COMPENDIUM

Compendium of Wrong-Way-Driving Treatments and Countermeasures

FHWA Publication No.: FHWA-HRT-23-035

FHWA Contact: Carol H. Tan, Ph.D. (ORCID: 0000-0002-0549-9782), HRSO-20, Team Leader, Safety Data and Analysis Team, (202) 493-3315, carol.tan@dot.gov

This document is a compendium for *Developing Crash Modification Factors for Wrong-Way-Driving Countermeasures* (FHWA-HRT-22-115).

INTRODUCTION

Wrong-way-driving (WWD) events have the potential to result in severe crashes, as well as injuries and fatalities. Thus, even though such events are relatively rare, information on potential countermeasures to reduce the occurrence of such events is valuable for road agencies to promote safety on their roadway networks. Multiple past efforts have documented implementation and testing of various strategies and devices to reduce wrong-way (WW) movements.

This document summarizes a selection of treatments that were of greatest interest to State departments of transportation (DOT) staff members and other practitioners who attended the Federal Highway Administration (FHWA) Workshop: Wrong-Way-Driving Safety Improvements (see link in Additional Resources). This compendium provides a brief description of each treatment, along with potential applications and considerations for use, reported effectiveness—including Crash Modification Factors (CMFs) where available, and references to resources for more detailed information on guidance and completed studies.

More details and an extended list of related countermeasures can be found in the resources provided with each countermeasure herein presented.

PAVEMENT MARKING ARROWS

Description

Painted arrows on freeway exit ramps and in through lanes near intersections on divided highways can be used as a countermeasure for WW movements. In locations where crossroad channelization and ramp/intersection geometry make WW movements easy, a WW arrow can be placed in each lane of an exit ramp near the crossroad terminal or in each through lane near the intersection on a divided highway, where it will be clearly visible to a potential WW movement driver.

U.S. Department of Transportation
Federal Highway Administration

Turner-Fairbank Highway Research Center

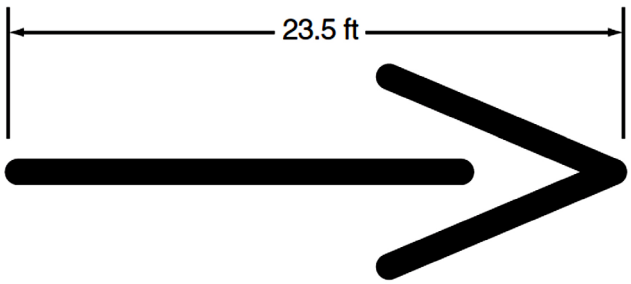
Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

https://highways.dot.gov/research

Key Advantages

- Provide additional feedback to a driver within the primary field of view.
- Are a relatively low-cost treatment that can be provided in combination with other treatments.

Illustration. Wrong-way arrow pavement marking (MUTCD Figure 3B-24.D (FHWA 2012)).



Source: FHWA.

Features

Applications of this treatment have the following features:

- Provide additional feedback to driver within the primary field of view.
- Are a relatively low-cost treatment that can be provided in combination with other treatments.
- Can lead to increased maintenance because painted markings typically have short lifespans.

Effectiveness

Painted arrows have been used extensively on roadways with recognizable results(Finley et al. 2014). Applications on freeway ramps have shown WW or lane-use arrows contribute to reduced WW crashes in both daytime and nighttime conditions (Finley et al. 2018). The presence of WW arrows on divided highways is associated with a reduction in the risk of WW crashes, particularly nighttime WW crashes (Finley et al. 2018).

Safety Benefits/Crash Modification Factors

The following benefits are expected:

- For daytime crashes at freeway ramps: CMF = 0.189 (from Evaluations of Low-Cost Safety Improvements Pooled Fund Study (ELCSI-PFS) Phase XI Evaluation) (Avelar, Kutela, and Finley. 2023).
- For nighttime crashes at freeway ramps: CMF = 0.227 (from ELCSI-PFS Phase XI Evaluation) (Avelar, Kutela, and Finley. 2023).

REFERENCES/LINKS

Avelar, R., B. Kutela, and M. Finley. 2023. *Developing Crash Modification Factors for Wrong-Way-Driving Countermeasures*. Report No. FHWA-HRT-22-115. Washington, DC: Federal Highway Administration.

FHWA. 2012. "Wrong-Way Traffic Control at Interchange Ramps," in *Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 Edition*. Washington, DC: Federal Highway Administration, p 83 (Figure 2B-18) and p. 388 (Figure 3B-24). https://mutcd.fhwa.dot.gov/kno_2009r1r2.htm, last accessed September 20, 2022.

Finley, M. D., R. E. Avelar, S. P. Venglar, G. H. Hawkins, and H. Al-Deek. 2018. *Traffic Control Devices and Measures for Deterring Wrong-Way Movements*. NCHRP Report No. 881. Washington, DC: Transportation Research Board. https://www.trb.org/Publications/Blurbs/178000.aspx, last accessed September 20, 2022.

Finley, M. D., S. P. Venglar, V. Iragayarapu, J. D. Miles, E. S. Park, S. A. Cooner, and S. E. Ranft. 2014. *Assessment of the Effectiveness of Wrong Way Driving Countermeasures and Mitigation Methods*. Report No. FHWA/TX-15/0-6769-1. Austin, TX: Texas Department of Transportation. https://tti.tamu.edu/documents/0-6769-1.pdf, last accessed September 20, 2022.

SUPPLEMENTAL SIGNS

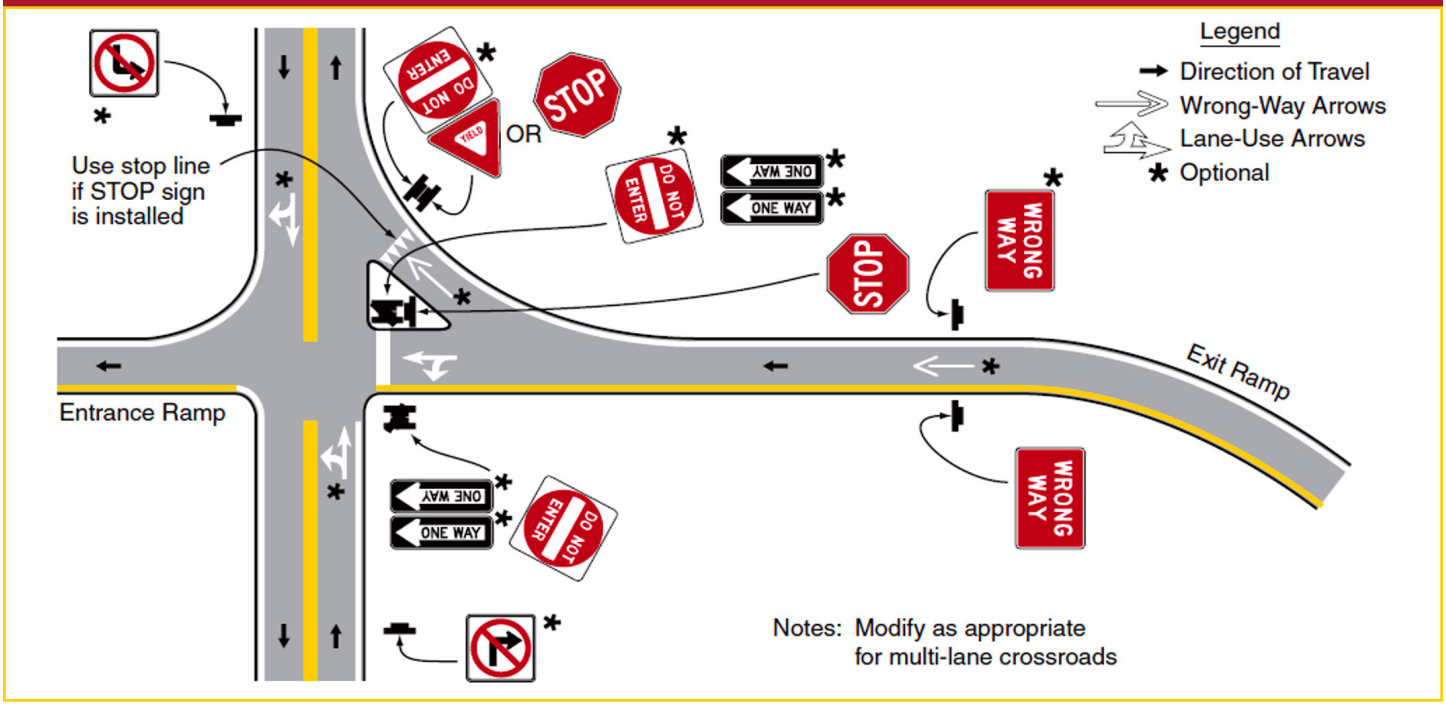
Description

Additional DO NOT ENTER (DNE) and WW signs can be added to reinforce the message to WW drivers. The DNE and WW signs may be enhanced by using a larger sign instead of the standard size sign to increase sign visibility. Placards may also be used to provide additional information to drivers.

Key Advantages

- More noticeable due to more signs and larger size.
- Relatively low-cost treatment and can be combined with other treatments.

Illustration. Example of application of regulatory signing and pavement markings at an exit ramp termination to deter WW entry (MUTCD Figure 2B-18 (FHWA 2012)).



Source: FHWA.

Features

Applications of this treatment have the following features:

- Are more noticeable due to the additional signs and plaques as well as increased visibility from size enhancement.
- Are a relatively low-cost treatment that can be provided in combination with other treatments.
- Have increased costs due to use of larger signs and/or use of more signs than standard design.

Effectiveness

Supplemental signs have been used in many States, with some installations prior to 2010 (Finley et al. 2014). Variations include rotating one or more additional signs or using a different mounting height to provide drivers with a different viewing angle (Finley et al. 2014). Studies indicate use is related to reduced crashes (Finley et al. 2018).

Safety Benefits/Crash Modification Factors

At exit ramps intersecting undivided cross streets (from ELCSI-PFS Phase XI Evaluation) (Avelar, Kutela, and Finley. 2023):

- For daytime crashes: CMF = 0.321 (DNE).
- For nighttime crashes: CMF = 0.640 (DNE) and 0.767 (WW).

REFERENCES/LINKS

Avelar, R., B. Kutela, and M. Finley. 2023. *Developing Crash Modification Factors for Wrong-Way-Driving Countermeasures*. Report No. FHWA-HRT-22-115. Washington, DC: Federal Highway Administration.

FHWA. 2012. "Wrong-Way Traffic Control at Interchange Ramps," in *Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 Edition*. Washington, DC: Federal Highway Administration, p 76 (Figure 2B-41). https://mutcd.fhwa.dot.gov/kno_2009r1r2.htm, last accessed September 20, 2022.

Finley, M. D., R. E. Avelar, S. P. Venglar, G. H. Hawkins, and H. Al-Deek. 2018. *Traffic Control Devices and Measures for Deterring Wrong-Way Movements*. NCHRP Report No. 881. Washington, DC: Transportation Research Board. https://www.trb.org/Publications/Blurbs/178000.aspx, last accessed September 20, 2022.

Finley, M. D., S. P. Venglar, V. Iragayarapu, J. D. Miles, E. S. Park, S. A. Cooner, and S. E. Ranft. 2014. *Assessment of the Effectiveness of Wrong Way Driving Countermeasures and Mitigation Methods*. Report No. FHWA/TX-15/0-6769-1. Austin, TX: Texas Department of Transportation. https://tti.tamu.edu/documents/0-6769-1.pdf, last accessed September 20, 2022.

BLANK-OUT SIGNS

Description

Blank-out WW signs can be added to attract the attention of WW drivers. These signs display the same messages as the standard MUTCD R5-1a sign but are activated only when a WWD event is detected.

Key Advantages

- Active only when event occurs.
- Can be used on ramps and main lanes.

Illustration. WRONG WAY sign (MUTCD Figure 2B-11 R5-1a (FHWA 2012a)).

Source: FHWA.

Features

Applications of this treatment have the following features:

- May be more successful with active signing message than passive signing or lighted passive signing in attracting WW drivers' attention.
- Are appropriate for exit ramps or the main lanes of a highway or freeway.
- Are currently an experimental application.
- Can be expensive to install at multiple locations.
- Have effectiveness that is related to performance of the detector system.

Effectiveness

Active roadway signing may be more successful than passive signing in capturing driver attention in some situations. The treatment requires a system of sensors to detect WW vehicles and activate the signs. Because the treatment is experimental, deployment and testing are limited and studies documenting specific influences on crashes are rare (Finley et al. 2014). However, anecdotal evidence suggests that the activated signs are useful in alerting WW drivers (FHWA 2012b).

Safety Benefits/Crash Modification Factors

The expected benefits include anecdotal reductions in WWD events.

REFERENCES/LINKS

FHWA. 2012a. "Regulatory Signs, Barricades, and Gates," in *Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 Edition*. Washington, DC: Federal Highway Administration, p 75 (Figure 2B-11 R5-1a). https://mutcd.fhwa.dot.gov/kno_2009r1r2.htm, last accessed September 20, 2022.

FHWA. 2012b. "Changeable Message Signs," in *Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 Edition*. Washington, DC: Federal Highway Administration, p 325. https://mutcd.fhwa.dot.gov/kno_2009r1r2.htm, last accessed September 20, 2022.

Finley, M. D., S. P. Venglar, V. Iragayarapu, J. D. Miles, E. S. Park, S. A. Cooner, and S. E. Ranft. 2014. *Assessment of the Effectiveness of Wrong Way Driving Countermeasures and Mitigation Methods*. Report No. FHWA/TX-15/0-6769-1. Austin, TX: Texas Department of Transportation. https://tti.tamu.edu/documents/0-6769-1.pdf, last accessed September 20, 2022.

SIGNS WITH FLASHING ENHANCEMENTS

Description

Standard MUTCD R5-1a WRONG WAY signs can be enhanced with treatments such as flashing beacons or light emitting diode (LED) borders to improve nighttime visibility for WW drivers (FHWA 2012a, 2012b; Finley et al. 2014). The lights are activated only when a WWD event is detected.

Key Advantages

- Improved visibility at night.
- Active only during detected events.

Illustration. WRONG WAY sign (MUTCD Figure 2B-11 R5-1a) with circular rapid flashing beacon and wrong-way-driving detection system.

Features

Applications of this treatment have the following features:

- Are more noticeable at night due to increased visibility from enhancement.
- Are appropriate for exit ramps or the main lanes of a highway or freeway.
- Are currently an experimental application.
- Require a power source, which could be solar.
- Have a detector system whose effectiveness is related to performance of the system.

Effectiveness

Because the flashing treatments are active only when an event is detected, the beacons or LEDs are better able to attract WW drivers' attention, particularly at night. The performance of the treatment relies on sensors to detect WW vehicles and activate the signs. These treatments are experimental and not widely deployed. However, where sufficient data are available, results suggest that the enhancements are useful in alerting WW drivers.

Safety Benefits/Crash Modification Factors

The following benefits are expected:

- Data show a 60-percent reduction in reported events for ramps with LED border signs (California) (Bucko 2020).
- Data show an 88-percent self-correction of WW drivers for ramps with LED border signs (Arizona) (Anderson and Lovell 2022).

REFERENCES/LINKS

Anderson, S., and J. Lovell. 2022. "ADOT's Wrong Way Vehicle Detection Program." Presented at the *FHWA Wrong Way Driving Workshop*. Phoenix, AZ: Arizona Department of Transportation. https://static.tti.tamu.edu/conferences/wwd22/presentations/day1/7-anderson-lovell.pdf, last accessed September 20, 2022.

Bucko, T. R. 2020. *Wrong Way Pilot Projects for Prevention of Wrong Way Collisions on Freeways*. Sacramento, CA: California Department of Transportation, Division of Traffic Operations. https://dot.ca.gov/-/media/dot-media/programs/safety-programs/documents/wrong-way/ww-pilot-projects-for-prevention-of-ww-collisions-on-freeways-a11y.pdf, last accessed August 9, 2022.

FHWA. 2012a. "Regulatory Signs, Barricades, and Gates," in *Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 Edition*. Washington, DC: Federal Highway Administration, p 75 (Figure 2B-11 R5-1a). https://mutcd.fhwa.dot.gov/kno_2009r1r2.htm, last accessed September 20, 2022.

FHWA. 2012b. "Enhanced Conspicuity for Standard Signs," in *Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 Edition*. Washington, DC: Federal Highway Administration, Section 2A.15, p 36. https://mutcd.fhwa.dot.gov/kno_2009r1r2.htm, last accessed September 20, 2022.

Finley, M. D., S. P. Venglar, V. Iragayarapu, J. D. Miles, E. S. Park, S. A. Cooner, and S. E. Ranft. 2014. *Assessment of the Effectiveness of Wrong Way Driving Countermeasures and Mitigation Methods*. Report No. FHWA/TX-15/0-6769-1. Austin, TX: Texas Department of Transportation. https://tti.tamu.edu/documents/0-6769-1.pdf, last accessed September 20, 2022.

GEOMETRIC IMPROVEMENTS

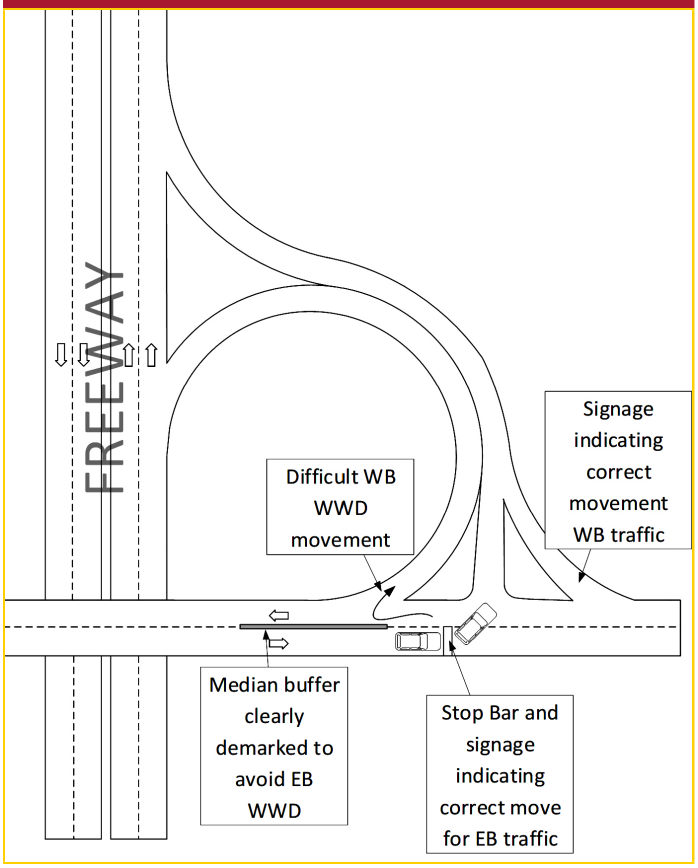
Description

A ramp or crossroad that is difficult to physically enter from the wrong direction will provide an inherent improvement for reducing wrong-way events and crashes. The geometric design of an access point can be tailored to conditions to provide improved separation between opposing directions of traffic, physical restrictions on prohibited turning movements, and more intuitive driving paths for desired movements (AASHTO 2019; National Academy of Sciences 2022).

Key Advantages

- Physical restriction on WW movements.
- Facilitation of correct movements.

Illustration. Example of application of geometric treatments to deter WW movements around exit ramps.



EB = eastbound; WB = westbound.

Features

Applications of this treatment have the following features:

- Provide or increase separation between adjacent entrance and exit ramps (or other pairs of access points).
- Are recommended to be used with raised medians to prevent selected turning movements (Finley et al. 2018).
- Are recommended to be used with painted or raised channelizing islands to guide drivers into desired paths and away from prohibited paths (Finley et al. 2014).
- Decrease radii of potential entry paths to discourage WW turning.
- Can be costly, depending on treatment and available right-of-way.

Effectiveness

Numerous ramp and intersection designs can be found across the country, many of them implemented to meet specific needs of a given intersection or interchange (AASHTO 2019). Anecdotal and formal studies indicate tailoring the geometric design to site conditions has the potential for success in reducing WW events and crashes (Finley et al. 2014, 2018).

Safety Benefits/Crash Modification Factors

The following benefits are expected:

- Remove driveway from frontage: CMF = 0.873 (daytime crashes from ELCSI-PFS Phase XI Evaluation) (Avelar, Kutela, and Finley. 2023).
- Add 100 ft to exit ramp: CMF = 0.972 (nighttime crashes from ELCSI-PFS Phase XI Evaluation) (Avelar, Kutela, and Finley. 2023).

REFERENCES/LINKS

American Association of State Highway and Transportation Officials (AASHTO). 2019. *A Policy on Geometric Design of Highways and Streets*. Washington, DC: AASHTO. (Also known as the *Green Book*.)

Avelar, R., B. Kutela, and M. Finley. 2023. *Developing Crash Modification Factors for Wrong-Way-Driving Countermeasures*. Report No. FHWA-HRT-22-115. Washington, DC: Federal Highway Administration.

Finley, M. D., R. E. Avelar, S. P. Venglar, G. H. Hawkins, and H. Al-Deek. 2018. *Traffic Control Devices and Measures for Deterring Wrong-Way Movements*. NCHRP Report 881. Washington, DC: Transportation Research Board. https://www.trb.org/Publications/Blurbs/178000.aspx, last accessed September 20, 2022.

Finley, M. D., S. P. Venglar, V. Iragayarapu, J. D. Miles, E. S. Park, S. A. Cooner, and S. E. Ranft. 2014. *Assessment of the Effectiveness of Wrong Way Driving Countermeasures and Mitigation Methods*. Report No. FHWA/TX-15/0-6769-1. Austin, TX: Texas Department of Transportation. https://tti.tamu.edu/documents/0-6769-1.pdf, last accessed September 20, 2022.

National Academy of Sciences. 2022. "NCHRP Project 3-135: Wrong-Way Driving Solutions, Policy, and Guidance" (web page). Washington, DC: Transportation Research Board. https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4548, last accessed August 10, 2022.

DETECTOR SYSTEMS

Description

A detector system forms the backbone of an active treatment strategy that involves more than static signs and pavement markings. Even though such a system can be costly, many potential uses exist for a system that accurately detects and sends notifications of WWD events.

Features

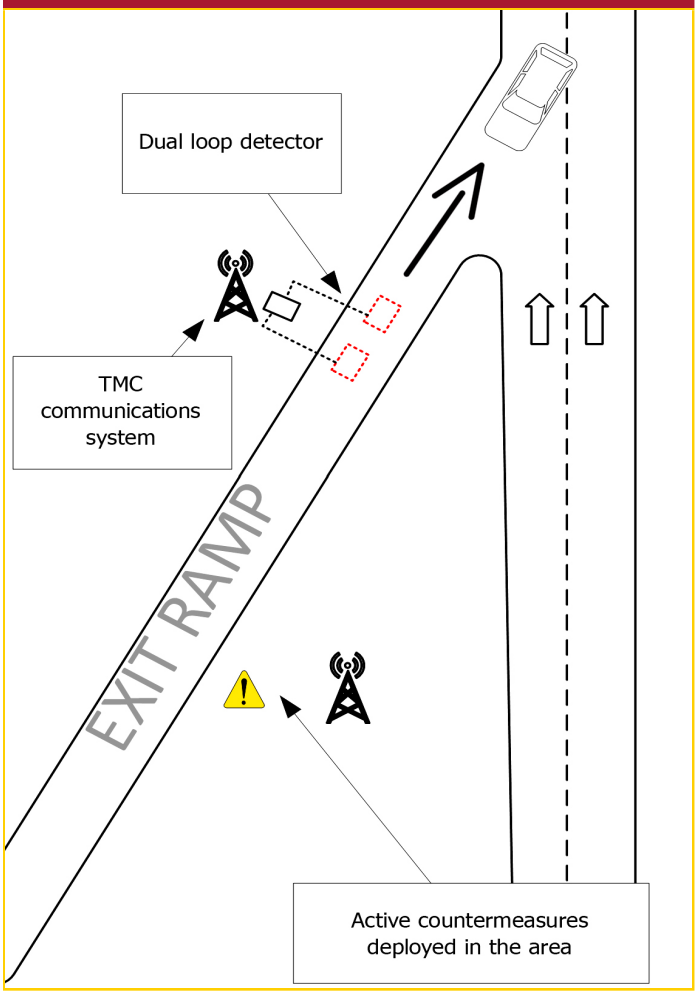
Applications of this treatment have the following features:

- Provide the necessary component for activating a treatment for a WW driver and for sending alerts to law enforcement and transportation agencies.
- Are a potential source of data to study and document WWD events and effectiveness of countermeasures (Golias, Mishra, and Ngo 2021).
- Have the possibility of providing notifications through new technologies such as in-vehicle alerts for connected and automated vehicles.
- Require purchasing detectors and supporting hardware, which provides power and connects the system to desired treatments and agencies.
- Require constant maintenance to retain performance.

Key Advantages

- Necessary component for driver and agency alerts.
- Potential for expanded use with new technologies.

Illustration. Example of application of a WW detector system installation on a freeway exit ramp that intersects a one-way frontage road.



EB = eastbound; WB = westbound.

Effectiveness

A detector system with the appropriate hardware and functioning communication supplies the information necessary for active treatments to perform their intended functions (Finley et al. 2014). A variety of systems are available. An agency using such a system must define its intended use and develop specifications for procurement, in addition to maintaining that system in the long term (Simpson 2013).

Safety Benefits/Crash Modification Factors

The following benefits are expected:

- Serves as the starting point for a response system to activate treatments.
- Notifies law enforcement (Simpson 2013).
- Provides alerts to drivers.

REFERENCES/LINKS

Finley, M. D., S. P. Venglar, V. Iragayarapu, J. D. Miles, E. S. Park, S. A. Cooner, and S. E. Ranft. 2014. *Assessment of the Effectiveness of Wrong Way Driving Countermeasures and Mitigation Methods*. Report No. FHWA/TX-15/0-6769-1. Austin, TX: Texas Department of Transportation. https://tti.tamu.edu/documents/0-6769-1.pdf, last accessed September 20, 2022.

Golias, M., S. Mishra, and H. Ngo. 2021. *Investigation on Wrong Way Prevention Technologies and Systems*. Report No. RES2020-02. Nashville, TN: Tennessee Department of Transportation. https://www.tn.gov/content/dam/tn/tdot/long-range-planning/research/final-reports/res2020-final-reports/RES2020_02_Final_Report_Approved.pdf, last accessed September 20, 2022.

Simpson, S. A. 2013. *Wrong-way Vehicle Detection: Proof of Concept*. Report No. FHWA-AZ-13-697. Phoenix, AZ: Arizona Department of Transportation. https://rosap.ntl.bts.gov/view/dot/25869, last accessed September 20, 2022.

ADDITIONAL RESOURCES

A number of resources were provided with the descriptions of the countermeasures listed in this document. A more complete list of resources, including those found in this document, can be found in those shared through presentations and links provided by speakers and attendees at the Federal Highway Administration Workshop: Wrong-Way Driving Safety Improvements held March 9–10, 2022.

The program, presentations, and resources from the Federal Highway Administration Workshop: Wrong-Way Driving Safety Improvements can be found here: https://events.tti.tamu.edu/conference/the-federal-highway-administration-workshop-wrong-way-driving-safety-improvements/program/.

The presentations and resources provided on the workshop website are included as they were shared during the workshop and are provided as additional information. Questions about these resources should be directed to the author, agency, or company that produced them.

Researchers—This study was performed under contract number DTFH6116D00039L by Raul Avelar (principal investigator) and researchers Boniphace Kutela and Melisa Finley of the Texas A&M Transportation Institute.

Distribution—This Compendium is being distributed according to a standard distribution. Direct distribution is being made to the FHWA divisions and Resource Center.

Availability—This Compendium may be obtained at https://highways.dot.gov/research.

Key Words—Crash modification factor, CMF, wrong-way driving, safety.

FEBRUARY 2024

Recommended citation: Federal Highway Administration, *Compendium of Wrong-Way-Driving Treatments and Countermeasures* (Washington, DC: 2024) https://doi.org/10.21949/1521979

FHWA-HRT-23-035
HRSO-20/02-24(WEB)E