U.S. Department of Transportation
Federal Highway Administration

OPERATIONS AND SAFETY

Operations Strategies to Improve Safety

Source of cover photos: Getty Images.

INTRODUCTION

Operations strategies aim to optimize the movement of people and goods across the transportation system. Operations includes all modes of travel and often requires multijurisdictional and interagency collaboration throughout planning, project development, and deployment.[1] While often considered tools for decreasing congestion and improving reliability, operations strategies can also be instrumental in reducing the risk of crashes associated with serious injury and death on roadways.[2]

The purpose of this brochure is to bring awareness to operations and safety professionals, planners, and other transportation practitioners of the wide range of operations strategies that support safety and the potential safety benefits of such strategies. The brochure highlights several operations strategies with known or potential safety benefits. It also discusses the opportunities to close existing gaps in measuring and analyzing the safety benefits of these strategies. This is one of two Federal Highway Administration (FHWA) brochures that focus on connecting operations and safety.[3]

HOW OPERATIONS STRATEGIES CAN IMPROVE SAFETY

Individual operations strategies can advance the overall goal of improving safety in a variety of ways. For example, operations strategies can support safety through:

Reducing the impacts of traffic disruptions created by events such as work zones, traffic incidents, special events, and inclement weather. These disruptions can cause unexpected and more challenging conditions for road users, which may lead to crashes. Operations strategies can increase safety by focusing on creating safe conditions on the road during these events, raising the awareness of drivers to new conditions, and limiting the duration of the disruptions.

Reducing time to access postcrash care through detecting incidents faster and improving emergency response times. Recent advances in the use of crowdsourced operations data at traffic management centers,[4] machine learning for video detection of incidents, and automated processing of real-time data support faster detection and response to crashes. Emergency vehicle signal preemption and dynamic lane use can help get medical services to those involved in incidents quicker.

1 Learn more about operations strategies from: FHWA. n.d. "What is TSMO?" (website). https://ops.fhwa.dot.gov/tsmo/, last accessed January 31, 2023.

2 See the U.S. Department of Transportation (DOT) Intelligent Transportation Systems (ITS) Joint Program Office (JPO) website "Spotlight on ITS for Roadway Safety" for more details on operations strategies for safety. https://www.itskrs.its.dot.gov/safety, last accessed January 28, 2023.

3 The companion brochure is: FHWA. 2022. *Operations and Safety: Making the Connections*. Publication No. FHWA-HOP-22-016. Washington, DC: FHWA.

4 FHWA. n.d. "Center for Accelerating Innovation: Crowdsourcing for Advancing Operations" (website). https://www.fhwa.dot.gov/innovation/everydaycounts/edc_6/crowdsourcing.cfm, last accessed January 6, 2023.

Reducing traffic conflicts, including vehicle-to-vehicle conflicts as well as pedestrian/bicyclist-to-vehicle conflicts. Operational improvements such as advanced signal timing systems, bicycle signals, leading pedestrian intervals, and separated bicycle lanes can help provide greater protection for all users at intersections and midblock. Geometric improvements such as the addition of left-turn lanes, pedestrian refuge islands, and longer merge zones around on- and off-ramps are also important operations-related strategies that can support safety.

Reducing speed differentials can result in reduced crash frequency and severity. Some studies have shown that speed variance can increase the risk of crashes in general as well as the risk of severe crashes when speeds vary significantly on higher speed roadways.[5] Operations strategies, such as ramp meters, variable speed limits, dynamic merging, and open-road tolling, which help to smooth traffic flow and increase efficiency, may also support safety.

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. It also helps drivers navigate unfamiliar routes and keeps safety at the forefront. Through parking and rest area information, it helps drivers and particularly truck drivers to eliminate distracted or fatigued driving, which leads to crashes.

SAMPLE OPERATIONS STRATEGIES TO CONSIDER FOR SAFETY

Agencies have a range of strategies for improving the operational performance of the transportation system, and many of them can support safety as well. This section provides a sampling of strategies that are typically considered for operations.[6] In addition to addressing one or more operational challenges, these strategies have also been proven (or show the potential) to improve safety.[7] As noted previously, they can improve safety in one of five ways:

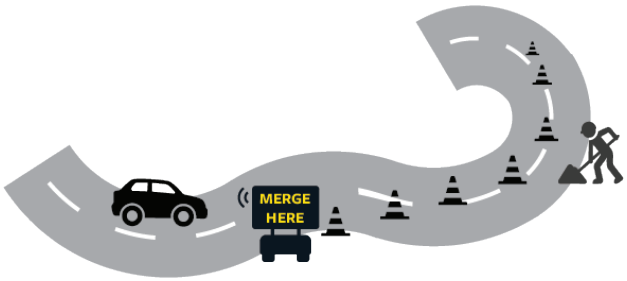
- Reducing the impacts of traffic disruptions
- Reducing time to postcrash care
- Reducing traffic conflicts
- Reducing speed differentials
- Improving driver awareness

5 FHWA. 2004. *The Safety Impacts of Differential Speed Limits on Rural Interstate Highways*. Publication No. FHWA-HRT-04-156. Washington, DC: FHWA. https://www.fhwa.dot.gov/publications/research/safety/04156/index.cfm, last accessed January 7, 2023.

6 Note that all pictures in this section are for illustrative purposes only.

7 Additional information on the safety impacts of operations strategies can be found in the "FHWA Crash Modification Factors Clearinghouse" web page by searching "TSMO": http://www.cmfclearinghouse.org/results.cfm?qst=tsmo, last accessed January 27, 2023.

Reducing the Impacts of Traffic Disruptions



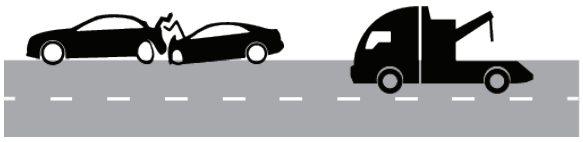
Source: Federal Highway Administration.

Work Zone Management

Includes a suite of strategies that help to manage the movement of all road users and goods during construction. The strategies aim to maintain road user and worker safety and support mobility. Work zone safety strategies include dynamic lane merge systems, variable speed limits, alert systems for workers, and queue detection and warning systems. More information is available at: https://workzonesafety.org.

Traffic Incident Management

Provides safe, quick clearance of crashes or incidents to prevent secondary crashes and reduce responder exposure. One study estimates the chance of secondary incidents increases by 2.8 percent for each minute the initial incident continues to pose a hazard.[8] More information is available at: https://ops.fhwa.dot.gov/tim.



Source: Federal Highway Administration.

Source: Federal Highway Administration.

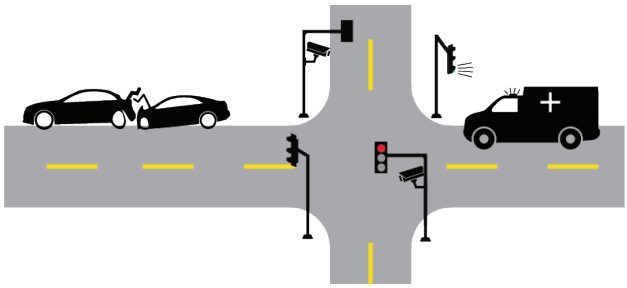
Road Weather Management

Promotes safety by treating roads, adjusting traffic control, and providing timely, accurate, and relevant information about the roadway impacts of weather on travelers and transportation agencies. This information allows agencies and drivers to make safe decisions during inclement weather.

More information is available at: https://ops.fhwa.dot.gov/weather.

8 Karlaftis, M. G., S. P. Latoski, N. J. Richards, and K. C. Sinha. 1999. "ITS Impacts on Safety and Traffic Management: An Investigation of Secondary Crash Causes." *ITS Journal – Intelligent Transportation Systems Journal 5*, no. 1:39–52.

Reducing Time to Postcrash Care



Source: Federal Highway Administration.

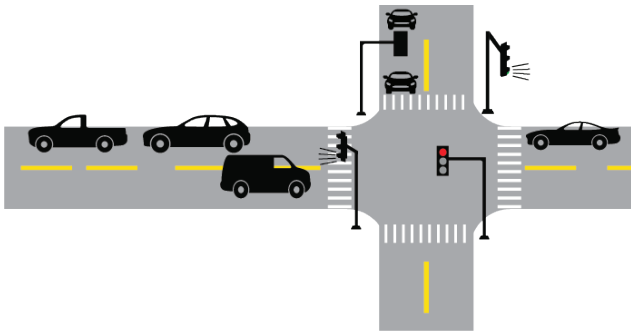
Incident Detection

Includes processes and technologies to detect incidents on the road so that necessary emergency medical services can quickly reach crash victims. This may include automated searching of closed-circuit television (CCTV) cameras, alerts from crowdsourced navigation applications, and analysis of real-time speed data. More information is available at: https://www.itskrs.its.dot.gov/sites/default/files/doc/07_NextGen%20TMCs_Final%20508_01_25_22.pdf.

Emergency Vehicle Preemption

Gives preferential treatment to emergency vehicles at traffic signals, allowing first responders to reach crash victims and transport them to treatment centers more quickly. More information is available at: https://rosap.ntl.bts.gov/view/dot/3655.

Reducing Traffic Conflicts



Source: Federal Highway Administration.

Adaptive Traffic Signal Control

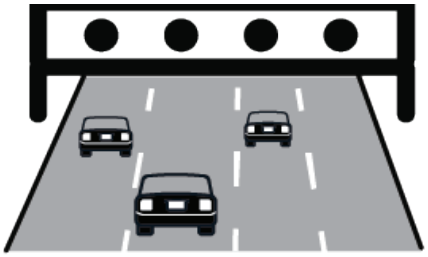
Adjusts the timing of traffic signals to accommodate changing traffic patterns and smooth traffic flow. Several studies have also shown crash reduction benefits. More information is available at: https://www.fhwa.dot.gov/innovation/everydaycounts/edc-1/asct.cfm.

Signal Timing Strategies for Pedestrian Safety

Have the potential to reduce conflicts between pedestrians and vehicles. FHWA has designated leading pedestrian intervals as a Proven Safety Countermeasure, and they have been shown to reduce pedestrian-vehicle crashes at intersections. More information is available at: https://safety.fhwa.dot.gov/provencountermeasures/pdfs/fhwasa17063v2.pdf.

Source: Federal Highway Administration.

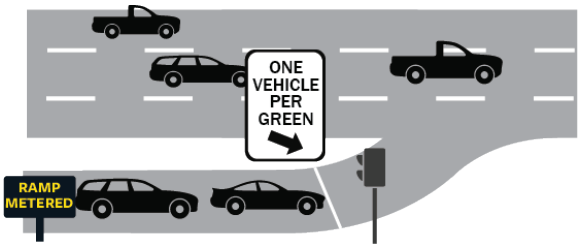
Reducing Speed Differentials



Source: Federal Highway Administration.

Open-Road Tolling (All-Electronic Tolling)

Collects tolls from vehicles traveling at highway speeds without drivers having to stop or slow down to pay a toll. Several studies show a reduction in crashes after converting facilities from tollbooth collection to open-road tolling. More information about related safety studies is available at: http://www.cmfclearinghouse.org/results.cfm?qst=open%20road%20tolling.

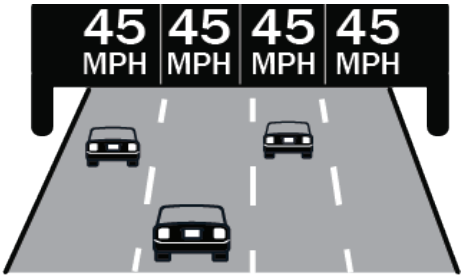


Source: Federal Highway Administration.

Adaptive Ramp Metering

Uses algorithms that can optimize the frequency at which vehicles enter the flow of traffic on the freeway. Adaptive ramp metering can also integrate technologies such as dynamic bottleneck identification, automated incident detection, and integration with adjacent arterial traffic signal operations. Several studies have shown a reduction in crashes after ramp meters were implemented, and one study found an overall crash frequency reduction after adaptive ramp meters were implemented.[9] More information is available at: https://ops.fhwa.dot.gov/publications/fhwahop14021/fhwahop14021.pdf.

9 U.S. DOT ITS JPO. 2018. "Ramp metering system improved delay by 25 percent and reduced crashes by 22 percent per ramp meter in Auckland, New Zealand." https://www.itskrs.its.dot.gov/its/benecost.nsf/ID/df522aaf83fcc67d85258221005ff3ed, last accessed January 27, 2023.



Source: Federal Highway Administration.

Variable Speed Limits

Harmonize vehicle speeds when congestion is building and reduce erratic flow conditions that lead to crashes. These systems enable speed limits to be changed dynamically in response to traffic or road weather conditions. Variable speed limits are an FHWA Proven Safety Countermeasure. More information is available at: https://safety.fhwa.dot.gov/provencountermeasures/variable-speed-limits.cfm.

Improving Driver Awareness

Alerts to Other Road Users or Hazards

Warn drivers of other road users (e.g., pedestrians) or hazards using flashing beacons, lane control signs, dynamic message signs, in-vehicle notifications, or personal devices. These tools can also be used to relay important safety information to travelers, such as notifications of slow-downs, queues, wrong-way driving, or a crash ahead. They can also warn drivers of crossing pedestrians or an upcoming red traffic signal. The rectangular rapid flashing beacon and pedestrian hybrid beacon are FHWA Proven Safety Countermeasures. More information is available at: http://www.cmfclearinghouse.org/index.cfm.

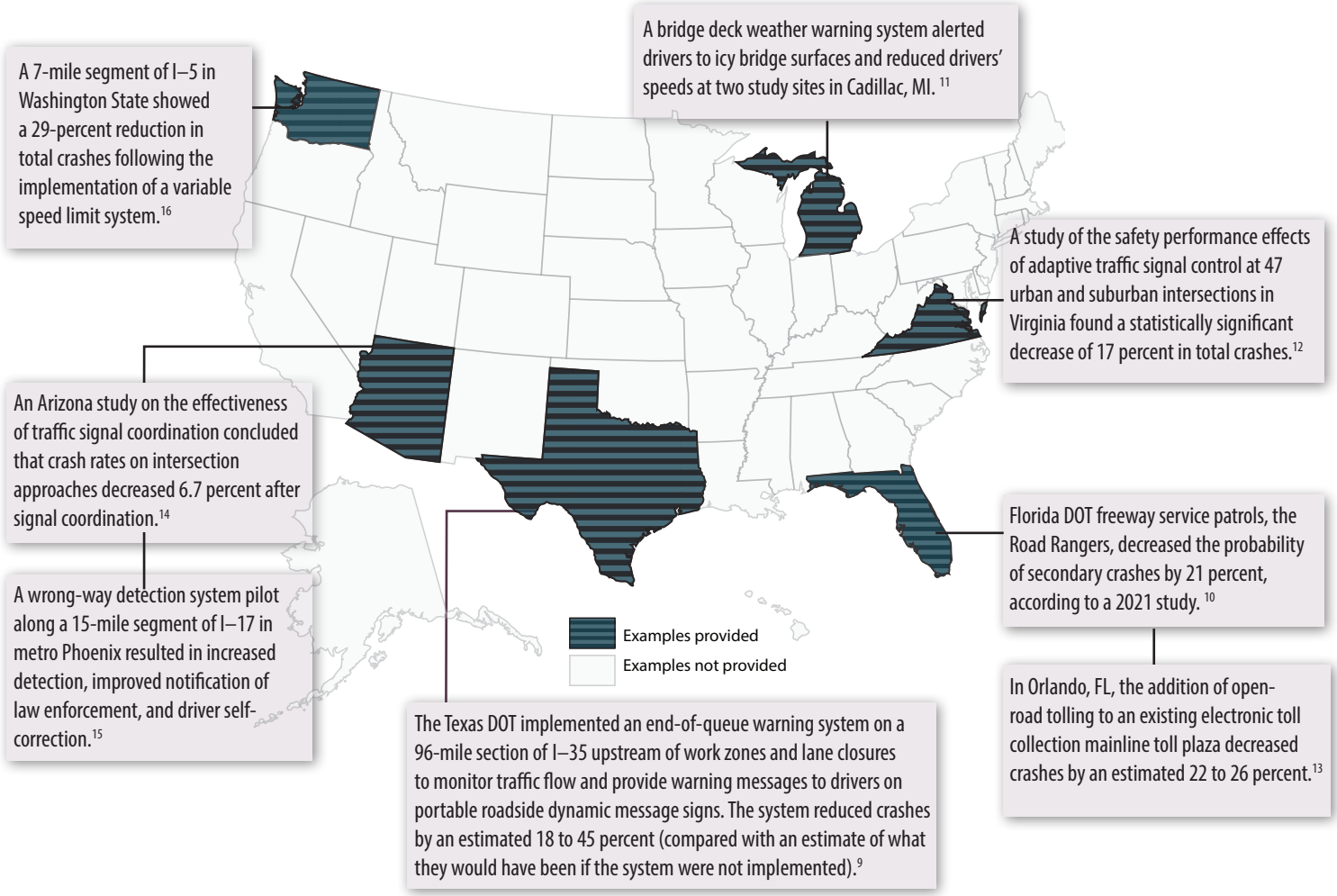
Source: Federal Highway Administration.

Truck Parking Management Systems

Monitor and distribute real-time parking availability information to truck operators and dispatchers to help commercial vehicle drivers plan for and take necessary rest periods. The systems reduce delays for truck drivers in searching for parking and have the potential to reduce fatigue-related truck incidents and road hazards created when trucks park on shoulders and ramps. More information is available at: https://ops.fhwa.dot.gov/freight/infrastructure/truck_parking/index.htm.

Source: Federal Highway Administration.

EXAMPLES OF IMPLEMENTED OPERATIONS STRATEGIES WITH SAFETY BENEFITS



10 American Road and Transportation Builders Association Work Zone Safety Consortium. 2015. *Innovative End of Queue Warning System Reduces Crashes Up to 45%*. https://workzonesafety-media.s3.amazonaws.com/workzonesafety/files/documents/training/courses_programs/rsa_program/RSP_Guidance_Documents_Download/RSP_EndOfQueueWarning_Guidance_Download.pdf, last accessed January 31, 2023.

11 Salum, J. H., A. E. Kitali, T. Sando, and P. Alluri. 2021. "Evaluating the Impact of Road Rangers in Preventing Secondary Crashes." Accident Analysis & Prevention 156: 106129. https://www.sciencedirect.com/science/article/pii/S0001457521001603, last accessed January 31, 2023.

12 Savolainen, P. T., T. Gates, M. Megat-Johari, and S. Mahmud. 2022. *The Interrelationships Between Speed Limits, Geometry, and Driver Behavior: Phase 3 – Implementation of the SHRP 2 Naturalistic Driving Study Results*. Final Report.

13 Ma, J., M. D. Fontaine, F. Zhou, D. K. Hale, and M. O. Clements. 2014. *Estimation of the Safety Effects of an Adaptive Traffic Signal Control System*. Presented at the 94th Annual Meeting of the Transportation Research Board (TRB). Washington, DC: TRB.

14 Klodzinski, J., E. Gordin, and H. M. Al-Deek. 2007. *Evaluation of Impacts from Deployment of an Open Road Tolling Concept for a Mainline Toll Plaza*. Presented at the 86th Annual Meeting of the TRB. Washington, DC: TRB. https://www.itskrs.its.dot.gov/its/benecost.nsf/ID/9bb081857096423e852573e5006bb90b, last accessed January 27, 2023.

15 FHWA. 2015. Intersection Safety Strategies. Publication No. FHWA-SA-15-085. Washington, DC: FHWA. https://safety.fhwa.dot.gov/intersection/stop/fhwasa15085.pdf, last accessed January 27, 2023.

16 U.S. DOT ITS JPO. 2022. Interstate 17 Wrong Way Vehicle Detection Pilot Program. https://www.itskrs.its.dot.gov/node/209838, last accessed January 27, 2023.

17 Pu, Z., Z. Li, W. Zhu, Z. Cui, and Y. Wang. 2017. *Evaluating Safety Effects of Variable Speed Limit System Using Empirical Bayesian Before-After Analysis*. Presented at the 96th Annual Meeting of the TRB. Washington, DC: TRB. https://trid.trb.org/View/1439331, last accessed January 27, 2023.

OPPORTUNITIES TO BETTER QUANTIFY THE SAFETY IMPACTS OF OPERATIONS STRATEGIES

The ability for agencies to quantify the effects of many operations strategies on the number and severity of traffic crashes is limited when compared with similar abilities for operational performance measures, but transportation agencies and researchers are making progress toward closing that gap.

Some of the challenges of using traditional safety analysis methods to quantitatively evaluate operations strategies include:[18]

- Operations strategies may be active only during certain times of day based on conditions, and operational characteristics vary in realtime as a function of traffic and weather conditions. Most existing safety analysis methods are based on an analysis of annual crash data.
- Specific types and combinations of road designs and operations strategies may be rare. Most existing safety analysis methods are based on statistical analysis of crash data and may require an adequate number of locations and time with the strategies of interest to obtain statistically significant results.
- Some operations strategies influence traveler behavior throughout a corridor, an area, a region, or across a transportation system—including trip timing, mode choice, route choice, or destination. Most existing safety analysis methods do not incorporate these cumulative, dispersed effects nor behavior changes and the potential safety performance effects.

FHWA began addressing the gap by conducting a safety analysis needs assessment for transportation systems management and operations (TSMO) in 2019.[19] The resulting publication identifies safety analysis methods that better evaluate operations strategies. FHWA also developed approaches for assessing the safety performance of safety service patrols and traffic signal coordination. FHWA expanded the Crash Modification Factors (CMF) Clearinghouse to TSMO as well. Researchers in Florida developed CMFs for five common operations strategies for Florida DOT,[20] and Ohio DOT integrated estimated safety benefits into its TSMO Countermeasures Benefit-Cost Summary Table.[21]

NON-BINDING CONTENTS

18 FHWA. 2019. *Safety Analysis Needs Assessment for Transportation Systems Management and Operations*. Report No. FHWA-SA-19-041. Washington, DC: FHWA. https://safety.fhwa.dot.gov/rsdp/downloads/fhwssa19041.pdf, last accessed January 27, 2023.

19 Ibid.

20 Alluri, P., T. Sando, C. Kadeha, H. Haule, J. Salum, M. S. Ali, J. Kodi, and A. Kitali. 2020. *Developing Florida-Specific Mobility Enhancement Factors (MEFs) and Crash Modification Factors (CMFs) for TSM&O Strategies*. Tallahassee, FL: Florida DOT. https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/research/reports/fdot-bdv29-977-46-rpt.pdf, last accessed Dec. 22, 2022.

21 Ohio DOT. n.d. "ODOT TSMO Countermeasures Benefit Cost Tool" (web page). https://www.dot.state.oh.us/Documents/TSMO/ODOT%20TSMO_Countermeasure_Benefit_Cost_Tool.xlsx, last accessed Dec. 22, 2022.

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