National Operations Center of Excellence

NOCoE Best Practices: Integrating Safety and Mobility

Report #7

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Introduction

INTRODUCTION

At the core of the transportation industry is the safe and efficient movement and people and goods. Safety and efficiency are sometimes characterized as a tradeoff; in reality, with thoughtful transportation system management and operations (TSMO) practices, operations is a means to achieving safe mobility. The Safe System Approach provides an effective framework for coordinating safety and TSMO strategies. Many Federal Highway Administration (FHWA) Proven Safety Countermeasures employ the use of TSMO strategies and technologies; agencies across the country have effectively implemented safety and TSMO strategies to advance a safe and efficient transportation system.

STRATEGIES

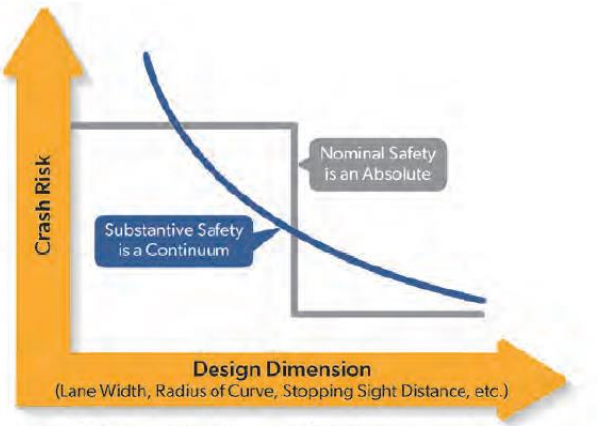
The AASHTO *Transportation Operations Manual* (TOM) addresses safe mobility and TSMO strategies:

Chapter 13: Performance-Based Practical Design

- Safety considerations including nominal versus substantive safety
- Relationship between Roadway Functional Classification, Mobility, and Access

The concept of nominal versus substantive safety considers safety as a continuum, as opposed to a binary checklist, there are incremental design and operations considerations that can holistically improve safety and reduce crash risk.

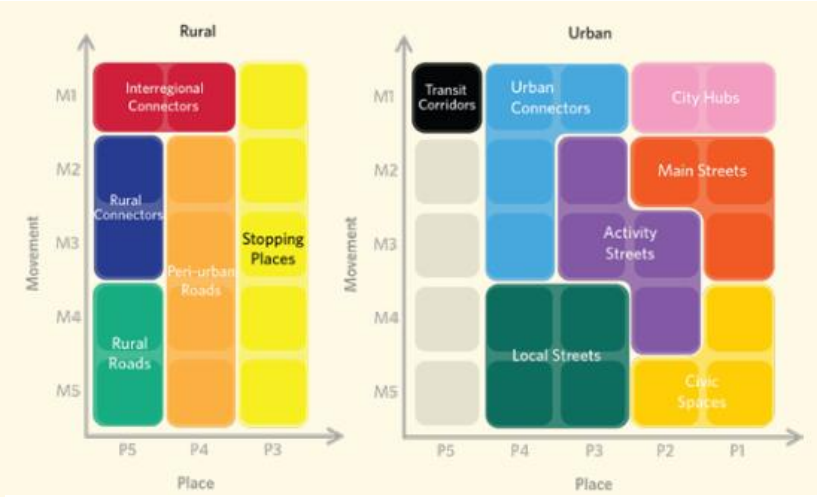
The TOM outlines how functional classification defines "the roadway's primary purpose in serving vehicular traffic while the context defines the surrounding area's character" (p. 198). There are many frameworks for context classification, including those available in AASHTO's *A Policy on Geometric Design of Highways and Streets* and ITE's *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach*.



Source: Adapted from ITE, *Integrating Safety in the Project Development Process and Beyond: A Context Sensitive Approach*, Figure 2-2.

Nominal and Substantive Safety Decision Models

Emergent approaches consider the Movement and Place One Network Framework tying transportation and land use more closely together. New Zealand has been a leader in this space, implementing the ONF as a tool to "help establish priority uses, performance measures and potential interventions for each road and street type" (ONF Fact Sheet, 2025). This approach acknowledges the unique context of both rural and urban settings and provides a strategic framework for addressing the transportation needs of each setting. By integrating planning and TSMO considerations early in the project lifecycle, TSMO practitioners can better understand the appropriate levels of service and implement TSMO strategies to meet project goals most effectively, using the *Highway Capacity Manual* and other operations tools.



Source: New Zealand Transport Agency, *One Network Framework Fact Sheet*, 2025.

Common Language from One Network Framework

Chapter 18: Module 18.2 – Improving Safety

In chapter 18 "Overview of Tactical Elements," the TOM addresses how TSMO strategies can manage congestion, improve safety, and monitor performance of the system. Many agencies use TSMO to support safety interventions as well as congestion challenges.

The TOM states:

- "Crash rates generally increase with increased congestion as system users encounter something they don't expect." (TOM, pg. 270)
- "Increased safety helps reduce crashes and incident-induced secondary crashes, thereby resulting in a safer, more efficient transportation system performance for the travel public." (TOM, pg. 270)

The role of operations is critical to implement and institutionalize the Safe System Approach.

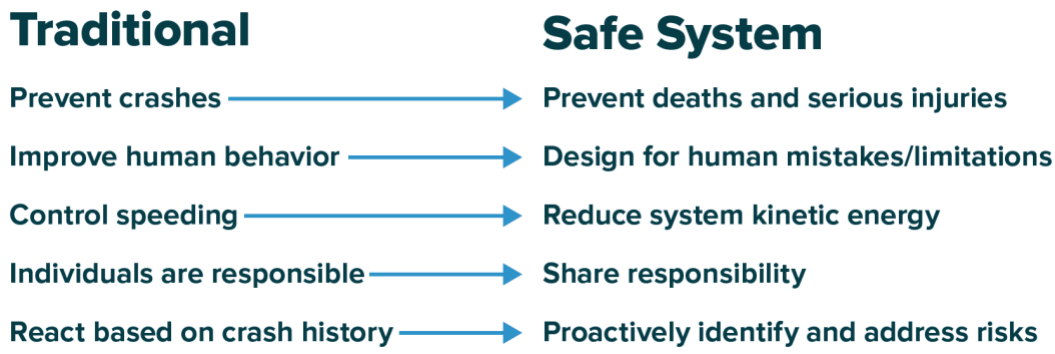
Chapter 26: Active Transportation Tactics

When starting in early states of connecting safety and operations, demand management is one of the first steps. Enhancing the options of modes of transportation can reduce exposure of people walking, biking, and rolling to vehicular traffic. Active transportation modes are sometimes the only option to people that do not own vehicles, it is an important operations strategy to accommodate all road users in the transportation system. Chapter 26 of the TOM "addresses a range of active transportation tactics intended to provide enhanced mobility and safety across a range of non-motorized trans-portation modes."

Safe System Approach

Safe System Approach

The Safe System Approach advances transportation safety beyond the 5Es of education, encouragement, enforcement, evaluation, and engineering. By integrating various aspects of the transportation system into an approach that encompasses shared responsibility, the transportation industry, including the operations community, can reduce and eliminate deaths and serious injuries. TSMO strategies play a key role in this industry shift.

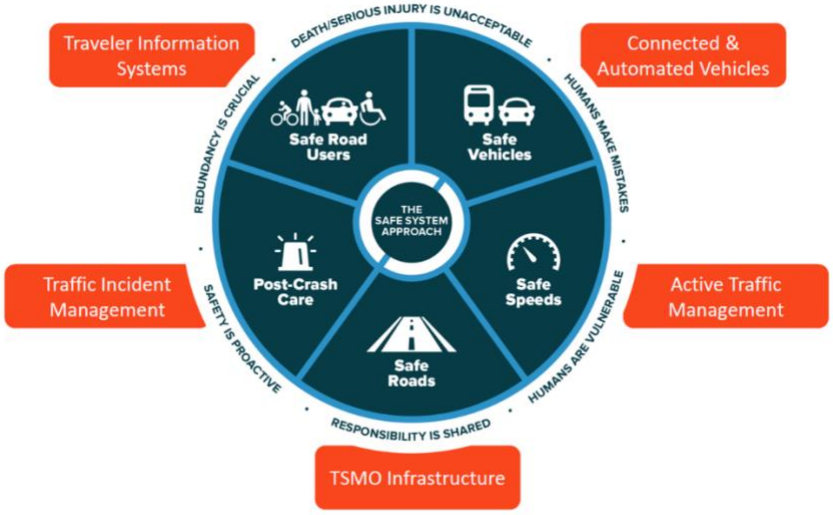


Source: FHWA, Safey System Approach Fact Sheet, 2020.

Traditional Road Safety Practices vs. the Safe System Approach

While the Safe System Approach should be implemented as a comprehensive, wholesale approach and not segmented into siloes, it can be useful to view TSMO strategies through the five spokes of the Safe System Approach wheel: Safe Road Users, Safe Vehicles, Safe Speeds, Safe Roads, and Post-Crash Care.

The TSMO community is well-equipped to implement these and other strategies that are consistent with the Safe System Approach. By recognizing that humans make mistakes, transportation engineers and professionals can design and plan for human limitations. Many TSMO strategies already account for human factors considerations; this approach takes this background and knowledge a step further to ensure that an efficient system is also safe for all road users.



Source: NOCoE, USDOT Safe System Approach wheel linked to TSMO, 2023.

Relationship of the Safe System Approach to TSMO

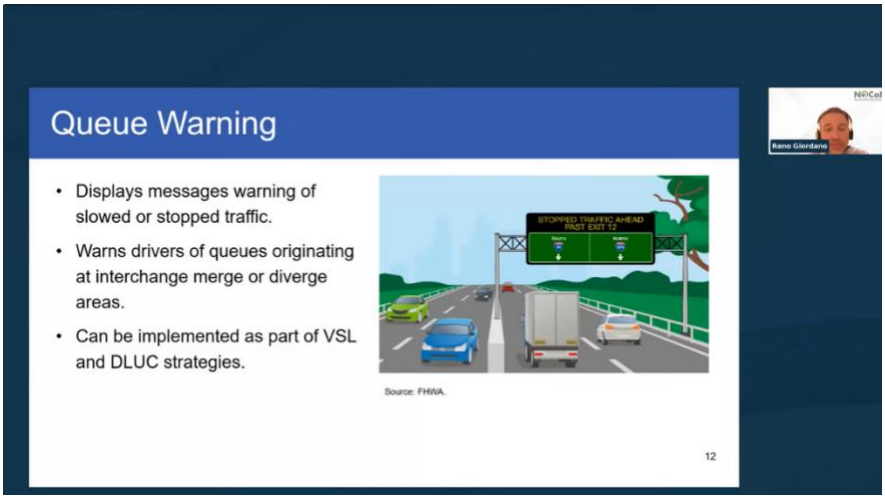
Strategies and Examples

Safe Road Users

Traveler Information Systems are a core component of TSMO strategies for many transportation agencies.

> *"Improving driver awareness through information provided before and during a trip including alerts for queues ahead, road condition changes, or real-time parking information helps drivers anticipate, plan for, and react to changing conditions." (FHWA, Operations and Safety: Operations Strategies to Improve Safety)*

Specifically, real-time information and alerts keep the traveling public informed and aware. These can include roadside messaging such as the use of dynamic message signage for queue warnings, weather condition information, and a change in traffic patterns.



Source: NOCoE, *Active Interchange Management* webinar, November 19, 2025.

Queue Warning Example to Support Safe Road Users

Safe Vehicles

Intelligent Transportation Systems (ITS) infrastructure can support the Safe Vehicles tenet of the Safe System Approach. These strategies can include smart and connected traffic signals and vehicle-to-everything (V2X) deployment. The implementation of TSMO strategies like Intersection Collision Warning Systems (ICWS) and Dynamic Curve Speed Warnings (DCSW). ICWS alert drivers with flashing lights on the roadway and may include onboard or in-vehicle alert systems with audio or visual warnings. These systems use sensors to detect vehicles entering an intersection and can be a key tool for unsignalized intersections in areas with low visibility or poor sightlines. A 2011 FHWA study of Minnesota, Missouri, and North Carolina found statistically significant crash reductions for all crash types except nighttime crashes for two-lane at two-lane intersections. As with all safety interventions, context is critical. FHWA also released information with implementation considerations for ICWS.

Source: FHWA, *Curve Safety Solutions Fact Sheet*, 2023.

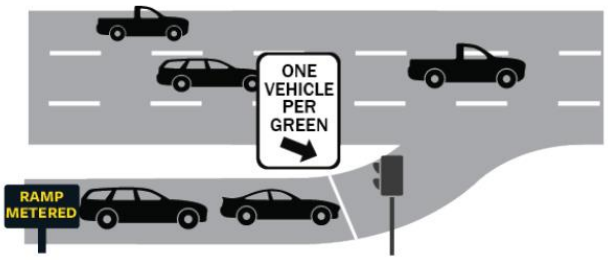
Dynamic Curve Warning Sign

Dynamic Curve Speed Warnings measure the speed of approaching vehicles and display flashing lights upon detection of vehicle traveling too fast. This alerts the driver of the curve ahead and prompts a reduction in speed. The dynamic system is more costly than static signage, but may be a useful tool in areas where static signage has been ineffective.

V2X deployment allows real-time communication between vehicles and infrastructure. This connected system can increase the ability to alert all road users of potential hazards and provides the opportunity for agencies to collect road user data. Using connected vehicle data, advanced analytics and predictive modelling can aid in safety analysis, including emerging near-miss analysis. This type of analysis can assist TSMO professionals and planners in identifying areas that may need additional safety and operational improvements. The U.S. Department of Transportation released *Saving Lives with Connectivity: A Plan to Accelerate V2X Deployment* with a vision for national, widespread deployment of secure, interoperable V2X technologies. The Department established short-term, medium-term, and long-term actions and steps from 2024 to 2036 in the areas of infrastructure deployments, vehicles, spectrum and interoperability, and benefits and technical assistance. This nationwide effort can assist with improved connectivity for a safer, more efficient transportation system.

Safe Speeds

Active traffic management (ATM) is an effective TSMO strategy for implementing context appropriate speed limits and speed management. Reducing speed differential can result in reduced crash frequency and severity. Tools such as variable speed limit signs, work zone speed harmonization, adaptive ramp metering, traffic responsive signal control, and speed safety cameras can be effective strategies for ensuring safer speeds on all roadways. These ATM tools allow agencies to adjust speed limits in real time based on weather, congestion, incidents, or special events to help drivers travel at safer speeds that align with current conditions. More predictable and consistent travel conditions create a smoother travel experience for all roadway users.



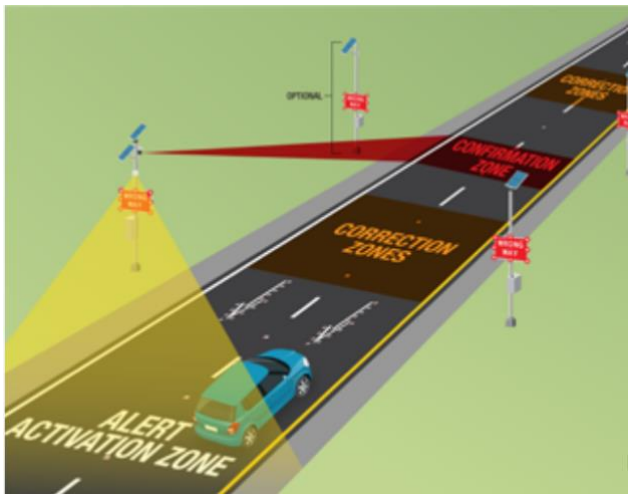
Source: FHWA, *Operations and Safety: Operations Strategies to Improve Safety*, 2023.

Ramp Metering

Safe Roads

There are several TSMO strategies that can be implemented to support Safe Roads. A few highlighted here include Wrong Way Driving Detection Systems, Leading Pedestrian Intervals, and Diverging Diamond Interchanges.

Wrong Way Driving Detection Systems



Source: Florida DOT, *Wrong Way Driving (WWD) Strategic Plan*, 2025.

Wrong Way Vehicle Detection System

Florida DOT adopted a Wrong Way Driving (WWD) Program Strategic Plan in February 2025. The agency's approach includes incorporating new research and countermeasures into an overall program with concrete implementation targets. Sensors identify a driver traveling in the wrong direction and then flashing lights alert other road users to the presence of a wrong way driver. The use of dynamic message signs shares real-time information to road users. View NOCoE Case Study on Florida DOT's approach: https://transportationops.org/case-studies/fdots-wrong-way-driving-program

Leading Pedestrian Intervals

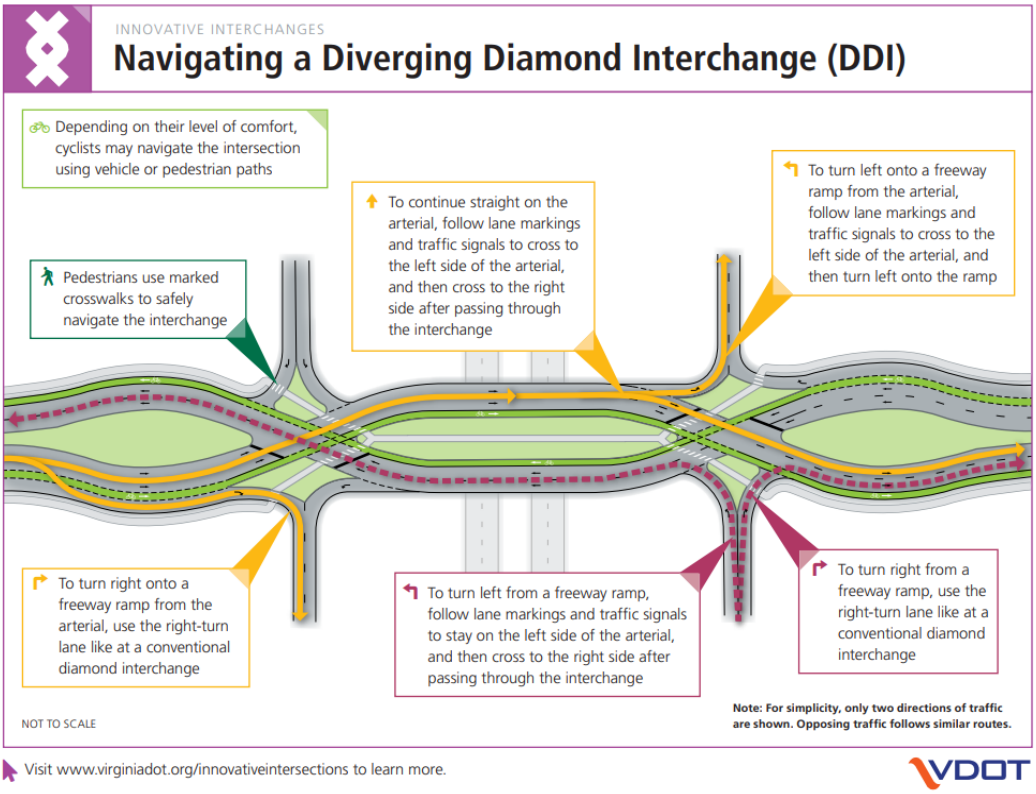
Leading Pedestrian Intervals are a FHWA Proven Safety Countermeasures. They allow pedestrians to advance into the crosswalk while the intersection is red for all drivers. This reduces the likelihood of turn-related conflicts in the intersection, as the pedestrian is more visible in driver sightlines. According to FHWA, LPIs result in a 13% reduction in pedestrian-vehicle crashes at intersections.

Source: FHWA, *Operations and Safety: Operations Strategies to Improve Safety*, 2023.

Leading Pedestrian Interval

Diverging Diamond Interchange

Missouri DOT constructed the nation's first Diverging Diamond Interchange in Springfield, Missouri, in June 2009. Compared to a conventional diamond interchange, the DDI reduces vehicle-to-vehicle conflict points by nearly 50 percent and eliminates many of the most severe crash types. This design solution with operations implications reduces impact angles by eliminating left turns and incorporating sidewalks into a DDI design separates multimodal roadway users in both time and space. Virginia DOT has implemented several DDIs and promote benefits including improved safety, increased efficiency, easier access to freeways, and cost effectiveness (*VDOT, Diverging Diamond Interchange*).



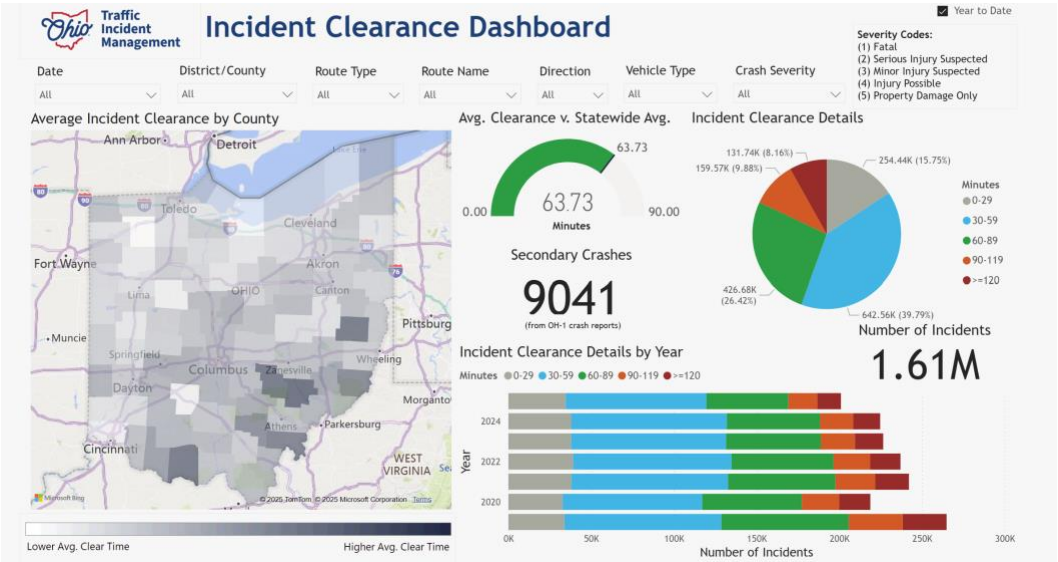
Source: Virginia DOT, *Curve Safety Solutions Fact Sheet*, 2024.

Navigating a Diverging Diamond Interchange

Post-Crash Care

Traffic Incident Management

Traffic Incident Management (TIM) consists of a planned and coordinated multi-disciplinary process to detect, respond to, and clear traffic incidents so that traffic flow may be restored as safely and quickly as possible (FHWA). Many agencies include TIM divisions that either coordinate with safety divisions or have combined offices within their organizational structure. Ohio Department of Transportation leads a statewide TIM committee to coordinate on ongoing TIM improvements, including a public-facing TIM dashboard. The incident clearance dashboard tracks average incidence clearance by county, incident clearance details by number of incidents, and multiple filters to allow comparison across year, routes, and crash severity.



Source: Ohio DOT, *Incident Clearance Dashboard*, 2025.

Incident Clearance Dashboard

Successful TIM requires coordination across various agencies and jurisdictions and with the traveling public. New technologies allow this coordination and communication to occur faster and more accurately, such as advanced incident detection, emergency vehicle preemption, and digital alert systems. TIM is a key TSMO strategy that supports safety on the roadways by reducing time to access post-crash care in the event of a crash and by reducing the likelihood of often more severe secondary crashes.

Emergency Vehicle Preemption

One specific strategy under TIM is Emergency Vehicle Preemption. This approach uses connected infrastructure technologies to change the traffic signal indication to green for an approaching emergency response vehicle, while promptly displaying a red signal to drivers who may cross the emergency vehicle's path. The longest continuously operating EVP system is in Minnesota, where state law requires that EVP wiring is included in all traffic signal design.

"Minnesota is also one of a few states that require the white/clear indicator lights for confirmation" (MnDOT, *Systems Engineering Analysis for Standard Traffic Signal: Concept of Operations*, May 2020). MnDOT describes the systems implementation as follows:

> "The basic concept is that an emergency vehicle that needs to travel as quickly as possible to or from an incident scene requests high priority movement through all or many of the signals on its travel route by either a call to a central control system, or by emitting an advance request for preemption service to each properly instrumented signal on its route. The continuous request is typically optical, audio (e.g., siren), or radio, and is sent well before the expected vehicle arrival time to the stop line. Each instrumented signal then attempts to service the call by either holding the green on the subject approach, or early terminating the green on a conflicting approach and granting right of way to the subject approach. Sometimes there may be conflicting calls for EVP service on instrumented approaches, in which case controller software must have pre-established rules for "negotiating" which call is served, typically the first call received. A system that relies on central control, not vehicle emitters and receivers, requires that vehicle location be accurately tracked as it passes through each intersection by, for example, automatic vehicle location technology." (MnDOT, *Systems Engineering Analysis for Standard Traffic Signal: Concept of Operations*, May 2020).

Resources

RESOURCE LIST

AASHTO Transportation Operations Manual (TOM)

- Chapter 13: Performance-Based Practical Design
- Chapter 18: Module 18.2 – Improving Safety
- Chapter 25: Active Transportation Tactics

FHWA

Coordination of Safety and TSMO (FHWA webpage)

Operations and Safety: Operations Strategies to Improve Safety (March 2023)

Making Safety Everyone's Business: Integrate Safety into All Programs and Projects (September 2024)

Operations and Safety: Making the Connections (March 2023)

Safety Analysis Needs Assessment for Transportation Systems Management and Operations (October 2019)

USDOT National Roadway Safety Strategy

Curve Safety Solutions (2023)

Improving Pedestrian Safety on Urban Arterials: Learning from Australasia (June 2023)

National Cooperative Highway Research Program

NCHRP Research Report 1135: Guide to Applying the Safe System Approach to Transportation Planning, Design, and Operations (2025)