick Build

This category refers to measures that can be implemented relatively quickly and do not require large amounts of construction. For example, temporary speed management measures such as rubber curbs can be used to create quick versions of some of these measures. A list of measures that can be installed relatively quickly is shown in Table 4.7. The measures are organized by tiers according to the Safe System Roadway Design Hierarchy.

Table 4.7 Quick Build Measures

Countermeasure	Safe System Approach Framework	How	Safe System Approach Principles and Elements	Section(s) Discussed
Tier 2: Reduce Vehicle Speeds				
Hash Marks on Intersection Approaches[4]	• Increase attentiveness and awareness • Reduce speeds	Implement hash marks near intersections; guidance provided by the MUTCD	**Elements** • Safe Speeds • Safe Roads	3.9.5

Table 4.7 Continued

Countermeasure	Safe System Approach Framework	How	Safe System Approach Principles and Elements	Section(s) Discussed
Tier 2: Reduce Vehicle Speeds				
Protected Intersections[4]	• Increase attentiveness and awareness • Reduce speeds • Reduce impact forces	Install protected intersections; guidance provided in Urban Street Design Guide	**Principles** • Humans Make Mistakes • Humans are Vulnerable • Safety is Proactive • Redundancy is Crucial **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.8.2.4 3.9.10
Turn Calming	• Reduce speeds	Install countermeasures that reduce vehicle turn radius or speeds at intersections	**Principles** • Humans Make Mistakes • Humans are Vulnerable **Elements** • Safe Road Users • Safe Speeds • Safe Roads	3.4.2 3.9.19
Yellow Change Intervals	• Reduce speeds	Research current yellow interval timings; guidance provided in Guidelines for Traffic Signal Timing in Utah	**Principles** • Humans Make Mistakes **Elements** • Safe Speeds • Safe Roads	3.9.22
Tier 3: Manage Conflicts in Time				
Protected Left-Turn Phasing	• Separate users in time	Review UDOT protected left-turn standards	**Principles** • Death/Serious Injury is Unacceptable • Humans Make Mistakes • Humans are Vulnerable **Elements** • Safe Roads	3.9.11
Tier 4: Increase Attentiveness and Awareness				
Daylighting Intersections	• Increase attentiveness and awareness	Restrict on-street parking near crosswalks and intersections	**Principles** • Humans Make Mistakes • Humans are Vulnerable • Safety is Proactive **Elements** • Safe Road Users • Safe Roads	3.4.3
Lighting	• Increase attentiveness and awareness	Review lighting standards; improve lighting at rural intersections and pedestrian crossings	**Elements** • Safe Road Users • Safe Roads	3.9.8
Signal Backplates with Retroreflective Borders	• Increase attentiveness and awareness	Use retroreflective borders on all UDOT signal heads; guidance provided in Signalized Intersections Design Manual	**Principles** • Humans Make Mistakes • Safety is Proactive • Redundancy is Crucial **Elements** • Safe Roads	3.9.16

Table 4.7 Continued

Countermeasure	Safe System Approach Framework	How	Safe System Approach Principles and Elements	Section(s) Discussed
Tier 4: Increase Attentiveness and Awareness				
Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections	• Increase attentiveness and awareness	Create program for implementing low-cost countermeasures at intersections	**Principles** • Humans Make Mistakes • Redundancy is Crucial **Elements** • Safe Roads	3.9.18

[4]Countermeasure also applies to Tier 4: Increase Attentiveness and Awareness

4.2.8 Further Research Safety Benefits or Implement Pilot Program

This category refers to measures where more research could be done to determine safety benefits or a pilot program could be implemented. Some of these measures are more common outside of the United States. Other measures are already currently implemented by UDOT, but their standards could potentially be revisited. A list of measures that require further research or a pilot program is shown in Table 4.8. The measures are organized by tiers according to the Safe System Roadway Design Hierarchy except for near-miss metrics as that countermeasure does not apply to roadway design.

Table 4.8 Measures to Research Further or Implement a Pilot Program

Countermeasure	Safe System Approach Framework	How	Safe System Approach Principles and Elements	Section(s) Discussed
Near-Miss Metrics	Identify locations where near miss conflicts occur, but not necessarily crashes	Research near miss metrics; potentially implement a pilot program	**Principles** • Humans Make Mistakes • Safety is Proactive	3.4.4
Tier 1: Remove Severe Conflicts				
Corridor Access Management	• Reduce impact forces	Review UDOT access management standards in Administrative Rule R930-6; only approve variances when necessary	**Principles** • Redundancy is Crucial **Elements** • Safe Roads	3.9.2
Dedicated Left- and Right-Turn Lanes at Intersections	• Separate users in space	Review UDOT turn lane standards; guidance provided by Administrative Rule R930-6; revise as necessary	**Elements** • Safe Roads	3.9.3

Table 4.8 Continued

Countermeasure	Safe System Approach Framework	How	Safe System Approach Principles and Elements	Section(s) Discussed
Tier 2: Reduce Vehicle Speeds				
Dwell-on-Red	• Reduce speeds	Research dwell-on-red; potentially implement a pilot program	**Principles** • Safety is Proactive **Elements** • Safe Speeds • Safe Roads	3.9.4
Speed Safety Cameras	• Reduce speeds	Research speed safety cameras; potentially implement a pilot program	**Principles** • Safety is Proactive **Elements** • Safe Road Users • Safe Speeds	3.3.3.5 3.9.17
Vehicle-Activated Signs at Intersections[4]	• Increase attentiveness and awareness • Reduce speeds	Research vehicle-activated signs at intersections; potentially implement a pilot program	**Principles** • Humans Make Mistakes • Humans are Vulnerable • Responsibility is Shared • Safety is Proactive **Elements** • Safe Road Users • Safe Roads	3.9.21
Yellow Change Intervals	Reduce speeds	Research current yellow interval timings; guidance provided in Guidelines for Traffic Signal Timing in Utah	**Principles** • Humans Make Mistakes **Elements** • Safe Speeds • Safe Roads	3.9.22
Tier 3: Manage Conflicts in Time				
LPI or Similar Treatments[4]	• Separate users in time • Increase attentiveness and awareness	Research LPIs and RTOR restrictions; potentially implement a pilot program	**Principles** • Humans are Vulnerable **Elements** • Safe Road Users • Safe Roads	3.3.3.2 3.3.3.3 3.3.3.5 3.6.2 3.9.7
Pedestrian Scramble[4]	• Separate users in time • Increase attentiveness and awareness	Research pedestrian scramble; potentially implement a pilot program	**Principles** • Humans are Vulnerable **Elements** • Safe Road Users • Safe Roads	3.9.9
Protected Left-Turn Phasing	• Separate users in time	Review UDOT protected left-turn standards	**Principles** • Death/Serious Injury is Unacceptable • Humans Make Mistakes • Humans are Vulnerable **Elements** • Safe Roads	3.9.11
Tier 4: Increase Attentiveness and Awareness				
Lighting	• Increase attentiveness and awareness	Review lighting standards; improve lighting at rural intersections and pedestrian crossings	**Elements** • Safe Road Users • Safe Roads	3.9.8

[4]Countermeasure also applies to Tier 4: Increase Attentiveness and Awareness

4.3 Summary

The purpose of this chapter was to evaluate and summarize how the measures discussed in the state of the practice can be implemented in Utah. The measures were sorted into categories based on where they could be implemented or the type of safety benefit provided. Additionally, physical countermeasures were sorted based on where they fit in the Safe System Roadway Design Hierarchy. It is important to recognize that there is no single solution to implementing the Safe System Approach. Rather, several strategies, countermeasures, policies, and practices need to be enacted to ensure that this shift is a systemic change, impacting all levels of the Safe System Pyramid.

5.0 CONCLUSIONS

5.1 Summary

The purpose of this research was to evaluate the guiding principles and elements of the Safe System Approach and determine ways that improvements can be made at intersections in Utah using the Safe System Approach methodologies. Case studies of locations that have implemented the Safe System Approach were analyzed, and measures and policies recommended by the FHWA and ITE were discussed. This research also investigated how other state DOTs are applying the Safe System Approach to their intersections. This section identifies common findings among case studies and recommendations for how to implement the Safe System Approach at intersections in Utah. Note that some of the findings emphasize adopting the Safe System Approach generally rather than specifically at intersections.

5.2 Findings

Different jurisdictions implemented the Safe System Approach generally and at intersections in a variety of ways. In researching how the Safe System Approach was adopted, common trends were identified. These trends are described in the following subsections.

5.2.1 Vision Zero Communities

One common trend among local jurisdictions implementing the Safe System Approach at intersections is the adoption of Vision Zero and a Vision Zero Action Plan. Note that Vision Zero Action Plans do not look at intersections exclusively, but commonly look along an entire HIN. Plans vary between cities due to different traffic patterns. However, a common outcome includes a shift in the community's view toward traffic crashes. More community members are active and participating in traffic safety as cities are being proactive in their approach to safety and mobilizing stakeholders to act.

5.2.2 Organizations Institutionalizing the Safe System Approach

While Vision Zero is more tailored to local jurisdictions, other tools exist to help state DOTs to adopt and institutionalize the Safe System Approach in their policies, programs, and practices. Some of these tools are exclusive to intersections, while others help to apply the Safe System Approach generally. The following subsections list tools used to apply the Safe System Approach at intersections and tools for implementing the Safe System Approach generally.

5.2.2.1 Tools for Adopting the Safe System Approach at Intersections

The following tools help state DOTs to implement the Safe System Approach specifically at intersections:

- Safe System at Intersections Methodology – Developed by the FHWA to help quantify how closely an intersection aligns with Safe System principles. Both FDOT and GDOT have included SSI in their ICE program and have found the inclusion of the SSI methodology to be beneficial, providing them additional insight regarding safety. While it has not been the deciding factor in safety projects, it has placed a strong emphasis on safer intersection layouts.
- Safe System Project-Based Alignment Framework – Tool developed by the FHWA to help quantify how closely a roadway project aligns with Safe System principles. Intersections can be evaluated exclusively, but other roadway projects can be evaluated as well.
- New Zealand Safe System audit – Similar to the FHWA Safe System Project-Based Alignment Framework in that it helps look at roadway projects through a Safe System lens. The audit may be used for intersection or corridor projects.
- Safe System Intersection Assessment Path – Developed by CRISP, the Safe System Intersection Assessment Path is a decision tree that helps planners and designers to follow Safe System principles when designing an intersection.

5.2.2.2 Tools for Adopting the Safe System Approach Generally

The following tools help state DOTs to adopt the Safe System Approach generally:

- Safe System Policy-Based Alignment Framework – Tool developed by the FHWA to help a DOT evaluate their policies and how they align with the Safe System Approach.
- State DOT executive order or director's policy – A state DOT mandating the Safe System Approach be incorporated in all projects and programs establishes that it is a priority for that DOT. Both Caltrans and WSDOT have done this, communicating to employees and the public the importance of shifting away from traditional safety approaches.
- Incorporating the Safe System Approach in the SHSP and the HSIP – This helps DOTs to align their programs and practices with the Safe System Approach. Caltrans and MassDOT have recently updated their SHSPs to reflect the principles and elements established in the Safe System Approach.
- Organizational Safety Culture Self-Assessment – Tool developed by the FHWA to help a DOT evaluate their safety culture and how it aligns with the Safe System Approach. It also provides strategies and an implementation plan for how to improve the safety culture in weaker areas.
- Safe System Roadway Design Hierarchy – Tool developed by the FHWA that can be used in the design process to ensure designs are more closely aligned with Safe System principles and elements.
- Safe System Approach Framework – Tool developed by the FHWA and ITE that can be used in the design process to ensure designs are more closely aligned with Safe System principles and elements. Many elements in the Safe System Approach Framework overlap with the Safe System Roadway Design Hierarchy.

5.2.3 Physical Countermeasures

Applying the Safe System Approach to intersections is not limited to new policies or programs. Physical changes can be added to the roadway to eliminate conflict points or reduce the kinetic energy involved in a crash. A variety of physical safety countermeasures were presented previously in Section 3.9. These countermeasures have varying effects on safety, but all of them have supporting research or case studies demonstrating that they improve safety in some capacity. These physical countermeasures support the Safe Roads and Safe Speeds elements of the Safe System Approach. Some of the physical countermeasures discussed in this research could be researched further to better understand their safety benefit, or a pilot program could be implemented.

5.3 Limitations and Challenges

During this research project, a couple of challenges and limitations were identified. A common trend identified in several case studies was that the safety impacts of Vision Zero Action Plans and countermeasures were offset by the COVID-19 pandemic. In several locations, fatalities decreased from 2019 to 2020. However, this is not necessarily due to the safety countermeasures, but the decrease in vehicles on the roadway. Traffic fatalities tended to increase after the pandemic as more vehicles returned to the roadway. Locations with Vision Zero Action Plans should continue to be monitored to evaluate their safety benefit without being offset by the pandemic.

Additionally, it is important to note that some of the case studies as well as policies enacted by other DOTs are relatively recent, and their impact is not fully known. Some of the material discussed in this research project was published as recently as June 2024. Therefore, the findings on some of the material are still limited due to their recency, and the long-term impacts are not fully known at this time.

6.0 RECOMMENDATIONS AND IMPLEMENTATION

6.1 Recommendations

This chapter includes recommendations, or suggestions for action, and an implementation plan for how UDOT can implement the Safe System Approach at intersections. It also includes recommendations for further research. Suggestions for action are described in the following subsections.

6.1.1 Encouraging Communities in Utah to Become Vision Zero Communities

UDOT can create a position for a Vision Zero specialist. As of February 2024, there are no Vision Zero communities in Utah (Vision Zero Network, 2024). The role of this specialist can include becoming familiar with how to write a Vision Zero Action Plan, how to receive recognition as a Vision Zero community, and acting as an advocate for communities in Utah to adopt Vision Zero and the Safe System Approach. This position could be housed within UDOT or the local Metropolitan Planning Organization.

6.1.2 Incorporating the FHWA SSI Method into ICE Program

To implement the Safe System Approach at intersections, UDOT can reach out to employees of FDOT or GDOT to view their SSI Tool and how it integrates into their ICE program. An engineer or programmer can be brought on board the ICE team to create an SSI tab in the UDOT SPICE spreadsheet. Doing this will establish that the Safe System Approach is a priority for UDOT and ensure that it is being considered in ICE studies. The Safe System Project-Based Alignment Framework may be incorporated into project life cycles as well. Additionally, the Safe System Roadway Design Hierarchy and Safe System Framework can be referenced in intersection design.

6.1.3 Institutionalizing the Safe System Approach

In addition to incorporating SSI into the SPICE spreadsheet, UDOT can implement practices or policies to more closely align with the Safe System Approach:

- Update UDOT SHSP to incorporate Safe System Approach principles and elements – This action can help UDOT more closely align with the Safe System Approach.
- Administer the Organizational Safety Culture Self-Assessment and/or the Safe System Policy-Based Alignment Framework – These tools can help UDOT to evaluate their existing traffic safety culture and identify areas that can be strengthened.
- Place a stronger emphasis on roundabouts and other intersection alternatives that reduce conflict points – Prioritizing intersection alternatives that reduce the number of conflict points, reduce speeds, and minimize crash angles are physical changes to the roadway that can improve safety.
- Modify the UDOT strategic goal of "zero crashes, injuries and fatalities" to "zero fatalities and serious injuries." – Doing so recognizes that since humans will make mistakes, preventing all crashes is not a priority, and an emphasis should be placed on crashes that result in fatalities or serious injuries.
- Modify the UDOT vision of "Keeping Utah Moving" to "Moving Utah Safely" – This change reinforces the notion that safety is a priority for UDOT and aligns with the Safe System Approach.
- Be aware of the findings and recommendations presented in NCHRP 17-125, "Guide for Applying Safe System Principles in the Road Safety Audit Process" when it releases in 2026 – Results from this research may provide additional insight into how UDOT can better institutionalize the Safe System Approach.
- Be aware of the findings and recommendations presented in NCHRP 17-132, "Tools to Support State DOT Implementation of the Safe System Approach," when it is completed sometime after 2026 – Results from this research may provide additional insight into how UDOT can better institutionalize the Safe System Approach.

Multiple groups at UDOT would be responsible for enacting the recommendations listed above, depending on the recommendation.

6.1.4 Future Research or Pilot Programs

Some of the physical countermeasures included in Section 3.9 have limited or no implementations in the United States. The following physical countermeasures can be further investigated by UDOT to determine their effectiveness in increasing safety. Pilot programs could also be implemented to research how Utah drivers respond. The UDOT Traffic and Safety Division should be responsible for conducting these pilot programs and research projects. Possible research topics or pilot programs include:

- Near-miss data;
- Yellow change interval standards;
- Protected left-turn phasing standards;
- LPIs or similar treatments;
- Lighting standards;
- Variable speed limits on intersection approaches;
- Dwell-on-red;
- Vehicle-activated signs at intersections or ICWS;
- Pedestrian scramble; and
- Speed safety cameras.

6.2 Implementation Plan

The FHWA Organizational Safety Culture Self-Assessment and Safe System Policy-Based Alignment Framework will provide UDOT with feedback regarding how well the Safe System Approach is currently integrated into the organization. Additionally, findings from these tools will provide UDOT with more specific direction on which recommendations from this research should be prioritized. The UDOT Traffic and Safety Division will implement the results of this research by evaluating the recommendations and determining which ones are appropriate according to funding and priority. Recommendations from this study can be used to implement the Safe System Approach specifically at intersections, or to integrate it generally into the organization.

6.3 Concluding Remarks

The Safe System Approach is a comprehensive approach to road safety that acknowledges human errors and vulnerabilities. It contains a multi-faceted strategy to create a safer and more resilient transportation system, aiming to diminish the crash severity between road users and mitigate impact forces to ensure that collisions are never fatal (FHWA, 2023). The Safe System Approach has been implemented in locations across the world. Several tools have been developed to help agencies adopt the Safe System Approach in general, as well as specifically at intersections. By using these tools to adopt the Safe System Approach, UDOT can continue to develop their safety culture and convey the importance of safety at UDOT intersections.

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