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Serious drought.
Help save water!

July 27, 2016

The Honorable Jim Beall
Chair, Senate Transportation and Housing Committee
California State Senate
State Capitol, Room 2209
Sacramento, CA 95814

Dear Senator Beall:

I am pleased to transmit the California Department of Transportation's (Caltrans') final report on "Prevention and Detection of Wrong-Way Collisions on Freeways." Caltrans has prepared the report in accordance with Vehicle Code section 21651.1.

Distribution to the California State Legislature has been made pursuant to Government Code section 9795. This report can be found at <http://www.dot.ca.gov/reports-legislature.htm>.

Sincerely,

MALCOLM DOUGHERTY
Director

Enclosure

Distribution:

The Honorable Jim Beall, Chair, Senate Transportation and Housing Committee ✓
The Honorable Jim Frazier, Chair, Assembly Transportation Committee
Diane Boyer-Vine, Legislative Counsel
Daniel Alvarez, Secretary of the Senate
E. Dotson Wilson, Chief Clerk of the Assembly

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July 27, 2016

The Honorable Jim Frazier
Chair, Assembly Transportation Committee
California State Assembly
1020 N Street, Room 112
Sacramento, CA 95814

Dear Assembly Member Frazier:

I am pleased to transmit the California Department of Transportation's (Caltrans') final report on "Prevention and Detection of Wrong-Way Collisions on Freeways." Caltrans has prepared the report in accordance with Vehicle Code section 21651.1.

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July 27, 2016

Ms. Diane Boyer-Vine
Legislative Counsel
State Capitol, Room 3021
Sacramento, CA 95814

Dear Ms. Boyer-Vine:

I am pleased to transmit the California Department of Transportation's (Caltrans') final report on "Prevention and Detection of Wrong-Way Collisions on Freeways." Caltrans has prepared the report in accordance with Vehicle Code section 21651.1.

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July 27, 2016

Mr. Daniel Alvarez
Secretary of the Senate
State Capitol, Room 3044
Sacramento, CA 95814

Dear Mr. Alvarez:

I am pleased to transmit the California Department of Transportation's (Caltrans') final report on "Prevention and Detection of Wrong-Way Collisions on Freeways." Caltrans has prepared the report in accordance with Vehicle Code section 21651.1.

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July 27, 2016

Mr. E. Dotson Wilson
Chief Clerk of the Assembly
State Capitol, Room 3196
Sacramento, CA 95814

Dear Mr. Wilson:

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Diane Boyer-Vine, Legislative Counsel
Daniel Alvarez, Secretary of the Senate
E. Dotson Wilson, Chief Clerk of the Assembly ✓

Prevention and Detection of Wrong-Way Collisions on Freeways

Caltrans

Final Report to the Legislature

Prepared in Compliance with California Vehicle Code Section 21651.1

July 1, 2016

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Table of Contents

Executive Summary

As required by California Vehicle Code section 21651.1, the California Department of Transportation (Caltrans), in consultation with the California Highway Patrol (CHP), has prepared this final report to the Legislature as an update to the June 1989 report "Prevention of Wrong-Way Accidents on Freeways". The preliminary report was submitted in early December 2015.

The rate of fatal wrong-way collisions on California freeways and expressways has decreased from nearly 0.4 fatal wrong-way collisions per billion vehicles miles traveled as reported in 1989 to approximately 0.13 in 2013. The data shows a downward trend in the rate of fatal wrong-way collisions per billion vehicle miles per year between 1995 and 2013.

Between 1995 and 2013, an annual average of 23 fatal collisions have been due to wrong-way driving, whereas the 1989 report stated that about 35 wrong-way fatal collisions occurred annually between 1961 and 1987. Between 1989 and 2013, vehicle miles traveled on California freeways and expressways increased by 26 percent.

The number of fatal wrong-way collisions reported in the first half of 2015 showed an unusual concentration in Caltrans Districts 3 (Marysville) and 11 (San Diego). In eight out of the nine fatal wrong-way collisions reviewed on Sacramento and San Diego area freeways in the first half of 2015, driving under the influence was a contributing factor. The primary cause of wrong-way collisions, especially those which are fatal, remains to be drivers who are under the influence of drugs or alcohol. The 2009 to 2013 Traffic Accident Surveillance and Analysis System (TASAS) data on fatal wrong-way collisions indicates that 69 percent of the wrong-way had been under the influence of drugs or alcohol. It should be noted that the total number of wrong-way collisions discussed in this report for 2015 and 2016 are from an incomplete data set. This collision data is preliminary as it is from the CHP computer aided dispatch (CAD) log system collected by both CHP and Caltrans staff, and not through Caltrans' TASAS. The TASAS database provides the most complete and accurate collision data on State facilities as the data is sourced directly from final CHP Traffic Collision Reports (TCR). Year 2013 TASAS data is the latest complete annual TASAS data set available.

Implemented in 1985, Caltrans' Wrong-Way Monitoring Program has succeeded in reducing the number of wrong-way collisions on state facilities. An annual "Wrong-Way Monitoring Program Report," including a checklist for wrong-way entry review, is prepared to identify and investigate locations that may warrant corrective action. District traffic safety engineers investigate and provide recommendations for safety improvements using engineering judgment. The checklist has been updated over the years with the latest version referencing the 2014 California Manual on Uniform Traffic Control Devices (CA MUTCD). Further updates to the checklist are anticipated upon the evaluation of the pilot projects and the completion of the on-going research by the Advanced Highway Maintenance and Construction Technology Research Center (AHMCT) at the University of California, Davis.

The CHP has been focused on combatting the wrong-way driving problem by education and enforcement. The CHP dispatch centers handle 911 telephone calls and quickly dispatch calls regarding wrong-way drivers to the CHP and allied agencies with updates as they are received from callers, primarily through cellular phones. Many CHP dispatch centers are part of a collaborative Traffic Management Center (TMC) shared with Caltrans which include real-time video screens for traffic monitoring. Cellular phones and closed circuit television (CCTV) cameras are two technologies widely used today, which were not available in 1989, that have contributed to an increase in the reporting of wrong-way drivers, and the ability to locate and track them on the state highway system.

Caltrans and the CHP began a wrong-way driver working group in May 2015 to discuss potential options/methods to combat wrong-way drivers. Evidence shows wrong-way traffic collisions are not specific to any location or off-ramp, therefore, the working group proposed pilot projects in Districts 3 and 11. The locations are on routes I-80, US-50, and I-5 in and near Sacramento and on routes SR-15, I-15, I-5, and I-8 in San Diego County. A number of off-ramp locations in the pilot projects have already been constructed with the remaining locations expected to be operational in late 2016. The pilot projects install additional two-way, red/clear retroreflective pavement markers, revised signage, and active monitoring systems to reduce the potential for wrong-way drivers from entering the highway system. The active monitoring systems utilize dual radars to detect the wrong-way drivers and activate red flashing lights bordering the wrong-way signs. Caltrans and the CHP will be notified in real-time of the wrong-way drivers through photos and alerts sent to joint Traffic Management Centers (TMC). Further information on the pilot projects can be found in Appendix E. A separate, auxiliary research project is being conducted by AHMCT with oversight and direction provided by Caltrans' Division of Research, Innovation and System Information (DRISI) to study the effectiveness of the pilot project enhancements with before-and-after studies. AHMCT will deliver a final report to Caltrans by December 31, 2017.

Traffic engineers from several states were surveyed to review current practices with the potential to reduce the number of instances of wrong-way driving on state highways. Since the 1989 report, Caltrans has completed its evaluation of the red, airport-type pavement lights as recommended, and has ceased using them due to significant reliability and maintenance issues. Site visits to Texas and Florida departments of transportation provided Caltrans first-hand information on their on-going wrong-way driving pilot projects. All three state departments of transportation are committed to working together, and with others, to reduce the number and severity of wrong-way collisions.

Caltrans and the CHP will continue to gather data, information from other states and nongovernmental agencies, and findings from pilot and research projects. California pledges support for the Federal Highway Administration's (FHWA) “Toward Zero Deaths” initiative and will strive to reduce the number of wrong-way driving incidents

Background

Requirements of California Vehicle Code Section 21651.1

> 21651.1. (a) The Department of Transportation, in consultation with the Department of the California Highway Patrol, shall update the June 1989 report entitled "Prevention of Wrong-Way Accidents" prepared by the Department of Transportation pursuant to Chapter 153 of the Statutes of 1987. The update shall account for technological advancements and innovation since publication of the 1989 report and shall include a review of methods studied or implemented by other jurisdictions, including state or local agencies within or outside the state, and methods studied by nongovernmental entities to prevent wrong-way drivers from entering state highways. A preliminary version of the updated report shall be provided to the Senate Committee on Housing and Transportation and the Assembly Committee on Transportation on or before December 1, 2015, and the final report shall be provided to those committees on or before July 1, 2016. The report shall identify any additional treatments and technologies with the potential to reduce the number of instances of wrong-way driving on state highways and shall include a plan to incorporate those treatments and technologies into the Department of Transportation's wrong-way monitoring and mitigation program for the state highway system.
>
> (b) This section is repealed on January 1, 2021, pursuant to Section 10231.5 of the Government Code.

Appendix A contains the complete text of Assembly Bill 162 which added Section 21651.1 to the Vehicle Code.

Recommendations and updates from Caltrans' June 1989 report *Prevention of Wrong-Way Accidents on Freeways*

These following nine action items were recommended in the 1989 report to further reduce wrong-way collisions. Each item is followed by an update from Caltrans:

1. Continue the annual monitoring of wrong-way accidents. An annual review is made in the field of off-ramps, which have been identified as entry points or are near concentrations of wrong-way accidents. This practice should be continued. The Checklist for Wrong-Way Entry Review, developed as part of this project, should be helpful.

   Update: Caltrans currently has a Wrong-Way Collision Monitoring Program Annual Monitoring Report and Checklist that has Table A (summary of Table B) and Table B (most recent five years of data). Both tables identify locations and ramps of wrong-way collisions on freeways and expressways throughout California. Appendix B contains the current Caltrans Wrong-Way Monitoring Checklist. This checklist will be updated upon completion of the ongoing research led by Caltrans' Division of Research, Innovation and System Information (DRISI).

2. Conduct periodic reviews of every ramp. The systematic periodic review of the ramps for missing or worn signs or pavement arrows, and a variety of changed conditions is very important. The review which began late last year, should be expeditiously completed. Future reviews should be scheduled on about a three to five year cycle.

   Update: Annually, locations and ramps that meet minimum criteria in the wrong-way monitoring program report are sent to the districts for review, investigation, and response. In the course of their daily field assignments, traffic operations and maintenance staff routinely review, report, and schedule work to ensure the system is kept in good condition.

3. Purchase new still camera, video, or movie camera, and detector equipment. The further systematic photographing of wrong-way vehicle entries at each ramp is not needed. However, each district should have access to reliable equipment for those cases where photographs or videotapes would be helpful. This equipment should be purchased by Headquarters Traffic Operations.

   Update: Caltrans' DRISI has the equipment and ability to monitor and detect wrong-way movement at specific ramp locations identified by the districts.

4. Continue the pavement light experiment in San Diego. Definitive data on the effectiveness of the pavement lights to prevent vehicles from entering the freeway in the wrong direction is still needed. New movie or video cameras are needed to obtain statistically significant data.

   Update: Since the 1989 report, Caltrans has completed its evaluation of the red airport-type pavement lights as recommended, and has ceased using them due to significant reliability and maintenance issues. In the spring of 2016, the Florida Department of Transportation (FDOT) installed red in-pavement illuminated, solar-powered, light-emitting diode (LED) pavement lights under a pilot project. The lights are set to flash under low ambient light conditions, typically from dusk to dawn. FDOT's pilot project evaluation will be forthcoming. Caltrans will review and discuss the pilot project findings with FDOT.

5. Conduct a training effort for designers. Ramp and intersection design can have a significant effect on wrong-way entries. Training classes or instructional materials should be developed for designers, especially the new ones.

   Update: Current training material for the Traffic Safety Academy includes discussions on wrong-way sign packages and markings as part of the Signs & Marking presentation. Designers are kept well-informed of updates made to the Highway Design Manual (HDM) and CA MUTCD. Several slides of the presentation stress the importance of proper signage at off-ramps, go over wrong-way regulatory signs and their placement, and consequences of wrong-way collisions. Future training development for the CA MUTCD will include a focus on wrong-way traffic control devices.

6. Consider edge lines or heavy bars across off-ramps. The only technique identified which has not been previously tried or considered in California is to carry edge lines or wide painted bars across the off-ramps. This technique should be further investigated.

   Update: The use of edge lines is important in guiding motorists and identifying intersections, and are typically dropped at intersecting roadways or major driveways. The CA MUTCD permits the use of edge line extensions through intersections in the form of a dashed line when additional guidance is necessary, as in foggy conditions. In cases where even more additional emphasis is desired, solid lines may be used. Caltrans investigated wide painted bars, and unlike edge lines, placing solid lines across the off-ramp may be construed as a limit line leading to unnecessary stops by motorists traveling in the correct direction on the off-ramp. This may cause an increase in the number of rear-end collisions, since a stop is not expected without the proper traffic control device in place, such as a stop sign or signal. Caltrans' current pilot projects will evaluate the placement of two-way, retroreflective, raised markers on the off-ramp edge lines to warn wrong-way drivers. A number of the off-ramp locations in the pilot projects have already been constructed with the remaining locations expected to be operational in late 2016.

7. Consider the option of using a second set of Wrong-Way and Do Not Enter signs, and wrong-way arrows further along the off-ramp. The option of using additional signs and markings on selected ramps may give drivers a second chance to realize that they are headed the wrong way before they enter the freeway.

   Update: CA MUTCD Section 2B.41 permits the use of additional WRONG WAY signs and pavement arrows where a ramp intersects a crossroad in such a manner that a wrong-way entry could inadvertently be made. Caltrans has employed using two sets of WRONG WAY and DO NOT ENTER signs on each side of exit ramps as a countermeasure to further reduce wrong-way collisions.

8. Contact the California Highway Patrol (CHP) regarding the wrong-way driver problem. The CHP has been very helpful in the past. They should be contacted again to stress our continued interest in identifying problem ramps.

Update: Since wrong-way collision times and locations are impossible to predict, the CHP has been focused on combating the problem by education and enforcement. The approach is to target those individuals most likely to become wrong-way drivers (impaired, elderly, and drowsy/sleepy). CHP Communication Centers and Caltrans Transportation Management Centers are joint facilities where staff from both departments communicate on a regular basis. The CHP reports theft and vandalism of wrong-way sign packages.

9. Review the Traffic and Design Manuals. Although not specifically discussed in this report, both the Traffic and Design Manuals should be reviewed to see that they reflect the latest thinking.

   Update: The CA MUTCD is periodically updated and reflects the most recent recommendations made by the California Traffic Control Device Committee (CTCDC). As new traffic control devices are developed, or the application of existing traffic control devices is changed, the CTCDC gives approval to conduct pilot studies of these devices. If deemed successful, the CTCDC recommends including these devices or their new applications in the CA MUTCD. The CA MUTCD contains guidance for signage and striping to deter wrong-way movements. The Traffic and Highway Design Manual are updated as necessary to ensure they are up to current standards. The latest amendment to the Highway Design Manual regarding the prevention of wrong-way movements occurred on December 30, 2015, with Chapter 500 Traffic Interchanges, Topic 504.3 (3) Location and Design of Ramp Intersections on the Crossroads.

Appendix B contains the complete text of the Highway Design Manual amendment dated December 30, 2015.

Wrong-Way Collisions in California

1987 Versus 2013 Data

Year 2013 data is the most current complete Caltrans Traffic Accident Surveillance and Analysis System (TASAS) data available for analysis. TASAS data is no longer available for years prior to 2005. In 2013, approximately 2.8 percent of all fatal collisions on the State's freeways and expressways were due to wrong-way collisions. By comparison, the 1989 report stated "Wrong-way fatal accidents account for about 4 percent of the fatal accidents on California's freeways." Between 1995 and 2013, an annual average of 23 fatal collisions have been due to wrong-way driving. The primary cause of wrong-way collisions, especially those which are fatal, remains to be drivers who are under the influence of drugs or alcohol. The 1989 report stated that, on average, 35 fatal wrong-way collisions occurred annually between 1961 and 1987, and drivers under the influence of drugs or alcohol were responsible for three of every four wrong way collisions on California freeways. The 2009 to 2013 Traffic Accident Surveillance and Analysis System (TASAS) data on fatal wrong-way collisions indicates that 69 percent of the wrong-way drivers had been under the influence of drugs or alcohol. The number of fatal wrong-way collisions has fluctuated each year between 1995 and 2013 as shown in Figure 1. The trend line, shown as the gray line, steadily decreased approximately 25 percent during this period. Between 1989 and 2013, vehicle miles traveled on freeways and expressways has increased by approximately 26 percent.

Figure 1 – Number of Fatal Wrong-Way Collisions on California Freeways and Expressways from 1995 to 2013

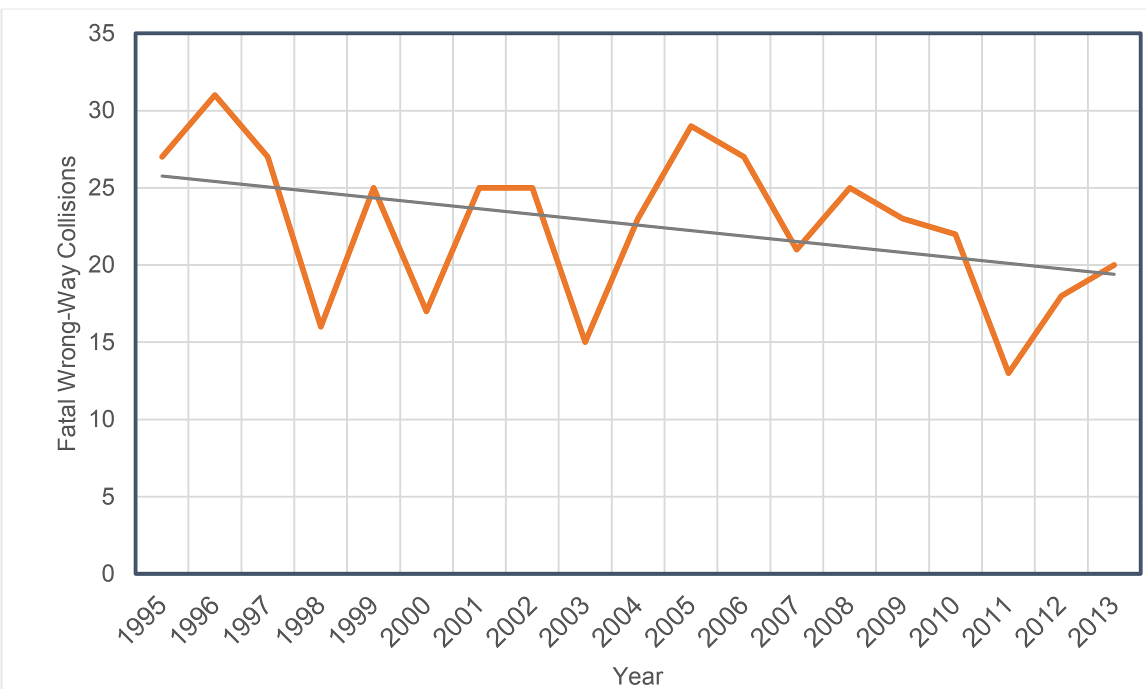
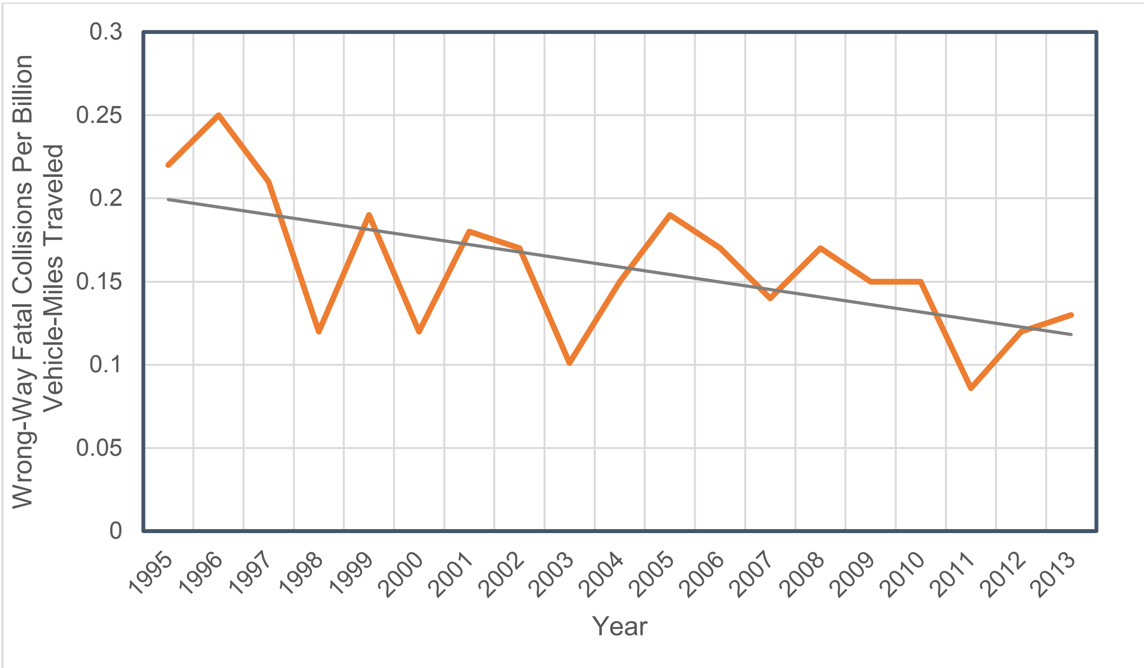
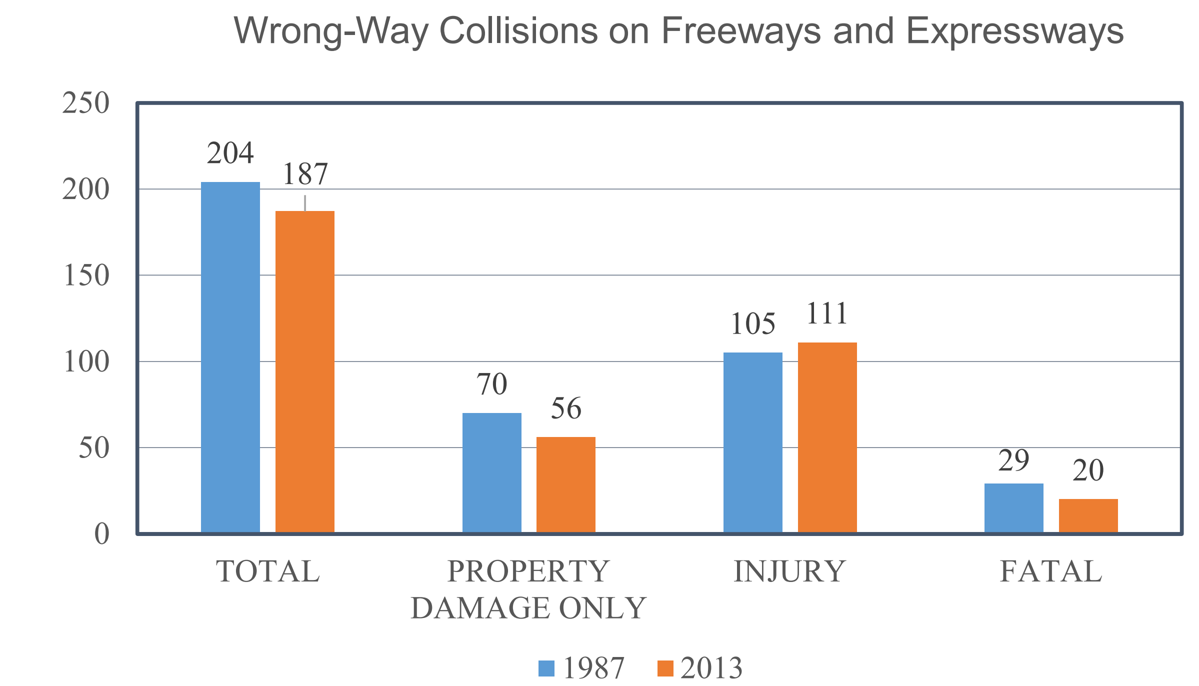


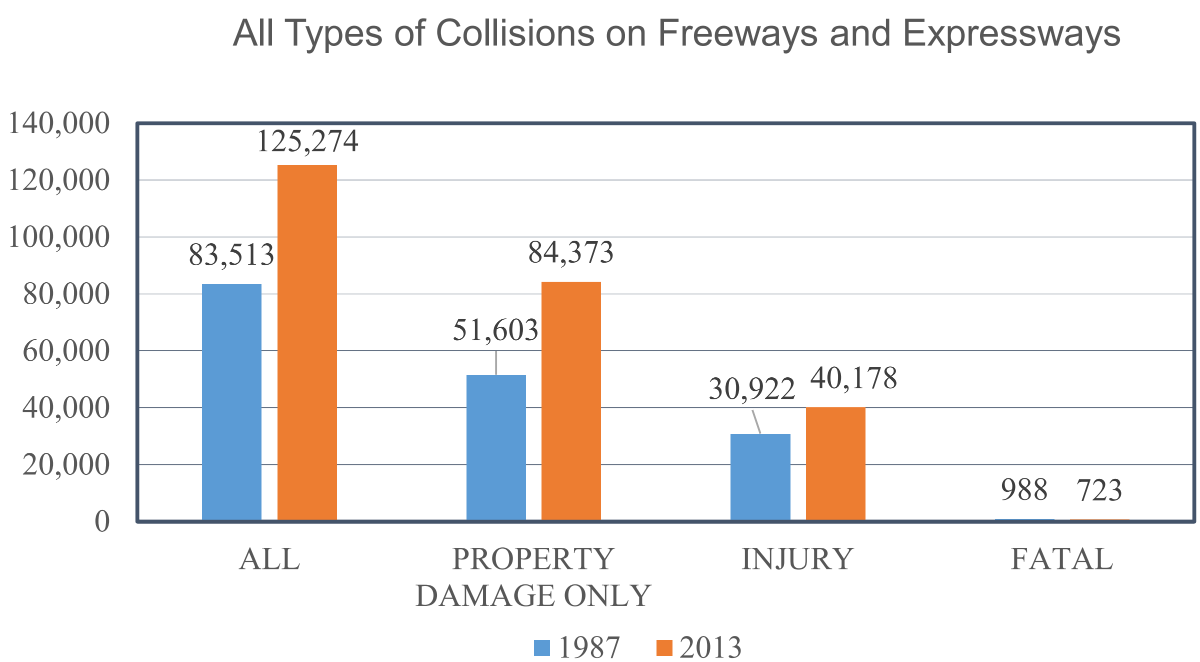
Figure 2 – Fatal Wrong-Way Collisions Rates on California State Freeways and Expressways



The rate of fatal wrong-way collisions on California freeways and expressways has decreased from nearly 0.4 fatal wrong-way collisions per billion vehicles miles traveled as reported in 1989 to approximately 0.13 in 2013. The rate has fluctuated each year between 1995 and 2013 as shown in Figure 2. The trend line, shown as the gray line, has steadily decreased by approximately 40 percent during this period.

Figure 3 - Wrong–Way Collisions Compared to All Collisions on California Freeways in 1987 and 2013





The charts above in Figure 3 show wrong-way collisions as compared to the total number of recorded collisions on California freeways and expressways during 1987 and 2013. About 0.24 percent of the collisions were wrong-way in 1987, whereas this percentage dropped to 0.15 percent in 2013. This represents an approximate decrease of 37.5 percent. In 2013, about 2.8

percent of all fatal collisions were due to wrong-way driving. From 1987 to 2013, that percent has remained approximately the same at 3.2 percent. Wrong-way collisions still remain more severe and more likely to result in injury or death than other types of collisions.

Table 1 below summarizes notable wrong-way collisions that occurred during 2015 in the Sacramento and San Diego regions. The Sacramento and San Diego regions are located within Caltrans' District 3 (Marysville) and District 11 (San Diego), respectively. The data represents a sample of the collision information gathered and used to determine the sites of the pilot projects and the separate auxiliary research locations.

Table 1 – 2015 Wrong-Way Collisions in the Sacramento and San Diego Regions

Dist.	Co.	Rte.	Direction	Lane #	Entry	U-Turn	Approx. Travel Distance (Miles)	Time	Day Date	Cause	# of Veh.	# of Fatal -ities
3	Sac	80	WB in EB lane	1	N/A	Yes	2.2	2:10 am	Sat. 1/10/15	DUI	2	3
3	Sac	50	EB in WB lane	1	WB off-ramp to Harbor Blvd.	No	5	2:30 am	Weds. 4/22/15	DUI	2	4
3	Yolo	505	SB in NB lane	1	Near Co. Road 19	No	2.0	10:20 pm	Sat. 5/02/15	DUI	2	4
3	Sac	80	EB in WB lane	1	EB off-ramp to Watt Ave.	No	1	12:30 am	Tues. 5/12/15	DUI	2	3
3	Sac	50	WB in EB lane	3/4	5th and X St. EB off-ramp	No	> 1	11:50 pm	Sat. 5/17/15	DUI	3	2
11	SD	15	NB in SB lane	2	Deer Springs Road	No	5.3	3:00 am	Sat. 6/20/15	DUI	2	2
11	SD	15	NB in SB express lane	1	-	-	-	3:07 am	Sat. 5/2/15	DUI	2	2
11	SD	15	NB in SB express lane	N/A	Del Lago direct access ramp	no	-	-	Mon. 6/22/15	-	2	0
11	SD	163	SB in NB lane	1	-	-		1:40 am	Sat. 5/16/15	DUI	2	2
11	SD	8	EB in WB lane	1	-	-	-	1:00 am	Thurs. 4/19/15	DUI	2	2

Dash (-) represents unknown

Wrong-way collisions are those collisions that occur on divided expressways and freeways with four lanes or more. At times, collisions that have occurred on two-lane highways due to one vehicle crossing over the center line have been incorrectly classified and reported to be wrong-way collisions. Statistics of wrong-way incidents in District 3 and 11 in 2015-2016 are as follows:

2015

- Within District 3, there were 313 reported wrong-way drivers from January 1, 2015 through December 31, 2015, with 24 resulting in collisions, 11 of which had injuries or fatalities. One hundred eighty-nine wrong-way drivers were located and stopped prior to any collision occurring. One hundred reported wrong-way drivers were either never located, or were not the cause of any known collisions.

- Within District 11, there were 384 reported wrong-way drivers from January 1, 2015 through December 31, 2015, with eight resulting in collisions with injuries or fatalities. Twenty three wrong-way drivers were located and stopped prior to any collision occurring. There were 353 reported wrong-way drivers that were either never located, or were not the cause of any known collisions.

2016

- Within District 3, there were 102 reported wrong-way drivers within District 3 from January 1, 2016 through April 15, 2016, with seven resulting in collisions – one of which had injuries or fatalities. Fifty-six wrong-way drivers were located and stopped prior to any collision occurring. Thirty-nine reported wrong-way drivers were either never located, or were not the cause of any known collision.

- Within District 11, there have been 117 reported wrong-way drivers from January 1, 2016 through April 15, 2016, with four resulting in collisions, two of which had injuries or fatalities. Thirteen wrong-way drivers were located and stopped prior to any collision occurring. One hundred reported wrong-way drivers were either never located, or were not the cause of any known collisions.

It should be noted that the total number of wrong-way collisions discussed in this report for 2015 and 2016 are from an incomplete data set. This collision data is preliminary as it is from the CHP computer aided dispatch (CAD) log system collected by both CHP and Caltrans staff, and not through Caltrans' Traffic Accident Surveillance and Analysis System (TASAS). The TASAS database provides the most complete and accurate collision data on State facilities as the data is sourced directly from final CHP Traffic Collision Reports (TCR). Year 2013 TASAS data is the latest complete annual TASAS data set available.

Wrong-Way Driving Prevention and Detection Technological Advancements, and Innovation

Past Research Discussion

The following discussion was taken directly from the report *Methods to Prevent Wrong-Way Entries Onto Freeway*s that was submitted to the Legislature on January 4, 1989 in response to Senate Bill 233, Chapter 153, Statutes of 1987.

> “The problem of wrong-way driving on freeways has been intensively studied by Caltrans (and its predecessor, the Division of Highways) since 1961, when the CHP reported on 743 incidents of wrong-way driving. With significant portions of new freeways being opened to traffic, immediate solutions were needed.
>
> “By 1964, a wrong-way package of signs and pavement arrows had been developed by the Division of Highways and was being installed on California's freeways. The original package included 24-foot white arrows painted on the pavement and black on white "DO NOT ENTER" signs mounted on the same posts with white on red "WRONG WAY" signs. White on green "FREEWAY ENTRANCE" signs at either side of the on-ramp entrances were also included. The package was later revised with international white on red "DO NOT ENTER" signs when they were found to be more effective. This revised package was adopted as a national standard in 1967.
>
> “During the late 1960's, the Division of Highways installed red-backed retroreflective pavement markers on all lane lines on freeways. These proved to be of limited value. The red-backed retroreflective markers are now used only in the vicinity of off-ramps as a secondary treatment.
>
> “In 1965, the Division of Highways installed parking lot spike barriers to determine if they could be used on off-ramps to physically stop vehicles from entering the wrong way. Unfortunately, these devices were found to be unsuitable for the following reasons: the spikes, even when modified with a fish-hook-like shape, would not cause tires to deflate quickly enough to prevent a vehicle from entering the freeway the wrong way; under high-volume traffic the spikes broke off leaving stubs that damaged the tires of right-way vehicles; and some right-way drivers, upon seeing the spike barriers, would apply their brakes. Also, camera surveillance of off-ramps indicated that most wrong-way drivers quickly realized that they were entering the freeway going the wrong-way, and took corrective action; the spike barriers prevented that corrective action.
>
> “The state of Georgia tested a pop-up device that presented a physical curb-like barrier to the wrong-way driver, but it was unsuitable for reasons similar to those of the spike barriers. A recent poll of all 50 states revealed that none has found a suitable physical barrier to prevent wrong-way drivers from entering off ramps. Most states use a wrong-way package similar to California's.
>
> “California tried adding horns and flashing red lights over the "WRONG WAY" signs in the 1970's, but these were found to be ineffective, and they drew complaints from neighbors.

“In the mid-1970's, wrong-way packages were upgraded and other improvements were made in signing, delineation, lighting, and ramp design at all on-ramps and off-ramps. Automatic cameras were used to record wrong-way entries. The cameras were in place for a minimum of 30 days at each of the 4,000 off-ramps across the State. The camera surveillance indicated that, through various improvements, wrong-way entries were reduced to low levels at 90 percent of the ramps with previous entry problems. These improvements have been incorporated into Caltrans’ current standard procedures.

“One device that was tested did show promise. Red, airport-type pavement lights, embedded in the pavement across an off-ramp, when activated by wrong-way vehicles, were shown by camera monitoring to further reduce wrong-way entries. However, Caltrans has completed its evaluation of the red, airport-type pavement lights as recommended and has ceased using them due to significant maintenance and reliability issues.

“Since 1985, Caltrans has had a program to monitor all wrong-way collisions. Ramps in the vicinity of wrong-way collisions, which can be identified as the entry point of the vehicles involved, are investigated. Field reviews are conducted to make sure that signs and pavement delineation are in good condition, and that there are no conditions which could mislead drivers. Improvements are made as appropriate.

“A 1971 report on wrong-way driving concluded that drunk drivers were responsible for three out of every four wrong-way collisions on California freeways, and that the typical wrong-way driver had received more traffic violations, more felony convictions, and had been involved in considerably more collisions of all types than the average motorist.

“Another common characteristic of wrong-way drivers that complicates the problem is that many drivers make intentional illegal U-turns on freeways. Nearly half of all wrong-way collisions are caused by drivers who have made illegal U-turns.

“The CHP has organized programs to reduce the main cause of wrong-way fatalities–people driving under the influence. The CHP is also aware of the need to report conditions which impair safe and efficient flow of traffic on freeways, such as theft and vandalism of wrong-way sign packages.

“As a part of the effort requested by Senate Bill 233, Chapter 153, Statutes of 1987, Caltrans conducted a special review of seven ramps in Los Angeles and Ventura Counties thought to be susceptible to wrong-way moves. Automatic cameras were installed at each ramp for a minimum of 30 days. The results were as follows:

- No wrong-way moves were detected at five of the ramps.
- At one ramp, one wrong-way vehicle was photographed, but no accident was reported in the area; it is assumed that the driver recognized his error and turned around. The wrong-way sign packages at this location were in place and in good condition.

- Five wrong-way moves were recorded at the remaining location. It is assumed that the drivers realized their mistakes and made corrections since no information was recorded regarding wrong-way drivers on the freeway during the study period. Because city-owned directional signs to a local recreation area may have contributed to driver confusion, the city was asked to take corrective action. Also, Caltrans placed a second set of wrong-way signs closer to the ramp terminus, installed a no-turn sign facing westbound traffic on the city street, and installed a one-way sign on the easterly side of the off-ramp.

"Careful attention to details in the proper positioning and maintenance of signs and pavement arrows, frequent review of ramps, and analysis of collision records are still the most effective steps Caltrans can take to reduce wrong-way entries and thus wrong-way collisions."

Research Plan for Evaluating the Effectiveness of Caltrans' Wrong-Way Driver Pilot Projects

Wrong-way driving is a serious hazard. As noted in Assembly Bill AB 162, wrong-way driving on state highways kills or injures numerous Californians each year, and collisions caused by wrong-way driving on highways are more likely to result in fatal or serious injuries than other types of collisions. Assembly Bill AB 162 is shown in Appendix A. The number of wrong-way collisions in 2015 appear unusually high, particularly in Caltrans' Districts 3 (Marysville) and 11 (San Diego). Most of these wrong-way collisions have been fatal. In 2015, 25 people killed in wrong-way collisions in the Sacramento and San Diego areas. There is a need to assess the magnitude of the wrong-way driving problem in California, and to evaluate the efficacy of enhancements and technologies with the potential to reduce the number of instances of wrong-way driving on state freeways and expressways.

With this in mind, Caltrans and the CHP began a wrong-way driver working group in May 2015, to discuss potential options/methods to combat wrong-way drivers. The CHP provided traffic collision information from recent wrong-way traffic collisions. Since wrong-way traffic collision evidence shows they are not specific to any location or ramp, the working group has proposed pilot projects in Districts 3 and 11 to install enhancements on several off-ramps to warn drivers, and notify authorities, when vehicles enter from the wrong direction. Active monitoring systems capable of identifying wrong-way drivers, transmitting information to a central location, and activating local flashing beacons will be installed in a subset of the off-ramps. Existing white and yellow, one-way retroreflective pavement markers in the lane lines, channelizing lines, and gore areas will be replaced by two-way, white/red (W/R), and yellow/red (Y/R) markers on all off-ramps in the study area. Appendix D provides an example of an enhanced pavement delineation plan sheet for exit ramps.

A separate, auxiliary research project conducted by Caltrans' Division of Research, Innovation and System Information (DRISI) will study the effects of these enhancements. The main objective of this research is to determine:

- The extent of the wrong-way driver problem by counting the instances of vehicles entering the off-ramps in the wrong direction.

- The effectiveness of enhancements by comparing the number and behavior of wrong-way drivers before-and-after installing the enhancements, as well as the number and behavior of wrong-way drivers entering a number of control off-ramps that do not receive enhancements.
- The accuracy of the active wrong-way monitoring and warning systems installed by the districts in a subset of off-ramps.

DRISI has been working with its research contractor, AHMCT, at the University of California at Davis, to develop and install zone-triggered video image processing systems (VIPS) at the subset of district off-ramps scheduled for active wrong-way monitoring and warning system installation. These systems will also be installed at the control off-ramps not receiving enhancements. Zone-triggered video segments will be collected and initially buffered locally for off-peak hour wireless transmission to AHMCT for subsequent off-line (non-real-time) post-processing and analysis. The researchers will then develop statistics to quantify the wrong-way driving problem, the effectiveness of the enhancements, and the accuracy of the active wrong-way monitoring and warning systems. The AHMCT-developed VIPS detectors will be unmarked and inconspicuous; therefore, they should have no effect on driver behavior.

The VIPS developed, installed, and monitored in this research are strictly for before-and-after studies to assess the impact and effectiveness of the off-ramp marking enhancements and the active wrong-way monitoring and warning systems. This research is not intended to perform any real-time wrong-way driving detection, and will not provide alerts to Caltrans, the CHP, or any other entity. Collected video will not be stored in the long term. The researchers currently anticipate the need to retain collected video for approximately one week before the data is extracted and the video is overwritten.

In analyzing the collected video, the researchers will look to determine the number of triggered video collections that are generated each day, which will be an indication of the amount of traffic on the ramp. Within this data set, they will determine the number of wrong-way events as observed during post-processing. This post-processing will be performed manually for at least a portion of the research project, although means for non-real-time automation of post-processing will be considered. The researchers will also look to determine how well the district-installed active wrong-way monitoring and warning systems perform. They will independently validate the performance of these systems by determining false positives (warning of a non-wrong-way event) and false negatives (no warning for an actual wrong-way event). They will also independently verify and quantify true positives (i.e. instances when the detection system issues a warning for an actual wrong-way event). When possible, the researchers will also try to determine the causes for any verified wrong-way events, such as cell phone use, distracted drivers, or visibly identifiable driver impairment.

The following table shows the six locations where Caltrans' District 3 currently plans to install active wrong-way monitoring and warning systems, and where Caltrans' DRISI plans to collocate the AHMCT-developed VIPS. Also shown are the five locations where only the AHMCT-developed VIPS will be installed as a control for the study.

County	Route	PM	Off-Ramp	Direction	Purpose
Yolo	50	2.811	5th Street / South River Road	WB	active
Yolo	50	2.812	Jefferson Blvd.	WB	active
Sacramento	50	L0.398	5th Street	EB	active
Sacramento	50	L1.437	12th & W Streets	WB	active
Sacramento	50	L1.600	16th & W Streets	WB	active
Sacramento	50	L2.396	26th & W Streets	WB	active
Sacramento	51	0.086	30th & T Streets	NB	control
Sacramento	51	0.579	30th & N Streets	NB	control
Sacramento	51	1.066	30th & H Streets	NB	control
Sacramento	51	1.255	29th & J Streets	SB	control
Sacramento	51	1.637	29th & E Streets	SB	control

AHMCT has procured the materials for the VIPS, and the prototype has been tested. They are working with Caltrans' DRISI and District 3 to install the systems on the selected off-ramps. This will enable collection of approximately three months of video data before District 3 installs the reflective marker enhancements and active wrong-way monitoring and warning systems (planned in summer of 2016). Route 51 is signed as Business Loop 80. Caltrans' District 11 is planning to install similar treatments on several of its off-ramps, and AHMCT plans to install VIPS on two of those off-ramps in the spring of 2017 – approximately six months prior to the district's installations at those two ramps.

County	Route	PM	Off-Ramp	Direction	Purpose
San Diego	5	R20.96	Sea World Drive	SB	active
San Diego	8	T0.54	Sunset Cliffs Blvd./Nimitz Blvd.	WB	active

This research project is a two-year study that will provide substantial benefits to Caltrans and the traveling public. It will allow AHMCT and Caltrans to determine the magnitude and causes of the wrong-way problem, and to assess the effectiveness of various mitigation strategies. This will provide the means for Caltrans to make data-driven decisions regarding solutions that will reduce the wrong-way driving problem – thus enhancing the safety of California's freeways and saving lives. The research project will culminate with a final report delivered by AHMCT to Caltrans by December 31, 2017.

Appendix E contains further information on the wrong-way prevention and detection pilot projects.

Current Wrong-Way Driving Countermeasures

California Highway Patrol

Currently, the California Highway Patrol (CHP) performs a multi-faceted approach at combating wrong-way drivers and wrong-way traffic collisions. Since wrong-way collision times and locations are impossible to predict, the CHP has been focused on combating the problem by education and enforcement. Their approach is to target those individuals who are most likely to become wrong-way drivers (impaired, elderly, and drowsy/sleepy). The majority of the recent wrong-way drivers have either been impaired or elderly. Additionally, the CHP provides information and tips to the general public on strategies to use if they see or encounter a wrong-way driver. This information is provided through CHP public information officers (PIOs) through talking points specific to wrong-way drivers.

CHP takes a proactive approach at combating impaired drivers through education and enforcement. The CHP utilizes grant-funded programs such as Every 15 Minutes, Sober Grad, and Designated Driver, to educate the public on the dangers of driving under the influence of alcohol and/or drugs (DUI). These messages are further supported by public outreach via media and commercials. In addition to the education component, the CHP combats impaired driving through concentrated DUI enforcement details and sobriety checkpoints, as well as general patrol duties. The CHP produces talking points for their PIOs regarding DUI, marijuana and drugged driving, sobriety checkpoints, and various DUI programs.

The CHP also conducts educational outreach to elderly drivers through the grant-funded Age Well, Drive Smart program. This program is targeted towards elderly drivers and it discusses the dangers of driving for the elderly, the challenges they face, recognition of diminished abilities, and provides elderly drivers with an opportunity to ask questions of the CHP. The CHP has a method to address elderly drivers who are stopped during an enforcement encounter and need to have their driving privileges re-examined. That process is conducted through the Department of Motor Vehicles and consists of a new examination for the driver to determine their abilities. The CHP produces talking points for their PIOs regarding senior driving and informational pamphlets for senior drivers.

The CHP dispatch centers handle 911 telephone calls and quickly dispatch calls on wrong-way drivers to the CHP field units and allied agencies with updates as they are received from callers. Many CHP dispatch centers are part of a collaborative TMC shared with Caltrans, and include real-time video for traffic monitoring.

California Office of Traffic Safety

The California Office of Traffic Safety (OTS), through the National Highway Traffic Safety Administration (NHTSA), provides grant funding to local agencies to reduce fatalities and injuries on California’s roads. Many wrong-way drivers have been found to be driving under the influence of drugs or alcohol (DUI). OTS funds countermeasures that have been proven to prevent impaired driving. One countermeasure is High Visibility Enforcement (HVE). HVE activities include saturation patrols and sobriety checkpoints. Saturation patrols are a universal traffic safety approach designed to create a deterrence and change unlawful traffic behaviors. The patrols are highly visible and a proactive law enforcement activity targeting a specific traffic safety issue. Sobriety checkpoints combine high visibility and a publicity strategy to promote voluntary compliance with the law. According to the Insurance Institute for Public Safety, routine checkpoints can cut alcohol-related fatal crashes by 20 percent.

In addition to funding many CHP programs, OTS also funds Mothers Against Drunk Driving, Recording Artists, Actors and Athletes Against Drunk Driving, Friday Night Live, and other programs aimed at educating younger drivers. These educational programs teach young drivers to make the right decision before getting behind the wheel.

California Department of Transportation (Caltrans)

Caltrans Wrong-Way Countermeasures and Monitoring Program consists of:

- Following the Federal Highway Safety Improvement Program, Caltrans has made continuous efforts to reduce the number and risk of wrong-way collisions on California's freeways and expressways.
- Caltrans implements the California Manual on Uniform Traffic Control Devices (CA MUTCD).
- Since 1985, Caltrans has implemented the Wrong-Way Monitoring Program (WWMP). Under the WWMP, Caltrans generates an annual report identifying locations where wrong-way collisions have occurred on freeways and expressways. A roadway segment is included if three or more wrong-way collisions occurred within the segment in a five-year period with a collision concentration of 0.50 wrong-way collisions per mile, per year, or greater:
    - The annual report including an investigation checklist is issued to the district traffic safety engineers for investigation. The investigations include reviewing the most recent five-year collision data, checking signs, markings, delineation, and lighting in the area of interchanges to verify their effectiveness and condition.
- Investigations of locations identified in the WWMP have resulted in the following items being installed or actions taken by Caltrans in addition to their standard treatments:
    - R6-1 ONE WAY signs
    - R5 Series (DO NOT ENTER and WRONG WAY) signs
    - Type V (I) Pavement Arrows added
    - R3-18 (NO U TURN/LEFT TURN) signs
    - R3-2 (NO LEFT TURN) signs
    - R1-3 (NO U TURN) signs
    - BIKE/PED signs
    - Refresh pavement markings
    - Roadside delineators
    - Two-way, red/white and red/yellow retroreflective markers were placed on ramp edge lines on five off-ramps in the year 2012
    - Reconfiguration of ramp geometry
- Caltrans has employed the following National Transportation Safety Board (NTSB) strategies:
    - Lowering the height of DO NOT ENTER and WRONG WAY signs.

- Using oversized DO NOT ENTER and WRONG WAY signs.
- Mounting both DO NOT ENTER and WRONG WAY signs on the same post, paired on both sides of the exit travel lane.
- Using two sets of DO NOT ENTER and WRONG WAY signs on each side of each exit ramp.

Caltrans DRISI contracted with CTC and Associates, LLC to gather information on effective methods used by other state departments of transportation (DOTs) for reducing wrong-way driving collisions. Information obtained includes the types of wrong-way improvements that are used by other DOTs to reduce wrong-way crashes, such as detection systems, warning signage, freeway interchange designs, and enhanced enforcement for driving under the influence (DUI).

CTC and Associates, LLC completed phone interviews with seven state DOTs: Florida, Illinois, Maine, Michigan, Montana, Texas, and Washington. Caltrans requested the following information from each of these states:

Please share the following documents related to wrong-way driving, if available, either by email attachment or online link:

- Standard plans and guidance for wrong-way countermeasures in your state.
- Any research on the effectiveness of your state's wrong-way driving countermeasures. Caltrans is especially interested in studies of wrong-way driving related crashes before and after changes to ramps.
- Wrong-way driving monitoring reports or reporting criteria for your state.
- Any research on the application of Intelligent Transportation Systems to wrong-way driving in your state.
- Any information your agency has on the causes of wrong-way driving incidents based on interviews with drivers involved in them. Caltrans is interested in drivers' accounts of why they went the wrong way up a ramp, where they were when they realized they were going the wrong way, and what specifically made them aware they were going the wrong way (for example a sign, or seeing oncoming traffic).

In addition, Caltrans asked each state DOT the following list of eight questions:

1. Does your agency use different kinds of wrong-way warning systems for different kinds of ramps (e.g. diamond vs. loop ramps)?
2. Have you used enhanced lighting as a countermeasure for wrong-way driving?
3. Do you know of any research indicating that certain types of interchanges or ramps have higher numbers of wrong-way driving incidents? Are drop-ramps serving carpool lanes especially problematic?
4. Is your agency involved in incrementally improving its wrong-way driving countermeasures to expand beyond signage and pavement markings?
5. Does your agency conduct public awareness campaigns concerning wrong-way driving?
6. Do you have methods for providing real-time warning of other drivers about wrong-way driving incidents, for instance, the use of changeable message signs (CMS)?

7. How do agencies in your state coordinate responses to wrong-way driving incidents when they are in progress?
8. Would your agency be interested in joining a pooled fund study investigating methods for reducing the rate of wrong-way driving incidents?

The detailed responses received from the seven DOTs can be found in Appendix F.

In addition, CTC and Associates conducted a literature search on wrong-way driving countermeasures, focusing on those resources that relate to the topics covered in the survey questions, the role of driver age, and the role of lack of familiarity in wrong-way driving incidents. The complete literature findings can be found in Appendix G.

Overall, both the consultation with state DOTs and the literature review showed that there are a large number of resources related to preventing wrong-way driving. Illinois and Texas seem to be at the forefront of wrong-way driving research, and Florida DOT and Michigan DOT are also engaged in ongoing wrong-way driving pilot projects. While no state DOT uses enhanced lighting as a countermeasure, most DOTs do not vary countermeasures by ramp type, and are investigating the use of countermeasures beyond pavement signs and markings. This includes the deployment of TAPCO devices (which use radar detection of wrong-way drivers to trigger flashing LEDs around wrong-way signs) as well as Texas DOT's exploration of the use of TraffiCalm devices. TraffiCalm devices employ two radar systems and a camera to remedy the problem of false alarms experienced with single radar, TAPCO devices. TAPCO devices used elsewhere have employed two radars. Texas DOT also provided useful information on real-time warnings to drivers and coordination of response to incidents, and Texas A&M Transportation Institute is developing a connected vehicle test bed that can be used for wrong-way driving research.

The literature review results indicate that there is an ongoing, widespread interest in wrong-way driving countermeasures, including a recent wrong-way driving summit, an ongoing NCHRP project, and pilot projects in Arizona and Florida. There seems to be ample evidence that partial cloverleaf interchanges are particularly problematic, and that the largest factors in wrong-way driving incidents are age and cognitive impairment (due to alcohol or some other factor). There is some evidence that lowering warning sign heights or using light emitting diodes (LED) and TAPCO devices may reduce wrong-way driving incidents. However, detection systems may require further development in order to eliminate false positives before DOTs are comfortable using them.

Site Visits with Texas and Florida Departments of Transportation

Texas and Florida Departments of Transportation were selected for site visits as these states have wrong-way pilot projects underway and were ranked number one (38 fatal collisions) and three (16 fatal collisions) for the average number of wrong-way fatal crashes for the years 2004-2011, respectively. California ranked number two with an average of 26 fatal collisions for this timeframe.

Texas Department of Transportation (TxDOT)

On April 5 and 6, 2016, Caltrans met TxDOT at their San Antonio Traffic Management Center to discuss and view in person the various countermeasures that have been implemented and studied to combat wrong-way drivers within San Antonio, Texas.

The San Antonio Wrong Way Driver Task Force was organized in the spring of 2011 to examine factors contributing to wrong-way driving and methods of addressing the issue. The Task Force is comprised of the TxDOT, San Antonio Police Department (SAPD), San Antonio Department of Public Works, Bexar County Sheriff's Office, Federal Highway Administration and Texas A&M Transportation Institute. A SAPD officer killed in the line of duty on March 15, 2011 by a wrong-way driver was the latest victim prior to the formation of the Task Force.

The challenges identified by the San Antonio Wrong Way Driver Task Force are commonly faced across the nation:

- Determining the points of entry for Wrong-Way Drivers
- More than 400 exit ramps exist in the San Antonio metro area
- Getting the attention of severely impaired drivers
- Methods used to address wrong-way drivers must be compliant with the Manual on Uniform Traffic Control Devices.

TxDOT owns, operates and maintains an extensive network of one-way frontage roads as part of the freeway system in the San Antonio area. The frontage roads serve commercial properties including restaurants, bars, hotels, gas station, and retail centers. The commercial driveways are designated as right in/right out only. There are several advantages to frontage roads, but the distinct disadvantage is that an inattentive or severely impaired driver can turn left from multiple driveways and enter the freeway system by way of an off-ramp. TxDOT has implemented access design improvements to the frontage road driveways to discourage drivers from making left turn movements.

TxDOT sponsored research performed by Texas A&M Transportation Institute to evaluate the state of the practice regarding wrong-way driving in the United States and Texas. In Texas as in California, the majority of wrong-way collisions were found to occur in major urban areas between the hours of midnight and 5:00 a.m. Driving under the influence was the primary contributing factor of the collisions. Researchers designed and conducted closed course studies to determine the effectiveness of select wrong-way driving countermeasures on alcohol-impaired drivers. TxDOT implemented the following signing and pavement markings enhancements to get the attention of the inattentive or severely impaired driver:

- Adding retroreflective tape lengthwise to sign posts.
- Increasing the size of ONE WAY signs.
- Adding a second set of WRONG WAY and DO NOT ENTER signs.
- TAPCO flashing red LEDs along the border of WRONG WAY signs.
- Wrong-way pavement arrows formed with two-way Red/Clear markers.

TxDOT was an early adopter of radar detection of wrong-way drivers and has shared their experience and knowledge with other state departments of transportation. TxDOT determined that detection of a wrong-way driver on the off-ramp requires a dual radar system. A single radar detection system proved to be unreliable, reporting far too many false positives. Currently, these WRONG WAY signs are set to flash under low ambient light conditions, typically, from dusk to dawn. The battery for the LED lights is housed in the sign pole and charged by a solar panel mounted on top of the sign support. The bright LED blinking lights are effective at getting drivers' attention. On the US 281 pilot project, research indicates a 34.62 percent reduction in the number of TxDOT TMC operator logs documenting wrong-way driver events from July 2012 to March of 2016. TxDOT is planning to use the dual radar system in future projects. Freeway mainline radar detection and warning systems are being used at four overhead sign bridge locations with two LED-illuminated, WRONG WAY signs, and two Blank Out signs which are activated upon detection of a wrong-way driver. Upon detection, changeable message signs (CMS) in both directions of travel are activated with a message warning motorists of a potential wrong-way driver. TxDOT TMC operators locate the wrong-way drivers through the use of closed circuit television (CCTV) cameras, and then communicate the information directly to the San Antonio Police Department Dispatcher.

Florida Department of Transportation (FDOT)

On April 7 and 8, 2016, Caltrans met FDOT key personnel involved with the wrong-way driver prevention efforts in Tallahassee, Florida, the statewide headquarters for FDOT.

The 2012 Florida Strategic Highway Safety Plan pledges support to the Federal Highway Administration's (FHWA) Toward Zero Deaths initiative. FDOT's initiative to reduce the number of fatal wrong-way driving collisions is one of their performance measures. Beyond conventional countermeasures that combine signage and pavement markings, FDOT has implemented pilot projects to test the effectiveness of technology-oriented countermeasures to reduce incidents of wrong-way collisions. The initial phase of the pilot projects refurbished or installed improved, enhanced signage and pavement markings. Enhancements include dual posting of DO NOT ENTER signs, larger signs, adding retroreflective tape lengthwise to sign posts, and the use of directional, thermoplastic pavement marking arrows with raised retroreflective red markers.

A pilot project has been constructed to evaluate the following countermeasure:

- Red, in-pavement, internally illuminated, solar powered LED pavement lights installed at four interchanges with three rows of lights placed on the off-ramps 100 feet apart upstream from the local street intersection, and are set to flash under low ambient light conditions - typically from dusk to dawn.

Pilot projects have been constructed to evaluate the following active monitoring systems:

- Blank Out WRONG WAY Signs
- TAPCO flashing red LEDs along the border of WRONG WAY signs.
- Rectangular Rapid Flashing Beacons (RRFB) placed above and below WRONG WAY signs.

These solar powered signs are activated by radar detection of a vehicle traveling the wrong way on an off-ramp. Notification of a wrong-way driver along with photos, is provided through a web-based cellular connection to FDOT and Florida Highway Patrol (FHP). Upon notification to the FDOT, the TMC operator posts a warning message on changeable message signs in the vicinity for both directions of traffic.

The TAPCO system was placed into operation in October 2014. Within the first 18 months of operation 26 wrong-way drivers were detected, of which 25 were able to self-correct and exit the system. The system sends an audible tone and up to seven photos to the TMC operator's computer terminal for viewing. The remaining wrong-way driven vehicle resulted in a collision witnessed by the TMC operator through a CCTV camera.

FDOT staff stated that radar detection systems are required to be tuned and tested with different types of vehicles to ensure the number of false positive notifications are manageable.

Evaluation of the above pilot project countermeasures is under way and the final reports will be provided to Caltrans upon completion. In addition to the effectiveness of preventing and detecting of wrong-way drivers, the countermeasures will be evaluated on reliability and maintainability over an extended period of time.

Wrong-way driving is one of FDOT's monthly public safety awareness campaigns with extensive public outreach including the use of the overhead changeable message signs (CMS) throughout the state.

Findings and Next Steps

The June 1989 report stated that an average of 35 fatal wrong-way collisions occurred annually between 1961 and 1987 and determined that drunk drivers were responsible for three out of every four wrong-way collisions on California freeways. An average of 23 fatal collisions occurred annually between 1995 and 2013 in California due to wrong-way driving. In eight out of the ten wrong-way collisions on Sacramento and San Diego area freeways in the first half of 2015, driving under the influence was the primary collision factor. The primary cause of wrong-way collisions, especially those which are fatal, remains to be drivers who are under the influence of drugs or alcohol. The 2009 to 2013 TASAS data on fatal wrong-way collisions indicates that 69 percent of the wrong-way drivers had been under the influence of drugs or alcohol..

A U-turn movement caused at least one of the wrong-way collisions reported in the first half of 2015, with five collisions reported as unknown as to how the vehicle came to be traveling the wrong way. A complicating characteristic of wrong-way drivers that some make intentional U-turns on freeways; they do not enter the system via an off-ramp. If no one witnesses the driver entering the system via the off-ramp, and there is no evidence to indicate doing so, there is the possibility that the driver performed a U-turn.

Caltrans has completed its evaluation of the red, airport-type pavement light as recommended in the 1989 report, and has ceased using them due to significant maintenance and reliability issues.

Implemented in 1985, Caltrans' Wrong-Way Monitoring Program has succeeded in reducing the number of wrong-way collisions on state facilities. An annual "Wrong-Way Monitoring Program Report" including a checklist for wrong-way entry review is prepared to identify and investigate locations that may warrant corrective action. Many states have implemented a wrong-way monitoring program based on Caltrans' program. Upon completion of the research project and evaluation of the pilot project, the checklist will be updated.

Caltrans has developed and partially constructed wrong-way driving deterrence and detection pilot projects in the Sacramento and San Diego areas. The purpose of the pilot projects is to determine if the addition of extra retroreflective pavement markers, revised signage, and active monitoring systems will reduce the potential for wrong-way drivers entering the system. Caltrans will conduct before-and-after research at freeway off-ramps in Sacramento and San Diego to allow AHMCT and Caltrans to determine the magnitude and causes of the wrong-way driver problem and to assess the effectiveness of the various mitigation strategies. This research will provide the means for Caltrans to make data-driven decisions regarding solutions that will reduce the number of wrong-way driving incidents, thus enhancing the safety of California's freeways, and ultimately saving lives. AHMCT will deliver a final report to Caltrans by December 31, 2017.

Caltrans and the CHP will continue to gather data, information from other states and non-governmental agencies, and findings from pilot and research projects to assist in implementing appropriate countermeasures to reduce the number of wrong-way driver incidents. California pledges support for the Federal Highway Administration's (FHWA) "Toward Zero Deaths" initiative and will strive to reduce the number of wrong-way incident

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Appendix A. Assembly Bill NO. 162

Assembly Bill No. 162

CHAPTER 101

An act to add and repeal Section 21651.1 of the Vehicle Code, relating to state highways, and declaring the urgency thereof, to take effect immediately.

[Approved by Governor July 15, 2015. Filed with Secretary of State July 15, 2015.]

LEGISLATIVE COUNSEL'S DIGEST

AB 162, Rodriguez. State highways: wrong-way driving.

Existing law requires a vehicle to be driven on the right half of a roadway, subject to specified exceptions. On a highway that has been divided into 2 or more roadways by means of intermittent barriers or by means of specified kinds of dividing sections, existing law makes it unlawful to drive a vehicle on that highway, except to the right of the intermittent barrier or dividing section that separates 2 or more opposing lanes of traffic.

This bill would require the Department of Transportation, in consultation with the Department of the California Highway Patrol, to update a 1989 report on wrong-way driving on state highways to account for technological advancements and innovation, to include a review of methods studied or implemented by other jurisdictions and entities to prevent wrong-way drivers from entering state highways, and to provide a preliminary version of the report to specified legislative committees on or before December 1, 2015, and the final report on or before July 1, 2016. The bill would require the report to identify any additional treatments and technologies with the potential to reduce the number of instances of wrong-way driving on state highways and to include a plan to incorporate those treatments and technologies into the Department of Transportation's wrong way monitoring and mitigation program. The bill would make related findings and declarations.

The bill would provide that its provisions are repealed as of January 1, 2021.

This bill would declare that it is to take effect immediately as an urgency statute.

The people of the State of California do enact as follows:

SECTION 1. The Legislature finds and declares all of the following:

(a) Wrong-way driving on state highways kills or injures numerous Californians each year.

(b) Accidents caused by wrong-way driving on highways are more likely to result in fatal or serious injuries than other types of accidents.

(c) According to the Department of the California Highway Patrol, from 2001 to 2014, inclusive, a total of 193 fatal collisions and 685 injury collisions occurred on state highways in this state as a result of wrong-way driving.

(d) Innovative countermeasures are needed to prevent drivers from entering the highway the wrong way.

SEC. 2. Section 21651.1 is added to the Vehicle Code, to read:

21651.1. (a) The Department of Transportation, in consultation with the Department of the California Highway Patrol, shall update the June 1989 report entitled "Prevention of Wrong-Way Accidents" prepared by the Department of Transportation pursuant to Chapter 153 of the Statutes of 1987. The update shall account for technological advancements and innovation since publication of the 1989 report and shall include a review of methods studied or implemented by other jurisdictions, including state or local agencies within or outside the state, and methods studied by nongovernmental entities to prevent wrong-way drivers from entering state highways. A preliminary version of the updated report shall be provided to the Senate Committee on Housing and Transportation and the Assembly Committee on Transportation on or before December 1, 2015, and the final report shall be provided to those committees on or before July 1, 2016. The report shall identify any additional treatments and technologies with the potential to reduce the number of instances of wrong-way driving on state highways and shall include a plan to incorporate those treatments and technologies into the Department of Transportation's wrong way monitoring and mitigation program for the state highway system.

(b) This section is repealed on January 1, 2021, pursuant to Section 10231.5 of the Government Code.

SEC. 3. This act is an urgency statute necessary for the immediate preservation of the public peace, health, or safety within the meaning of Article IV of the Constitution and shall go into immediate effect. The facts constituting the necessity are:

In order to make progress on prevention of wrong-way accidents as quickly as possible, it is necessary that this act take effect immediately.

Appendix B. Highway Design Manual Amendment

restrictive metering all provide an opportunity to reevaluate the need for a HOV preferential lane. HOV preferential lanes should remain in place or be added to the scope of projects generated in response to any of the above scenarios. Alternate solutions should be investigated before removal is considered. For example: better control over ramp traffic can be attained by retrofitting ramps to meter HOV traffic which bypasses the ramp meter. Underutilization of an existing lane plus the need for additional right of way for storage, the availability of an alternate HOV entrance ramp within 1½ mile, or the availability of a direct HOV access (drop) ramp will typically provide adequate justification for the removal of a HOV preferential lane at specific locations.

The Deputy District Director of Operations, in consultation with the HQ Traffic Liaison, is responsible for approving decisions to remove HOV preferential lanes. Written documentation should be provided in the appropriate project document(s).

(j) Enforcement Areas and Maintenance Pullouts

Division of Traffic Operations policy requires an enforcement area be provided on all two-lane and three-lane on-ramps with HOV preferential lanes. Deviation from this policy requires concurrence from the HQ Traffic Liaison, which must be reflected in the Project Initiation Document.

On single-lane ramps, a paved enforcement area is not necessary, but the area should be graded to facilitate future ramp widening (see Figure 504.3A). Enforcement areas are used by the California Highway Patrol (CHP) to enforce minimum vehicle occupancy requirements. At locations where the HOV preferential lane is metered, the CHP enforcement area should begin as close to the limit line as practical. Where unmetered, it should begin approximately 170 feet downstream of the limit line. On three-lane ramps, the CHP enforcement area should be downstream of the mast arm standard, approximately 70 feet from the limit line. The length of the CHP enforcement area and its distance downstream of the limit line may be adjusted to fit conditions at the ramp with CHP approval.

The District Traffic Operations Branch responsible for ramp metering must coordinate enforcement issues with the CHP. The CHP Area Commander must be contacted during the Project Report stage, prior to design, to discuss any variations needed to the CHP enforcement area designs shown in this manual. Variations must be discussed with the HQ Traffic Liaison and the Project Delivery Coordinator and/or District Design Liaison.

A paved pullout area near the controller cabinet should be provided for safe and convenient access for Maintenance and Operations personnel. If a pullout cannot be provided, a paved or "all weather" walkway should be provided to the controller cabinet, see Index 107.2. See Topic 309, Clearances, for placement guidance of fixed objects such as controller cabinets.

(3) *Location and Design of Ramp Intersections on the Crossroads.*

Factors which influence the location of ramp intersections on the crossroads include sight distance, construction and right of way costs, bicycle and pedestrian mobility, circuitous travel for left-turn movements, crossroads gradient at ramp intersections, storage requirements for left-turn movements off the crossroads, and the proximity of other local road or bicycle path intersections.

Ramp intersections with local roads are intersections at grade. Chapter 400 and the references therein contain general guidance. For ramp intersections, a wrong-way movement onto an off-ramp can have severe consequences. The California MUTCD also

Appendix C. Caltrans Wrong-Way Monitoring Checklist

Checklist for Wrong-Way Entry Review

1. Review pertinent collision reports. Using aerial photographs or other mapping websites to review ramps, cross roads, and median openings three miles downstream of the mainline traffic (less in urban, more in rural areas) from the collision location. The field investigation of ramps located within these three miles of the wrong-way collision site may reveal needed improvements in signing, striping, or lighting. Bring with you the appropriate figures that appear in the 2014-CA MUTCD from page 204 beginning with Figure 2B-11 to page 219, and beginning with page 744 with Figure 3B-24 to page 752. In addition to the identified off-ramp entrance, review the downstream interchanges, one or two closest to the collision location, to determine whether any nearby off-ramp might have been the entrance for a similar wrong-way collision.

2. Inspect off-ramps during both daytime and nighttime conditions, especially if the collision occurred at night. It is desirable to check the general visibility close to the same time of day and weather conditions as when the collision occurred (sunrise, sunset, dark, fog, rain, etc.) Choose a safe observation location near entry points to the off-ramp where a wrong-way driver may have driven. Exit your vehicle and view the scene from the wrong-way driver's perspective.

3. Check if DO NOT ENTER sign packages (R5-1 over R5-1a) are:

    - Present in the minimum quantities (See CA MUTCD figures).
    - Visible from the entry decision point and not too far back.
    - Mounted at the recommended height (about 2 feet above the edge of the traveled way pavement but visible to headlights).
    - Not faded.
    - Not hidden by other objects or bushes.
    - Oriented at the best possible viewing angle.
    - In good repair (riveted or bolted connections, etc.)
    - Free from graffiti.
    - Upgraded with current signs made of improved retroreflective sheeting.

4. Check if the 24-foot wrong-way pavement arrows (Figure 3B-24) are:

    - In the proper locations starting at about 20 feet from the limit line.
    - Present in the minimum quantity (at least 2 per lane).
    - Visible, with a reflective, freshly painted look.
    - Not faded, covered with grease, or chipped away.
    - Not embedded between directional arrows in left/right only lanes.
    - Placed with highly reflective thermoplastic material (may be specified for replacement and additional wrong-way arrows)

5. Check if other pavement directional arrows (Figure 3B-24) are:

   - Visible.
   - Not faded, covered with grease, or chipped away.

6. Check for the presence of other signs that discourage wrong-way movements:

   - ONE WAY (R6-1) is installed about 1 ½ feet above the edge of traveled way pavement, but visible to headlights.
   - No Right /Left Turn (R3-1, R3-2).
   - No U-Turn (R3-4).
   - Keep Right (R4-7).
   - Divided Highway (R6-3, R6-3a, W6-1, W6-2).
   - Two-Way Traffic (W6-3).

7 Off-ramp openings should discourage wrong-way entry from the cross street. The opening should:

   - Be narrow.
   - Have an island or painted median dividing parallel, adjacent on and off-ramps.
   - Have small radius corners on either side of the throat and be aligned towards local street travel.
   - Have red, clear markers that may be used on the freeway mainline approaching exit.
   - Have lane line pattern with pavement markers on ramps per Figure 3A-102 (CA), Details 14 and 14A; Figure 3A-111(CA), Detail 37; or Figure 3B-14(CA).

8. Freeway entrances must be obvious and accessible. Check to ensure that:

   - Pathfinder/trailblazing signs are adequate for motorists to find the freeway entrances.
   - Entrance packages are in place and in good condition.
   - One 18-foot entrance arrow per lane exists and is in good repair (Figure. 3B-24(CA)).
   - Freeway entrances have better lighting than exits.
   - Interchanges are complete so that motorists never have to enter a freeway using an off-ramp.

9. When left-turn movements may be confusing in an intersection adjacent to an off-ramp, it is recommended to:

   - Install turning guide lines, either solid or broken.
   - Install pavement markers to aid the turning movement.
   - Install pavement markers on guide lines (good wear for high ADT).
   - Install directional pavement arrows.

10. Consider eliminating factors which contribute to wrong-way moves on adjacent right-of-way by:

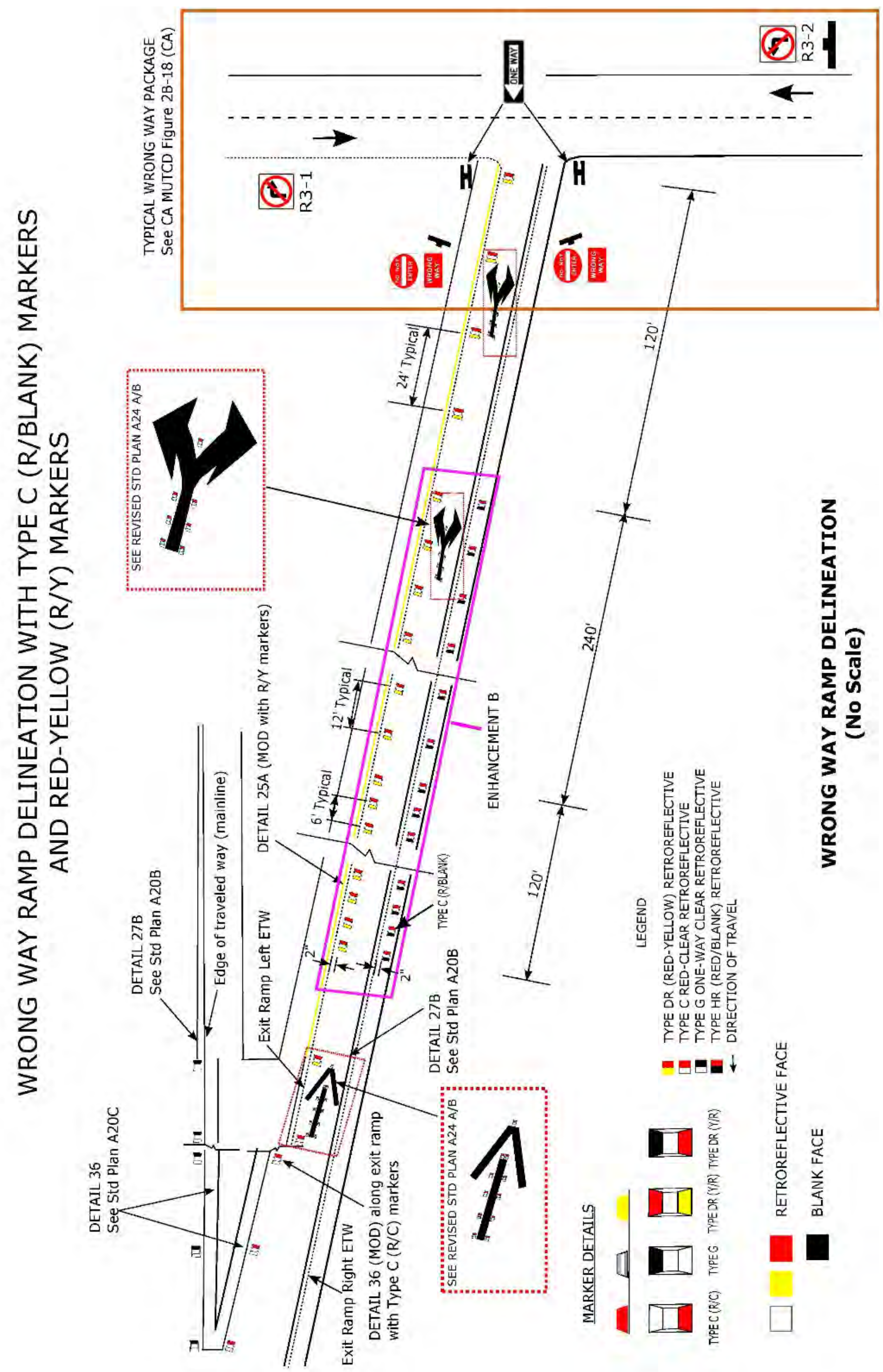
- Recommending removal of guide signs or privately owned directional signs located close to the off-ramp which may encourage wrong-way entry.
- Locating guide signs for frontage roads paralleling off-ramps far from the off-ramp opening.
- Removing bushes and structures that decrease visibility.
- Discouraging locating business driveways next to off-ramps in the original right-of-way agreement during the planning process.

11. Any recommendations which result from the field investigation should be approved by a supervisor with traffic engineering experience before filling out the Traffic Investigation Report (TIR) form. Recommendations shown on the TIR form must be accomplished in a timely manner to prevent tort liability. Do not editorialize the recommendations. Never write suggestions on the TIR form which will not be accomplished. Recommendations for making wrong-way preventive treatments, such as wrong-way packages and/or installation of lights do not require a safety index greater than or equal to 200, but do require engineering judgment; Minor B funding is at the discretion of the district.

12. At locations where sign theft is a problem, try:
    - Replacing any missing signs with those made of synthetic material.
    - Coating the back of existing signs with a thick layer of grease.

13. For recurring problems, try the following:
    - Reviewing through another pair of eyes.
    - Installing more DO NOT ENTER sign packages, larger DO NOT ENTER sign packages, illuminating the signs, or increasing the number of pavement arrows.
    - Monitoring with cameras or videos to isolate the sources and patterns of the problems.
    - Observing traffic flow during different times of day.
    - Increasing traffic flow on low ADT off-ramps (reroute).
    - Closing the ramp or a road to the intersection.
    - Re-grading or realigning ramps with limited sight distances.
    - Re-grading or realigning portions of freeways where decision sight distances are below what have been required in the Caltrans' Highway Design Manual.

Appendix D. Example of an Enhanced Pavement Delineation Plan Sheet for Exit Ramps



Appendix E. Wrong-Way Prevention and Detection Pilot Projects

District 3 – US 50 in Sacramento and West Sacramento

Background

From January to May, 2015, there were four nighttime wrong-way collisions on Sacramento area freeways that left a total of 12 people dead. All four of the wrong-way drivers were intoxicated, with blood alcohol concentration (BAC) levels ranging from 0.14 percent to 0.23 percent, far greater than the legal definition of driving under the influence (DUI) of 0.08 percent BAC. Two of the drivers entered the freeway via an off-ramp (WB Yol-50 off-ramp to Harbor Blvd, and the EB Sac-50 off-ramp to 5th St.), with one making a U-turn. The fourth cause of the wrong-way movement is unknown.

The wrong-way packages at these off-ramps, as well as other off-ramps in the Sacramento area, meet or exceed the wrong way sign standards outlined in the CA MUTCD. Although the high level of intoxication for each driver undoubtedly contributed to the decision to enter the freeway off-ramp in the wrong direction, the reasons the ramp attracted the intoxicated drivers are unknown.

In response to these collisions, Caltrans decided to conduct a pilot program along a number of Sacramento area off-ramps, with the intent of determining if changing off-ramp pavement marking patterns and installing active warning systems can reduce the number of wrong-way driving incidents.

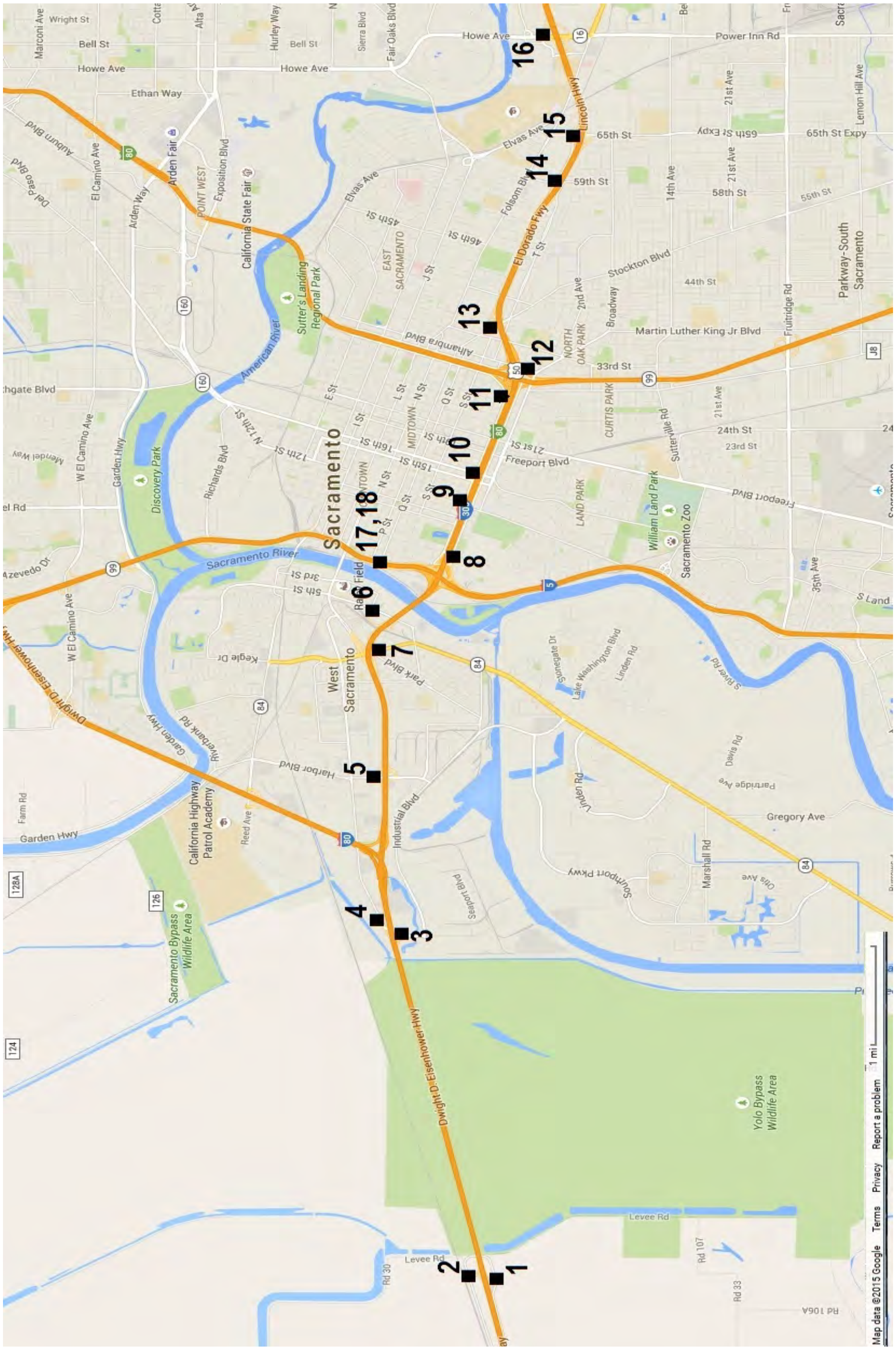
Proposal

The purpose of this pilot project is to determine if the addition of extra pavement markers, revised signage, and active monitoring systems will reduce the potential of a wrong-way driver entering the freeway. As a result, 18 off-ramps, as shown in Figure D-1 along US 50 in the Sacramento area, have been selected for study. This segment of US 50 was chosen not only due to wrong-way collisions, but also because it is a corridor between the Bay Area and South Lake Tahoe. Non-local drivers are more likely to be unfamiliar with the route and its various interchanges, making a wrong-way movement more likely if a driver exits the freeway for gas or food and then attempts to re-enter the freeway.

Although it is possible for any off-ramp to be driven the wrong-way, this project directed its focus on those ramps where the combination of ramp alignment and local road features suggested the ramp may have a higher potential for a wrong-way movement than other ramp layouts.

The work proposed on these ramps is divided into two categories of work: revision of pavement markings/signs and installation of an active wrong-way monitoring system. Once the enhancements are installed, Caltrans will be able to compare before-and-after data to determine if the improvements have any effect on wrong-way movements.

Figure E. Selected Off-Ramp Locations



Enhancement Locations

Ramp locations may have minor enhancements above those listed below following more detailed field reviews. Enhancements are as follows:

Ramp #	County	Route	PM	Ramp Location	Enhancement					
					A	B	C	D	E	F
1	Yolo	80	5.439	Co Rd. 32A WB off-ramp	X	X				
2	Yolo	80	5.693	Chiles Rd. EB off-ramp	X	X				
3	Yolo	80	9.004	Enterprise Blvd. EB off-ramp	X	X			X	
4	Yolo	80	9.417	W Capitol Ave. WB off-ramp	X	X				
5	Yolo	50	1.210	Harbor Blvd. WB off-ramp	X	X				
6*	Yolo	50	2.811	5th St (River Road) WB off-ramp	X	X	X			X
7*	Yolo	50	2.812	Jefferson Blvd. WB off-ramp	X	X	X		X	
8*	Sacramento	50	L0.398	5th St. EB off-ramp	X	X	X			
9*	Sacramento	50	L1.437	10th & W WB off-ramp	X	X	X	X		
10*	Sacramento	50	L1.600	16th & W WB off-ramp	X	X	X			
11*	Sacramento	50	L2.396	W St WB off-ramp	X	X	X			
12	Sacramento	50	R0.256	34th St. EB off-ramp	X	X				
13	Sacramento	50	R0.789	Stockton Blvd. WB off-ramp	X	X			X	
14	Sacramento	50	R1.846	59th St. EB off-ramp	X	X			X	
15	Sacramento	50	R2.822	65th St. WB off-ramp	X	X			X	
16	Sacramento	50	R3.915	Howe Ave. WB off-ramp	X	X			X	

Ramp #	County	Route	PM	Ramp Location	Enhancement					
					A	B	C	D	E	F
17	Sacramento	5	23.090	NB off-ramp to Q St.	X	X		X		
18	Sacramento	5	23.090	SB off-ramp to Q St.	X	X		X		

* These six active monitoring system locations denoted by an asterisk are included in the Caltrans DRISI research plan to collocate the Advanced Highway Maintenance and Construction Technology Research Center (AHMCT) developed video image processing systems (VIPS).

Enhancement Key

A – Replace retroreflective pavement markers on the exit ramp.

- Change existing one-way white to two-way white/red (W/R) for the lane line(s), channelizing line(s), and gore area.
- Change existing one-way yellow to two-way yellow/red (Y/R) for the left edge line (Detail 25A).
- Install or refresh Detail 41 for a left turn to an entrance ramp where there is an adjacent exit ramp.

B – Install Y/R and W/R retroreflective pavement markers with 24 ft. spacing for 240 ft. starting at the end of the ramp, changing to 12 ft. spacing for 120 ft., then 6 ft. spacing for 120 ft., and finally 24 ft. spacing to the gore point. Markers which fall between normal marker spacing limits (24 ft.) will be non-reflective for right way traffic (but still red for wrong-way traffic) to avoid any adverse effect on drivers traveling in the correct direction.

C – Install an active monitoring system which can identify, record, and transmit wrong-way driver information to a central location, and activate flashing beacon(s). The system proposed is the Traffic and Parking Control Company, Inc. (TAPCO) Blinkersign R5-1A (WRONG WAY) Dual Radar w/ Camera and BlinkLink Alert Network solar-powered, LED-bordered sign(s) [TAPCO Option 5 Activation].

D – Replace/add new 36” Do Not Enter sign(s).

E – Replace/add new 48” Do Not Enter sign(s).

F – Replace/add new 72” Do Not Enter sign(s).

District 11 - Wrong-Way Enhancements, Detection and/or Notification at Freeway Exit Ramps - Pilot Projects at Regular and Express Lanes Exit Ramps

Locations:

- State Route 15 (SR-15) and Interstate 15 (I-15) between Interstate 805 (I-805) and State Route 78 (SR-78) at all exit ramps.
- Interstate 5 (I-5), Interstate 8 (I-8) at two exit ramps.

See Figures E-2, E-3, and E-4

Goals:

- Reduce wrong-way driving incidents on freeways.
- Focus on non-complex and relatively inexpensive enhancement strategies to get the attention of wrong-way drivers on freeway exit ramps so that they turn around before entering the main lanes. Implement such strategies widespread over time if they are determined beneficial.
- Install pavement markers with red reflectors on the backside at all pilot project exit ramps. Install other devices to detect and notify CHP and TMC Dispatch of wrong-way occurrences at some possibly higher-risk exit ramps.

Enhancements to Deter Wrong-Way Motorists on Freeways

Caltrans recently developed pilot projects to study enhancements aimed at deterring wrong-way drivers at exit ramps on selected freeways in San Diego and Sacramento. In San Diego (Caltrans District 11), the pilot study will primarily focus on the exit ramps of SR-15 and I-15 between I-805 and SR-78. The wrong-way warning signs at these ramps will be enhanced with reflective pavement markers that have red on the backside. At nine locations, additional upgrades will include blinking LED-bordered wrong-way signs, and a vehicle detection device with camera verification, which will alert the CHP and Caltrans TMC Dispatch of any wrong-way occurrences.

Background

Freeway main lanes already feature sections of pavement markers that reflect red when wrong-way vehicle’s headlights shine on them. These pilot projects in San Diego will expand on that enhancement by installing red-backside pavement markers on off-ramps. The goal is to get the attention of wrong-way drivers so that they turn around on the off-ramps before they even reach the main lanes. The effectiveness of other devices to detect and notify CHP and TMC Dispatch of wrong-way drivers, and whether that helps prevent any collisions, will also be reviewed.

The installation of the enhancements A and B on I-15 and SR15 was completed in April 2016, with enhancement C anticipated to occur in fall 2016. Enhancements at the 5 locations on I-5 and I-8 will be installed by spring 2017. These installations will occur later due to construction scheduling or the time necessary to gather baseline data of any wrong-way occurrences and test the reliability of devices to detect wrong-way drivers at those ramps. These two locations on I-5 and I-8 are within 1 to 2 miles of the CHP San Diego Headquarters, so response time for any occurrences should be minimized. These two active monitoring system locations are included in the Caltrans DRISI research plan to collocate the AHMCT developed VIPS.

Enhancements

Ramp locations may have minor enhancements above those listed below following more detailed field reviews. Enhancements A and B were installed in April 2016 on all 60 off-ramps and direct access ramps (DAR) listed below and enhancement C is scheduled for completion in the fall 2016. Basic enhancements proposed and completed by location are as follows:

Ramp #	County	Route	PM	Ramp Location	Enhancement		
					A	B	C
1	San Diego	15	M4.542	NB off-ramp to University Ave.	X	X	X
2	San Diego	15	M4.755	SB off-ramp to University Ave. E	X	X	X
3	San Diego	15	M4.925	NB off-ramp to El Cajon Blvd.	X	X	X
4	San Diego	15	M5.150	SB off-ramp to El Cajon Blvd.	X	X	X
5	San Diego	15	M5.487	NB off-ramp to Adams Ave.	X		
6	San Diego	15	M5.634	SB off-ramp to Adams Ave.	X	X	
7	San Diego	15	R5.880	NB off-ramp to Camino Del Rio S	X		

Ramp #	County	Route	PM	Ramp Location	Enhancement		
					A	B	C
8	San Diego	15	R6.211	SB off-ramp to Camino Del Rio S	X		
9	San Diego	15	R6.600	NB off-ramp to EB Friars Rd.	X		
10	San Diego	15	R6.861	NB off-ramp to WB Friars Rd.	X		
11	San Diego	15	R6.966	SB off-ramp to Friars Rd.	X		
12	San Diego	15	R8.106	NB off-ramp to Aero Dr.	X		
13	San Diego	15	R8.524	SB off-ramp to Aero Dr.	X		
14	San Diego	15	R8.930	NB off-ramp to WB Balboa Ave.	X		
15	San Diego	15	R9.074	NB off-ramp to EB Tierrasanta Blvd.	X		
16	San Diego	15	R9.432	SB off-ramp to Tierrasanta Blvd.	X		
17	San Diego	15	R9.812	NB off-ramp to Clairemont Mesa Blvd.	X		
18	San Diego	15	R10.155	SB off-ramp to Clairemont Mesa Blvd.	X		
19	San Diego	15	M13.077	NB off-ramp to Miramar Way	X		
20	San Diego	15	M13.655	SB off-ramp to Miramar Way	X		
21	San Diego	15	M14.016	NB off-ramp to Pomerado Rd./Miramar Rd.	X		
22	San Diego	15	M14.515	SB off-ramp to Miramar Rd./Pomerado Rd.	X		
23	San Diego	15	M14.843	NB off-ramp to Carroll Canyon Rd.	X		
24	San Diego	15	M15.118	SB off-ramp to Carroll Canyon Rd.	X		
25	San Diego	15	15.64	NB off-ramp to Hillery Dr.	X	X	X
26	San Diego	15	15.64	SB off-ramp to Hillery Dr.	X	X	X
27	San Diego	15	M15.683	NB off-ramp to Mira Mesa Blvd.	X		

Ramp #	County	Route	PM	Ramp Location	Enhancement		
					A	B	C
28	San Diego	15	M16.183	SB off-ramp to Mira Mesa Blvd.	X		
29	San Diego	15	M17.118	NB off-ramp to Scripps-Poway Prky./Mercy Rd.	X		
30	San Diego	15	M17.514	SB off-ramp to Mercy Rd./Scripps-Poway Prky.	X		
31	San Diego	15	M17.953	NB off-ramp to Poway Rd./Rancho Penasquitos	X		
32	San Diego	15	M18.400	SB off-ramp to Rancho Penasquitos/Poway Rd.	X		
33	San Diego	15	M18.970	NB off-ramp to Ted Williams Parkway/SR-56	X		
34	San Diego	15	19.29	NB off-ramp to Sabre Springs Parkway	X	X	
35	San Diego	15	19.29	SB off-ramp to Sabre Springs Parkway	X	X	
36	San Diego	15	M19.640	SB off-ramp to SR-56/Ted Williams Parkway	X		
37	San Diego	15	M20.428	NB off-ramp to Carmel Mountain Rd.	X		
38	San Diego	15	M20.772	SB off-ramp to Carmel Mountain Rd.	X		
39	San Diego	15	M21.717	NB off-ramp to Camino Del Norte	X		
40	San Diego	15	M22.125	SB off-ramp to Camino Del Norte	X		
41	San Diego	15	M22.744	NB off-ramp to Bernardo Center Dr.	X		
42	San Diego	15	M23.130	SB off-ramp to Bernardo Center Dr.	X		
43	San Diego	15	23.24	NB off-ramp to W. Bernardo Dr.	X	X	
44	San Diego	15	23.24	SB off-ramp to W. Bernardo Dr.	X	X	
45	San Diego	15	M 23.465	NB off-ramp to Rancho Bernardo Rd.	X		
46	San Diego	15	M 23.909	SB off-ramp to Rancho Bernardo Rd.	X		
47	San Diego	15	M 25.802	NB off-ramp to Pomerado/W.Bernardo Dr.	X		

Ramp #	County	Route	PM	Ramp Location	Enhancement		
					A	B	C
48	San Diego	15	M 26.040	SB off-ramp to Pomerado/W. Bernardo Dr.	X	X	
49	San Diego	15	M 26.728	NB off-ramp to Via Rancho Parkway	X	X	
50	San Diego	15	M 26.999	SB off-ramp to Via Rancho Parkway	X		
51	San Diego	15	27.26	NB off-ramp to Del Lago Blvd.	X	X	X
52	San Diego	15	27.26	SB off-ramp to Del Lago Blvd.	X	X	X
53	San Diego	15	M27.388	NB off-ramp to Centre City Parkway	X	X	
54	San Diego	15	R28.496	NB off-ramp to Citrocado Parkway	X		
55	San Diego	15	R29.095	SB off-ramp to Citrocado Parkway	X		
56	San Diego	15	R29.830	NB off-ramp to Ninth Ave.	X		
57	San Diego	15	R30.325	SB off-ramp to Ninth Ave.	X		
58	San Diego	15	R30.504	NB off-ramp to Valley Parkway	X		
59	San Diego	15	R30.848	SB off-ramp to Valley Parkway	X		
60	San Diego	15	R30.85	NB off-ramp to Hale Ave.	X	X	
				TOTAL	60	17	8

Enhancement Key

60 Ramps and DARs

Enhancement A – Replace the retro-reflective pavement markers on the exit ramp. Change existing Type G one-way clear to Type C two-way red/clear (R/C) for the lane line(s), channelizing line(s) and gore area.

Change existing Type H one-way yellow to two-way red/yellow (R/Y) for the left edge line (Detail 25A).

Install or refresh Detail 41 for a left turn to an entrance ramp when there is an adjacent exit ramp.

Install Type Red/Clear retroreflective markers on all ramp Type V arrows.

Additional Type Red/Blank retro reflective markers may be installed along the limit or crosswalk lines of some ramps at a later date to further deter wrong way drivers from entering the ramps.

17 Ramps and DARs

Enhancement B – Install R/Y and Type C (R/C) retro-reflective pavement markers with 12-foot spacing for 240 - feet and 6-foot spacing for 120-feet starting 120 - feet from the end of the ramp.

8 Ramps and DARs

Enhancement C – Install TAPCO BlinkerSign (or equivalent) R5-1 (DO NOT ENTER) and R5-1A (WRONG WAY) Dual Radar w/Camera & BlinkLink Alert Network solar-powered, LED-bordered sign(s). [TAPCO Option 5 Activation].

Figure E-2

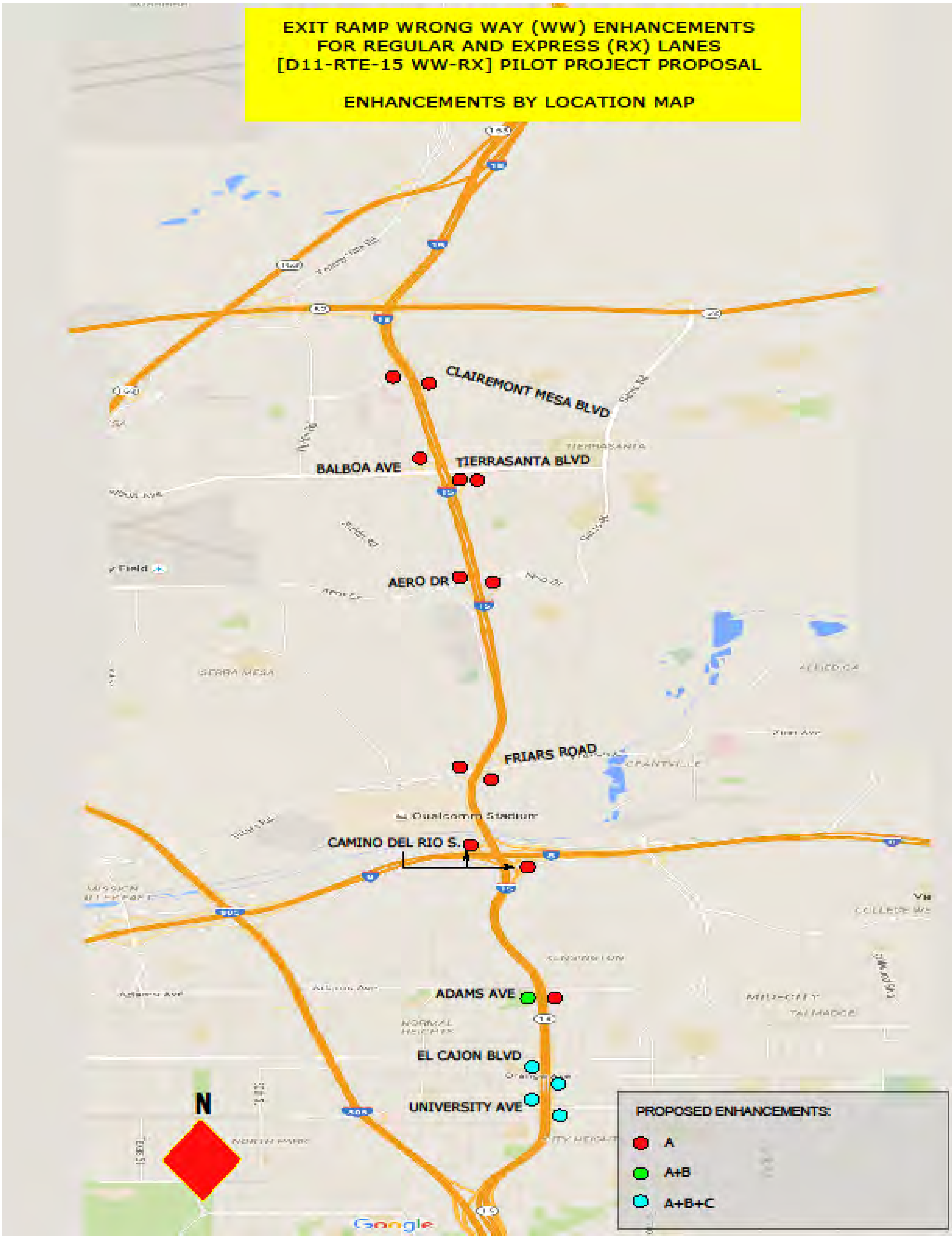

EXIT RAMP WRONG WAY (WW) ENHANCEMENTS
FOR REGULAR AND EXPRESS (RX) LANES
[D11-RTE-15 WW-RX] PILOT PROJECT PROPOSAL
ENHANCEMENTS BY LOCATION MAP
CLAIREMONT MESA BLVD
BALBOA AVE
TIERRASANTA BLVD
AERO DR
FRIARS ROAD
Qualcomm Stadium
CAMINO DEL RIO S.
ADAMS AVE
EL CAJON BLVD
UNIVERSITY AVE
N
PROPOSED ENHANCEMENTS:
A
A+B
A+B+C
Google

Figure E-3

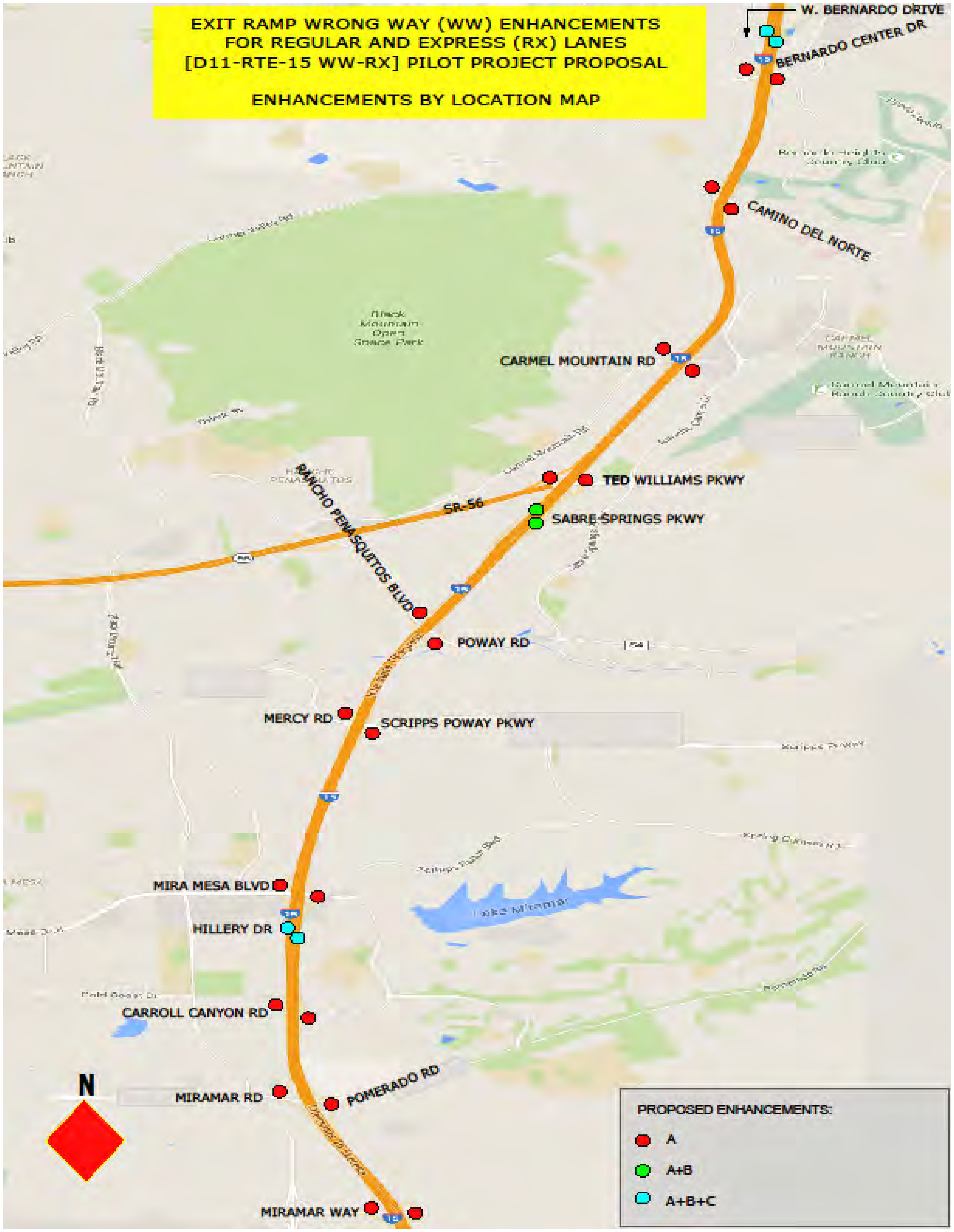
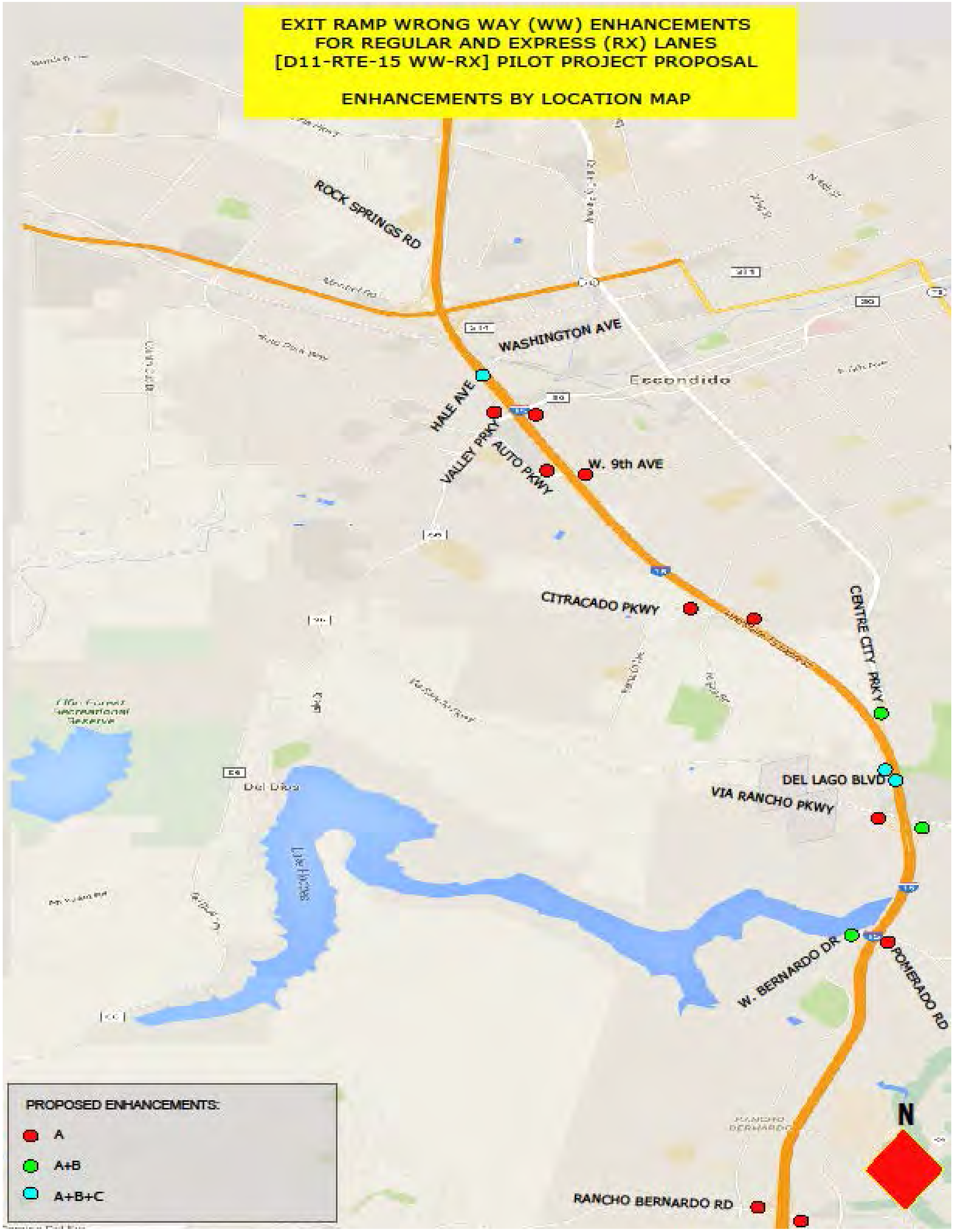

EXIT RAMP WRONG WAY (WW) ENHANCEMENTS
FOR REGULAR AND EXPRESS (RX) LANES
[D11-RTE-15 WW-RX] PILOT PROJECT PROPOSAL
ENHANCEMENTS BY LOCATION MAP
W. BERNARDO DRIVE
BERNARDO CENTER DR
CAMINO DEL NORTE
CARMEL MOUNTAIN RD
TED WILLIAMS PKWY
SABRE SPRINGS PKWY
SR-56
RANCHO PENASQUITOS BLVD
POWAY RD
MERCY RD
SCRIPPS POWAY PKWY
MIRA MESA BLVD
HILLERY DR
CARROLL CANYON RD
MIRAMAR RD
POMERADO RD
MIRAMAR WAY
N
PROPOSED ENHANCEMENTS:
A
A+B
A+B+C

Figure E-4


EXIT RAMP WRONG WAY (WW) ENHANCEMENTS
FOR REGULAR AND EXPRESS (RX) LANES
[D11-RTE-15 WW-RX] PILOT PROJECT PROPOSAL
ENHANCEMENTS BY LOCATION MAP
ROCK SPRINGS RD
WASHINGTON AVE
Escondido
HALE AVE
VALLEY PRKY
AUTO PKWY
W. 9th AVE
CITRACADO PKWY
CENTRE CITY PRKY
DEL LAGO BLVD
VIA RANCHO PKWY
W. BERNARDO DR
POMERADO RD
RANCHO BERNARDO RD
N
PROPOSED ENHANCEMENTS:
A
A+B
A+B+C

Appendix F. Interview Responses from Other State Departments of Transportation

Florida Department of Transportation

Contact: Raj Ponnaluri, Arterial Management System Engineer

Documents

- For wrong-way driving monitoring reports, see: https://firesportal.com/Pages/Public/QuickStats.aspx
- Because Florida doesn't have video recordings of wrong-way driving incidents, it's difficult to know which drivers correct, and when. Florida does have the technology to take photographs of both the front and back of vehicles when detected going the wrong-way on a ramp, however, these photographs are not saved due to public records issues.

Questions

1. **Does your agency use different kinds of wrong-way warning systems for different kinds of ramps (e.g. diamond vs. loop ramps)?**

   No. The FHWA has approved two experimental measures in Florida: the use of LED raised pavement markers as a warning, and the use of rectangular rapid flashing beacons. The latter are being used at six locations in the Tampa Bay area. The former have not yet been deployed; Florida believes it may be one of the best countermeasures, since an impaired driver's cone of vision drops horizontally.

2. **Have you used enhanced lighting as a countermeasure for wrong-way driving?**

   No, but lighting is a significant cause for concern, and helps. Florida is adopting a statewide practice of having lighting at all exit ramps in three to five years.

3. **Do you know of any research indicating that certain types of interchanges or ramps have higher numbers of wrong-way driving incidents? Are drop-ramps serving carpool lanes especially problematic?**

   Illinois DOT has done significant work in this area. One of their conclusions is that semi-cloverleaf ramps have a higher rate of wrong-way driving incidents, since the exit and entry ramps are next to each other. Florida does not have drop-lanes.

4. **Is your agency involved in incrementally improving its wrong-way driving countermeasures, to expand beyond signage and pavement markings?**

   Yes. Florida is interested in warning systems on exit ramps, including devices manufactured by the Traffic & Parking Control Co., Inc. (TAPCO). These devices include LEDs around the wrong-way sign, and radar to detect drivers and initiate the flashing of LEDs. The device can also take a picture of the back of the car as it passes and send an automatic alert to a traffic management center. Florida is using these devices on a pilot basis in several locations.

5. **Does your agency conduct public awareness campaigns concerning wrong-way driving?**

   Not directly, but Florida DOT interacts with the media on a regular basis concerning driving under the influence, which is a factor in wrong-way driving.

6. **Do you have methods for providing real-time warning of other drivers about wrong-way driving incidents, for instance, the use of changeable message signs?**

   No. Florida has the technical ability, but doesn't do so regularly and does not have a standard operating procedure. Information from Texas DOT seems to suggest that it is a mistake to inform drivers which lane a wrong-way driver is in, since the wrong-way driver might change lanes, so caution should be used when sharing information with other drivers. Wrong-way driving incidents move so quickly, that by the time they are detected and the message is passed to a traffic management center, the wrong-way incident is often already resolved or a collision has occurred.

7. **How do agencies in your state coordinate responses to wrong-way driving incidents when they are in progress?**

   Florida DOT's travel management center is collocated with the Florida Highway Patrol, therefore, coordination is very good.

8. **Would your agency be interested in joining a pooled fund study investigating methods for reducing the rate of wrong-way driving incidents?**

   Yes. Florida is looking for tangible, realistic, implementable actions. Mr. Ponnaluri would be happy to assist in writing the scope, which should focus on making good decisions using available crash data, and other technology solutions and not just pavement markings and signage.

Illinois Department of Transportation

Contact: Tim Sheehan, Safety Design Unit Chief

Documents

Illinois initiated a wrong-way driving investigation through its Centers for Transportation in 2010, with several phases. See below website information:

- *Investigation of Contributing Factors Regarding Wrong-Way Driving on Freeways*, 2012: http://cetrans.isg.siue.edu/wwd/FHWA-ICT-12-010.pdf
- *Statistical Characteristics of Wrong-Way Driving Crashes on Illinois Freeways*, 2014: http://www.tandfonline.com/doi/abs/10.1080/15389588.2015.1020421?journalCode=gcpi20
- *Guidelines for Reducing Wrong-Way Crashes on Freeways*, 2014: https://www.ideals.illinois.edu/bitstream/handle/2142/48998/FHWA-ICT-14-010.pdf?sequence=2
- Illinois hosted the Wrong-Way Driving Summit in 2014: https://www.ideals.illinois.edu/handle/2142/49045

The 2012 report investigated 10 locations for trends, including which types of ramps were more prevalent. Illinois engaged in mitigation via signage and pavement markings for 420 interchanges on freeways using standard details provided to all districts. A future report will evaluate the effectiveness of these mitigation measures.

Questions

1. **Does your agency use different kinds of wrong-way warning systems for different kinds of ramps (e.g. diamond vs. loop ramps)?**

   No. Wrong-way driving incidents are concentrated on partial cloverleaf ramps, and Illinois uses additional signage and pavement markings on those.

2. **Have you used enhanced lighting as a countermeasure for wrong-way driving?**

   No.

3. **Do you know of any research indicating that certain types of interchanges or ramps have higher numbers of wrong-way driving incidents? Are drop-ramps serving carpool lanes especially problematic?**

   Partial cloverleaf ramps have more wrong-way driving incidents. See*: Investigation of Contributing Factors Regarding Wrong-Way Driving on Freeways*, 2012: http://cetrans.isg.siue.edu/wwd/FHWA-ICT-12-010.pdf.

4. **Is your agency involved in incrementally improving its wrong-way driving countermeasures, to expand beyond signage and pavement markings?**

   Illinois deployed a TAPCO flashing warning sign at one problem location and is looking for other solutions.

5. **Does your agency conduct public awareness campaigns concerning wrong-way driving?**

   No, however there was some media coverage of Illinois' Wrong-Way Driving Summit.

6. **Do you have methods for providing real-time warning of other drivers about wrong-way driving incidents, for instance, the use of changeable message signs?**

   No.

7. **How do agencies in your state coordinate responses to wrong-way driving incidents when they are in progress?**

   Police respond to 911 calls. Illinois DOT does not coordinate with police during incidents but does work with them on reconstructing wrong-way driving accidents.

8. **Would your agency be interested in joining a pooled fund study investigating methods for reducing the rate of wrong-way driving incidents?**

   Maybe, depending on the cost and goals.

Maine Department of Transportation

Contact: Duane Brunell, Safety Office

Documents

Maine DOT has no formal research in the area of wrong-way driving incidents. Problem ramps appear to be cloverleaf and partial cloverleaf locations. Maine does not have a huge interstate system compared to other states, therefore, has very few wrong-way driving incidents. Nevertheless, Maine is interested in upgrading its wrong-way warning systems. Maine uses the MUTCD for standard plans and guidance.

Questions

1. **Does your agency use different kinds of wrong-way warning systems for different kinds of ramps (e.g. diamond vs. loop ramps)?**

   No.

2. **Have you used enhanced lighting as a countermeasure for wrong-way driving?**

   No.

3. **Do you know of any research indicating that certain types of interchanges or ramps have higher numbers of wrong-way driving incidents? Are drop-ramps serving carpool lanes especially problematic?**

   Cloverleaf and partial cloverleaf ramps are the most problematic. Wrong-way incidents usually involve the elderly or drunk drivers.

4. **Is your agency involved in incrementally improving its wrong-way driving countermeasures, to expand beyond signage and pavement markings?**

   Maine DOT is looking at TAPCO systems with LED lights surrounding signs, which flash after radar detection of a vehicle. The system can also send electronic alerts to DOT dispatch and state police via email or text. Maine DOT's pilot unit is also connected to a digital camera that can send five still frames so operators can see if a vehicle is continuing onto the freeway rather than self-correcting. Maine DOT is still working on technology issues with this system (and is not using alerts). It is also making a request to the FHWA to use rectangular rapid flashing beacons (RRFBs) on an experimental basis. Because these devices are solar powered and Maine is a winter state, it is unclear if they will maintain their charge. (Rhode Island has just completed a major effort with RFFBs). Maine DOT is also looking at low cost solutions, such as turn lane skips and further use of ENTER HERE signs.

5. **Does your agency conduct public awareness campaigns concerning wrong-way driving?**

   No.

6. **Do you have methods for providing real-time warning of other drivers about wrong-way driving incidents, for instance, the use of changeable message signs?**

   No. Maine does not have the density of CMSs that would make this approach effective. It is looking at a major CMS upgrade along its interstates and once that happens may use them to alert the public of oncoming wrong-way drivers.

7. **How do agencies in your state coordinate responses to wrong-way driving incidents when they are in progress?**

   Coordination with the Department of Public Safety occurs through the DOT's dispatch capabilities.

8. **Would your agency be interested in joining a pooled fund study investigating methods for reducing the rate of wrong-way driving incidents?**

   Probably not. Maine DOT is a minor player in this area.

Michigan Department of Transportation

Contact: Tracie Leix, Supervising Engineer

Documents

From 2010 to 2011 Michigan DOT conducted an effort analyzing 110 wrong-way crashes that occurred between 2005 and 2009. As a consequence of the study it is implementing several countermeasures. Regions have until 2019 to install these countermeasures. Michigan DOT has no research on Intelligent Transportation Systems (ITS) or driver accounts of why they were driving the wrong way.

Questions

1. **Does your agency use different kinds of wrong-way warning systems for different kinds of ramps (e.g. diamond vs. loop ramps)?**

   Michigan's target ramp style for new countermeasures is the partial cloverleaf interchange (on/off-ramps parallel to each other and perpendicular to the cross street) and similar designs (trumpet, etc.). Michigan has an estimated 161 interchanges that it is targeting with seven low cost countermeasures. Other interchanges in the state will require two of the seven countermeasures: lowering the bottom height of the WRONG WAY/DO NOT ENTER signs, and adding reflective sheeting on sign posts.

2. **Have you used enhanced lighting as a countermeasure for wrong-way driving?**

   No.

3. **Do you know of any research indicating that certain types of interchanges or ramps have higher numbers of wrong-way driving incidents? Are drop-ramps serving carpool lanes especially problematic?**

   Michigan's research indicates that partial cloverleaf style interchanges were susceptible to wrong-way movements. It does not have drop ramps for carpool lanes.

4. **Is your agency involved in incrementally improving its wrong-way driving countermeasures, to expand beyond signage and pavement markings?**

   No. Michigan DOT is always seeking to improve its systems, but has not installed any countermeasures beyond signing and pavement markings/delineation.

5. **Does your agency conduct public awareness campaigns concerning wrong-way driving?**

   No.

6. **Do you have methods for providing real-time warning of other drivers about wrong-way driving incidents, for instance, the use of changeable message signs?**

   Michigan DOT is currently discussing this internally. For more information, contact Hilary Owen.

7. **How do agencies in your state coordinate responses to wrong-way driving incidents when they are in progress?**

   When possible, the dispatch center contacts MDOT Operations for coordination.

8. **Would your agency be interested in joining a pooled fund study investigating methods for reducing the rate of wrong-way driving incidents?**

   Maybe. Please contact Mark Bott, Engineer of Traffic and Safety.

Montana Department of Transportation

Contact: Ivan Ulberg, Traffic Design Engineer, Traffic and Safety Bureau

Documents

Montana is engaged in a statewide upgrade of all ramp signage, but is using standard treatments, including red delineators, redundant wrong-way signs, dropping the height of signs to four feet, the use of words rather than symbols, and the painting of arrows on ramps. It has not conducted before-and-after studies, and has only one to seven wrong-way crashes a year, making it difficult to analyze trends.

Questions

1. **Does your agency use different kinds of wrong-way warning systems for different kinds of ramps (e.g. diamond vs. loop ramps)?**

   No.

2. **Have you used enhanced lighting as a countermeasure for wrong-way driving?**

   No. Montana DOT lights all its ramps.

3. **Do you know of any research indicating that certain types of interchanges or ramps have higher numbers of wrong-way driving incidents? Are drop-ramps serving carpool lanes especially problematic?**

   Montana sees more incidents at urban interchanges. Drivers are usually tired, elderly, or under the influence.

4. **Is your agency involved in incrementally improving its wrong-way driving countermeasures, to expand beyond signage and pavement markings?**

   Montana DOT has no formal plan to expand beyond signage and pavement markings but is open to this possibility for interchanges with repeated incidents.

5. **Does your agency conduct public awareness campaigns concerning wrong-way driving?**

   No. Public awareness campaigns focus on drinking and driving and buckling seatbelts. Wrong-way accidents are the cause of a small percentage of crashes.

6. **Do you have methods for providing real-time warning of other drivers about wrong-way driving incidents, for instance, the use of changeable message signs?**

   No.

7. **How do agencies in your state coordinate responses to wrong-way driving incidents when they are in progress?**

   Coordination occurs by phone and radio.

8. **Would your agency be interested in joining a pooled fund study investigating methods for reducing the rate of wrong-way driving incidents?**

   Maybe.

Texas Department of Transportation

Contacts:

Jianming Ma, Traffic Operations Division, Texas Department of Transportation

John Gianotti, Transportation Engineer, Texas Department of Transportation

Melissa Finley, Research Engineer, Traffic Operations and Roadway Safety Division, Texas A&M Transportation Institute

Documents

- A recent Texas study (*Assessment of the Effectiveness of Wrong Way Driving Countermeasures and Mitigation Methods*, http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/0-6769-1.pdf) examined the effectiveness of countermeasures using wrong-way driving events in San Antonio (see Chapter 4, p. 90 for data). Results showed a 38 percent reduction in wrong-way driving incidents from 2007 to 2011 on I-281, after implementing LED-embedded TAPCO signs. More recent data from 2012 to 2015 shows a 29 percent reduction. The difference in rates of reduction is due in part to more recent data relying only on Texas TransGuide operator logs rather than a combination of TransGuide data and San Antonio Police Department data (TransGuide is an Intelligent Transportation System developed by the San Antonio District of the Texas Department of Transportation). For information on the effectiveness of using two-foot sign elevations, contact Eric Hemphill of the North Texas Tollway Authority: 214-224-2166, ehemphill@ntta.org.

- Texas does not have statewide criteria for wrong-way driving monitoring reports. It tracks incidents via 911 calls. Its crash reporting includes a way to flag wrong-way driving via a number of different variables, and relies on the police to code these. Houston is starting to work with police and 911 logs to mark wrong-way driving events.
- Texas DOT does not have information on driver accounts of why they went the wrong way, but the San Antonio Police Department might. Interviewees were not aware of a formal way for processing wrong-way drivers.

Questions

1. **Does your agency use different kinds of wrong-way warning systems for different kinds of ramps (e.g. diamond vs. loop ramps)?**

   No.

2. **Have you used enhanced lighting as a countermeasure for wrong-way driving?**

   No. Roadways are continuously illuminated.

3. **Do you know of any research indicating that certain types of interchanges or ramps have higher numbers of wrong-way driving incidents? Are drop-ramps serving carpool lanes especially problematic?**

   There is no data available from Texas.

4. **Is your agency involved in incrementally improving its wrong-way driving countermeasures, to expand beyond signage and pavement markings?**

   Texas uses two types of radar, one for ramps (TAPCO) and one for freeways lanes. TAPCO devices have not worked optimally as an intelligent transportation system. In theory, it can send alerts for wrong-way driving incidents, which should allow bringing the incident up on camera more quickly than is possible now. Another type of radar that is connected to fiber optics is used to send alerts for wrong-way driving incidents on mainlines. Texas uses dynamic message signs to alert drivers of incidents, but these are not linked directly to the radar systems. TAPCO systems are also supposed to be able to do this, but Texas has not used them this way yet. Instead, operators put up messages manually. TAPCO devices currently use single radars and have had problems with false alarms. Newer devices by TraffiCalm systems use two radars, one pointing down-ramp and another pointing up-ramp, along with a camera. TraffiCalm is also in contact with Arizona DOT and other departments of transportation. Texas Transportation Institute is also contracted with Texas DOT to develop the concept of operations and functional requirements for a connected vehicle test bed that can be used for wrong-way driving. Phase I will ended in December 2015, and Phase II will involve purchasing a system and conducting a proof of concept over a year to a year-and-a-half for one location in Texas.

5. **Does your agency conduct public awareness campaigns concerning wrong-way driving?**

   No. Public service announcements (PSA) via the media and social media are common for drunk driving but not wrong-way driving specifically. The media contacts Texas DOT when there are a cluster of wrong-way driving incidents.

6. **Do you have methods for providing real-time warning of other drivers about wrong-way driving incidents, for instance, the use of changeable message signs?**

   Warnings are not provided in real time. But operators can put up warnings on dynamic message signs (DMS) based on 911 calls monitored by traffic operations. There was a media report of a driver who moved out of the way of a wrong-way driver because of a DMS warning.

7. **How do agencies in your state coordinate responses to wrong-way driving incidents when they are in progress?**

   Incidents are coordinated via the TransGuide operations room which has cameras throughout San Antonio. The San Antonio Police Department dispatcher sits to the left of the operations officer. When a 911 call comes in, an e-tone is triggered if the incident involves a wrong-way driver. Police give the location of the incident, and the operator puts up DMS messages and looks for cameras in the area. Having the dispatcher work next to the operator is invaluable.

8. **Would your agency be interested in joining a pooled fund study investigating methods for reducing the rate of wrong-way driving incidents?**

   Maybe. See also NCHRP 03-117, which is ongoing: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3856.

Washington Department of Transportation

Contact: Rick Mowlds, Signing Engineer

Documents

Washington State DOT does not have research on the effectiveness of countermeasures or ITS systems, or driver accounts. It does have information on specific interchanges (cloverleaf ramps) that are problematic. It is making some changes to signage and striping, but does not know yet if these changes are effective.

Questions

1. **Does your agency use different kinds of wrong-way warning systems for different kinds of ramps (e.g. diamond vs. loop ramps)?**

   Systems are different for loop and diamond ramps.

2. **Have you used enhanced lighting as a countermeasure for wrong-way driving?**

   No.

3. **Do you know of any research indicating that certain types of interchanges or ramps have higher numbers of wrong-way driving incidents? Are drop-ramps serving carpool lanes especially problematic?**

   Cloverleaf ramps are problematic. Drop-ramps have not been a problem.

4. **Is your agency involved in incrementally improving its wrong-way driving countermeasures, to expand beyond signage and pavement markings?**

   Washington State DOT has not had the funding for ITS applications. An assistant regional administrator did put an LED flashing beacon on wrong way signs on a pilot basis.

5. **Does your agency conduct public awareness campaigns concerning wrong-way driving?**

   No.

6. **Do you have methods for providing real-time warning of other drivers about wrong-way driving incidents, for instance, the use of changeable message signs?**

   No. Washington State DOT is not using changeable message signs to warn drivers of a possible wrong-way driver.

7. **How do agencies in your state coordinate responses to wrong-way driving incidents when they are in progress?**

   State patrol responds to 911 calls and traffic management centers are alerted when this happens. In an urban area the TMC may have a camera that can assist state patrol officers. The TMC is in the same building with the district state patrol office. Wrong-way incidents also trigger subsequent investigations into signage and markings.

8. **Would your agency be interested in joining a pooled fund study investigating methods for reducing the rate of wrong-way driving incidents?**

   Yes. Illinois' Wrong-Way Driving Summit was very useful.

Appendix G. Literature, Guidance, and Research

National Guidance

Highway Special Investigation Report: Wrong-Way Driving, National Transportation Safety Board, 2012.
http://www.ntsb.gov/safety/safety-studies/Documents/SIR1201.pdf
Abstract: This special investigation report looks at one of the most serious types of highway accidents -- collisions involving vehicles traveling the wrong way on high-speed divided highways. The goal of this investigative project is to identify relevant safety recommendations to prevent wrong-way collisions on such highways and access ramps. The investigations included in the report take a focused view of the driver and highway issues concerning wrong-way driving: driver impairment, primarily from alcohol use, with consideration of older driver issues and possible drug involvement; the need to establish, through traffic control devices and highway design, distinctly different views for motorists approaching entrance and exit ramps; monitoring and intervention programs for wrong-way collisions; and in-vehicle driver support systems. The report contains safety recommendations issued to the Federal Highway Administration; the National Highway Traffic Safety Administration; the states, the District of Columbia, and Puerto Rico; the American Association of State Highway and Transportation Officials; the Automotive Coalition for Traffic Safety, Inc.; the International Association of Chiefs of Police; the National Sheriffs' Association; SAE International; the Alliance of Automobile Manufacturers; Global Automakers; and the Consumer Electronics Association.

Research in Progress

Traffic Control Devices for Wrong-Way Movement Prevention, NCHPR 03-117, Ongoing, End Date: September, 2017.
http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3856
Abstract: The recommendations from the National Cooperative Highway Research Program (NCHRP) Report 650 had been addressed in the Regulatory and Warning Sign Technical Committee proposal of the National Committee on Uniform Traffic Control Devices (NCUTCD) dated January 2012, ONE WAY signing and wrong-way movement signing. However, NCUTCD Council indicated that this report addresses rural high-speed facilities related to one way signing needs but does not look specifically at safety applications for all traffic control devices related to wrong-way movement at both rural high-speed facilities and urban applications where the median is wider than 30 feet and may be a high or low-speed street or highway. Also, NCHRP Report 650 does not address rural applications that are lower-speed. Is the same number of one way signs needed for all these applications? Are additional markings needed? What about freeway ramp locations regarding improved safety needs? The objectives of this research are to: (1) Evaluate divided highways and streets as well as ramps related to improved safety and reduction of crashes by the use of traffic control devices including signs, pavement markings, delineators, reflectors, and other devices in the Manual on Uniform Traffic Control Devices (MUTCD) such as beacons and/or flashing light-emitting diode (LED) units within the sign, and enhanced conspicuity of standard signs in Section 2A.15 of the MUTCD. (2) Determine the number and location of ONE WAY signs required and the number and positioning of DO NOT ENTER and WRONG WAY signs at both divided highways and freeway/expressway ramps, recommended or optional for divided highways in urban locations or in rural lower-speed applications. Evaluate the median in terms of signing needs related to ONE WAY, DO NOT

ENTER, WRONG WAY, STOP, and YIELD signs. Is a median greater than 30 feet considered two intersections? What impact should the median width have on signing/marking requirements? (3) Provide actual recommended text and figures for the MUTCD for Parts 2B and 3.

Directional Rumble Strips for Reducing Wrong-Way Driving Freeway Entries, University of Minnesota, Ongoing, Start Date: August, 2014.
http://www.roadwaysafety.umn.edu/research/search/projectdetail.html?id=2015039%5D
Abstract at: http://trid.trb.org/view/1354821
Abstract: Wrong-way driving (WWD) on highways is a serious traffic safety problem. A recent study of the Fatality Analysis Reporting System (FARS) showed that traffic fatalities caused by WWD were between 300 and 400 annually from 2004 to 2011 in the United States (ATSSA, 2014). This number of fatalities has been consistent even though total traffic fatalities declined by 4% over the 8-year period from 2004 through 2011. In this study, we will develop a new countermeasure (directional rumble strips) for mitigating WWD issues in order to support the focus of the region's Roadway Safety Institute on safety systems and high-risk road users. First, to evaluate the feasibility of using directional rumble strips on freeway exit ramps, the research team conducted an initial field test of what drivers hear and feel, i.e., the sound and vibration that occur when vehicles run over regular transverse rumble strips at normal speed. An instrumented, test vehicle was used to collect field data to help researchers develop a mechanical model of the vibration that passengers feel in their vehicles. Such a mechanical model will be used for concept design and a feasibility study of directional rumble strips based on estimated noise levels and vibration. Based on the estimated vibration frequency and noise ranges generated by different rumble strips, several conceptual designs of directional rumble strips will be recommended for further field evaluation. Each will generate elevated noise and vibration for wrong-way driving, and normal noise and vibration for right-way driving. To evaluate the effectiveness of the proposed directional rumble strips, a field test of noise and vibration will be conducted to verify the models and develop the design guidelines at the National Center for Asphalt Technology (NCAT) at Auburn University.

Evaluating the Wrong-Way Driving (WWD) Incidents Problem on the Florida's Turnpike Enterprise (FTE) Roadway System, Florida's Turnpike Enterprise, Ongoing, End Date: November, 2015.
Abstract at: http://trid.trb.org/view/1354410
Abstract: The goal is to evaluate the wrong-way driving (WWD) incidents problem and potential countermeasures on the Florida's Turnpike Enterprise (FTE) roadway system. This includes data collection on WWD incidents on the FTE road network including a pilot study site on SR821, analysis of WWD trends, identification of typical problem areas and possible causes, designing and conducting a WWD survey for FTE customers, and providing recommendations to mitigate WWD incidents on FTE's roadway network.

Related Research

Wrong-Way Driving Detection and Prevention System: A Pilot Deployment, University of Central Florida, February 2015.
http://media.cmgdigital.com/shared/news/documents/2015/02/11/WWD_Slides_for_Media_DRAFT_2-11-2015.pdf
This presentation describes and ongoing pilot deployment of a wrong-way driving detection and prevention system in Florida.

Prediction of Potential Wrong-Way Entries at Exit Ramps of Signalized Partial Cloverleaf Interchanges, *Traffic Injury Prevention*, Volume 16, Issue 6, 2015: 599-604.
Abstract at: Abstract at: http://trid.trb.org/view/1347232
Abstract: Several previous studies, based upon wrong-way driving (WWD) crash history, have demonstrated that partial cloverleaf (parclo) interchanges are more susceptible to WWD movements than others. Currently, there is not a method available to predict WWD incidents and to prioritize parclo interchanges for implementing safety countermeasures for reducing WWD crashes. The focus of this manuscript is to develop a mathematical method to estimate the probability of WWD incidents at exit ramp terminals of this type of interchange. Methods: VISSIM (Visual simulation) traffic simulation models, calibrated by field data, are utilized to estimate the number of potential WWD maneuvers under various traffic volumes on exit ramps and crossroads. The Poisson distribution model was implemented without field observation and crash data. A comparison between the field data and simulation outputs revealed that the developed model enjoys an acceptable level of accuracy. The proposed model is largely sensitive to left-turn volume toward an entrance ramp (LVE) than stopped vehicles at an exit ramp (SVE). The results indicated that potential WWD events increase when LVEs increase and SVEs decrease. Also, the probability of WWD event decreases as road users are more familiar with the facility. The proposed method can diminish one of the challenges in front of transportation engineers, which is to identify high WWD crash locations due to insufficient information in crash reports. The results are helpful for transportation professionals to take proactive steps to identify locations for implementing safety countermeasures at high risk signalized parclo interchanges.

Warnings Designed to Prevent Accidents Caused by Wrong-Way Drivers on Motorways in Germany, *Advances in Transportation Studies*, Volume 35, 2015: 103-114.
Abstract at: http://trid.trb.org/view/1356708
Abstract: Heavy accidents caused by wrong-way driving on motorways happen proportionally seldom but lead to above-average heavy consequences in most of the cases. Therefore, wrong-way driving and wrong-way driving accidents get a high level of attention in the public perception. The incorrect entering of the motorway thereby represents one of the most common causes for wrong-way driving. Within a research project, a new detection system was developed detecting wrong-way drivers on their way up on the wrong carriageway of a motorway. Road users can be promptly supplied with targeted warning messages via an operational headquarter. In the course of this research project, appropriate warning concepts were to develop. This article deals with the validation and optimization of warning concepts in a study with test persons using a driving simulator laboratory.

Combating Wrong-Way Drivers on Divided Carriageways, Institution of Professional Engineers New Zealand (IPENZ) Transportation Conference, 2015, Christchurch, New Zealand, 2015.
Abstract at: http://trid.trb.org/view/1357929
Abstract: The issue of motorists entering the Auckland Motorway Alliance (AMA) network via off-ramps is a significant safety issue. This phenomenon of wrong-way drivers appears to be a growing issue around the rest of the country as the length of motorway and expressway grows and the driving population ages. The bulk of motorists who make the mistake of turning down an off-ramp against the traffic flow are people who would typically be deemed as competent drivers. These motorists appear to quickly recognize their error and make a hasty retreat. Those drivers who make it past the off-ramp and onto the mainline tend to be impaired drivers, either by way of drugs, alcohol or some age-related impairment. It is these motorists who end up contributing to the death and serious injury road statistics. Stopping these wrong-way drivers once they are on a divided carriageway is a significant challenge. However, there are some

relatively simple tools that can be deployed to reduce the risk of a driver making a wrong turn in the first place. The AMA has successfully trialed some wrong-way detection technology as proof of concept and is now working towards the implementation of a raft of prevention measures. Some of the findings the AMA has learned are presented in this paper. There are also some helpful hints for all drivers to protect themselves, their families and friends against the risk of them being featured in the statistics as either a perpetrator or an innocent victim of wrong-way driving.

Wrong-Way Driving Crashes on French Divided Roads, *Accident Analysis & Prevention*, Volume 75, Issue 0, 2015: 69-76.
Abstract at: http://trid.trb.org/view/1342159
Abstract: The objective of divided roads is to increase users' safety by posting unidirectional traffic flows. It happens however that drivers proceed in the wrong direction, endangering themselves as well as other users. The crashes caused by wrong-way (WW) drivers are generally spotlighted by the media and call for public intervention. This paper proposes a characterization of wrong-way driving crashes occurring on French divided road on the 2008–2012 period. The objective is to identify the factors that delineate between wrong-way driving crashes and other crashes. Building on the national injury road crash database, 266 crashes involving a wrong-way driver were identified. Their characteristics (related to timing, location, vehicle and driver) are compared to those of the 22,120 other crashes that occurred on the same roads over the same period. The comparison relies on descriptive statistics, completed by a logistic regression. Wrong-way driving crashes are rare but severe. They are more likely to occur during night hours and on non-freeway roads than other crashes. Wrong-way drivers are older, more likely to be intoxicated, to be locals, to drive older vehicles, mainly passenger cars without passengers, than other drivers. The differences observed across networks can help prioritizing public intervention. Most of the identified WW-driving factors deal with cognitive impairment. Therefore, the specific countermeasures such as alternative road signs should be designed for and tested on cognitively impaired drivers. Nevertheless, WW-driving factors are also risk factors for other types of crashes (e.g. elderly driving, drunk driving and age of the vehicle). This suggests that, instead of (or in addition to) developing WW-driving specific countermeasures, managing these risk factors would help reducing a larger number of crashes.

Characteristics of Wrong-Way Driving on Motorways in Japan, *IET Intelligent Transport Systems*, Volume 9, Issue 1, 2015: 3-11.
Abstract at: http://trid.trb.org/view/1342057
Abstract: Characteristics of wrong-way incidents and crashes that occurred on the entire motorway network in Japan are analyzed in this study with an emphasis on wrong-way crashes. Nearly 40% of vehicles in wrong-way crashes took U-turns on the main carriageway, followed by 20% entering the wrong way at interchanges after passing the tollgate, 18% before passing the tollgate and 12% at rest areas. Wrong entries and suspected dementia were the two main contributing factors for wrong-way crashes, each accounting for nearly 30% of the total number of wrong-way crashes, followed by each 8-10% for confusion with ordinary road, taking U-turns on the main carriageway and driving under the influence of alcohol. Most wrong-way crashes because of wrong entries were caused by older drivers over the age of 60 (61%) and young drivers (22%) and most of those because of confusion with ordinary road were also caused by older drivers (86%). All the wrong-way crashes caused by suspected dementia were by older drivers over the age of 65 and occurred between 4-10 p.m. Finally some applications of recent ITS technologies to prevent wrong-way driving that have been implemented recently on motorways in Japan are briefly introduced.

Application of Access Management Techniques to Reduce Wrong-Way Driving Near Interchange Areas, *Access Management Theories and Practices*, American Society of Civil Engineers, 2015: 236-246.
Abstract at: http://trid.trb.org/view/1342984
Abstract: Past studies indicated that interchange configurations, access control, and geometric design are related to Wrong-Way Driving (WWD) and minor ramp geometric changes can be effective in reducing the number of wrong-way entries onto freeways. In this paper, access management techniques and geometric elements, which are capable of discouraging wrong-way maneuvers, are identified and discussed. Additionally, every aspect of these elements and their relationship to WWD is investigated. These geometric elements include interchange types, exit ramp terminals, frontage roads, raised medians, channelizing islands, and control radius. The aforementioned elements should be given a special consideration during the design stage of interchanges and intersections.

Current Practices of Safety Countermeasures for Wrong-Way Driving Crashes, Transportation Research Board 94th Annual Meeting, Transportation Research Board, 2015.
Abstract at: http://trid.trb.org/view/1338212
Abstract: Driving the wrong way on high-speed, physically divided highways, namely wrong-way driving (WWD), has been a consistent issue in the United States since the introduction of the interstate system in the 1950s. This type of crash, which constitutes only about three percent of crashes on these facilities, tend to be more severe, increasing the probability for fatalities or incapacitating injuries. Despite employing numerous countermeasures to combat WWD issues in the nation, no recent research has been conducted to investigate the effectiveness and level of acceptance of these countermeasures and current practices. The purpose of this paper is to fill this gap by assessing the information gathered from a survey at the first National WWD Summit held in July 2013 and by studying emerging countermeasures currently employed in various jurisdictions. On the basis of analyzing the survey results and developed countermeasures, an insight into various characteristic aspects of WWD countermeasures is provided.

Wrong-Way Driving Prevention: Incident Survey Results and Planned Countermeasure Implementation in Florida, Transportation Research Board 94th Annual Meeting, Transportation Research Board, 2015.
Abstract at: http://trid.trb.org/view/1337596
Abstract: Wrong-way driving (WWD) crashes are rare on Central Florida roadways. However, WWD is a severe hazard, especially on high speed limited access roadways. This research developed a first of its kind driver survey to obtain details about unreported WWD events on Central Florida toll roads and freeways. This phone survey asked participants about WWD events either witnessed personally by the participant or by a family member, friend, or acquaintance. The 400 completed surveys showed that State Road (SR) 408 and Florida's Turnpike (SR 91) experienced the most WWD events. Only 14% of the WWD events resulted in a crash, and only 10% of participants who personally witnessed a WWD event reported the event, even though 50% of these participants felt a high risk of danger from the WWD event. Nine percent of the WWD events that were not reported resulted in a crash. These results show that WWD is more frequent than indicated by crashes or 911 calls. Based on these results, the Central Florida Expressway Authority (formerly known as the Orlando-Orange County Expressway Authority) plans to pilot test and evaluate the use of Rapid Rectangular Flashing Beacons (RRFBs) as a WWD countermeasure at 5 ramps along SR 408 and SR 528. This will be the first use of RRFBs to combat WWD. Elsewhere in Florida, Florida's Turnpike Enterprise is installing flashing "Wrong Way" signs along the Homestead Extension (SR 821) and Sawgrass Expressway (SR 869) in South Florida and the Florida Department of Transportation

is implementing a variety of WWD countermeasures at I-10 ramps in Tallahassee in North Florida.

Mitigating Wrong-Way Movements near Interchange Areas Using Access Management Techniques, Transportation Research Board 94th Annual Meeting, Transportation Research Board, 2015.
Abstract at: http://trid.trb.org/view/1337537
Abstract: Past studies indicated that interchange configurations, access control, and geometric design are related to wrong-way driving (WWD) and minor ramp geometric changes can be effective in reducing the number of wrong-way entries onto freeways. In this paper, access management techniques and geometric elements, which are capable of discouraging wrong-way maneuvers, are identified and discussed. Additionally, every aspect of these elements, including interchange types, exit ramp terminals, frontage roads, raised medians, channelizing islands, and control radius, and their relationship to WWD is investigated. Furthermore, a survey questionnaire was also designed to ask professionals to rank these elements based on the level of attention they received in different jurisdictions. The aforementioned elements should be given special consideration during the design stage of interchanges and intersections.

Automatically Detecting Wrong-Way Drivers on the Highway System, Transportation Research Board 94th Annual Meeting, Transportation Research Board, 2015.
Abstract at: http://trid.trb.org/view/1337036
Abstract: Vehicles that utilize exit ramps by entering in the wrong direction present one of the most serious traffic hazards on the national highway system. On average, approximately 350 people are killed annually in the United States as a result of wrong-way crashes. This typically occurs when the errant driver is impaired or confused. Existing intelligent transportation system field devices (traditionally used in the role of traffic management) are capable of dual functionality to enhance safety by detecting wrong-way drivers. This paper explores some of the possibilities of dual functionality using a combination of existing and new field devices coupled with new algorithms to create a wrong-way detection system. The wrong-way detection system is not expected to eliminate all wrong-way crashes. The system is designed to detect wrong-way drivers immediately upon entry; notify the traffic management center and public safety dispatch of the wrong-way entry point; and inform the errant driver of their potentially fatal mistake via visual and/or audible warnings to prompt drivers into corrective action. Should the errant driver continue onto the highway in the wrong direction, the system tracks the errant vehicle and provides audible updates to the traffic management and dispatch centers in real time of the errant vehicle's location allowing officers additional lead time to respond to the errant driver's actions. The detection system automatically warns right-way mainline drivers in the near vicinity of the on-coming wrong-way vehicle through the use of the existing dynamic message signs and ramp meters.

Wrong Way Driving on German Motorways – Safety Gain by a Low Cost Detection System, Transportation Research Board 94th Annual Meeting, Transportation Research Board, 2015.
Abstract at: http://trid.trb.org/view/1336889
Abstract: Wrong-way drivers on motorways are relatively rare, but – in many cases – cause severe accidents often with harmful consequences. Therefore, they acquire a lot of attention in general public. This paper first illustrates occurrence, causes and consequences of wrong-way drives on German motorways based on a literature review. Currently, about 2,000 messages are recorded yearly which on average lead to 200 accidents. In Germany, countermeasures consist of avoiding the emergence of wrong-way drivers by the design of the interchange or the markings. Furthermore, the ambient traffic is to be warned by means of a fast traffic detection. However, no automated detection through technical systems is used so far for this purpose.

Such systems need to be very cost-efficient for a comprehensive application in order to work efficiently despite low accident rates. On behalf of the Federal Ministry of Economic Affairs and Energy, the investigation presented in this work thus deals with the development of such a cost-efficient system. This was implemented in the form of an energy self-sufficient system based on low power radio technology. The improvement of detection times was shown in laboratory tests. The necessary high detection rate and the low false alarm rate could be demonstrated in a field study. The investigation of the efficiency of a faster warning was carried out with test persons in a driving simulator laboratory. As a result, it can be stated that the use of low cost technologies for the detection of wrong-way drivers has promising perspectives.

Overview of Safety Countermeasures for Wrong-Way Driving Crashes, *ITE Journal*, Volume 84, Issue 12, 2014: 31-38.
Abstract at: http://trid.trb.org/view/1339849
Abstract: Driving the wrong way on high-speed, physically divided highways, namely wrong-way driving (WWD), has been a consistent issue in the United States since the introduction of the interstate system in the 1950s. This type of crash, which constitutes only about 3 percent of crashes on these facilities, tends to be more severe, increasing the probabilities for fatalities or incapacitating injuries. Despite numerous countermeasures to mitigate WWD issues in the nation, little research has been conducted to investigate the effectiveness and level of acceptance of these countermeasures. The purpose of this paper is to fill this gap by assessing the information gathered from a survey at the first National WWD Summit held in July 2013 and by studying emerging countermeasures currently employed in various jurisdictions. On the basis of analyzing the survey results and implemented countermeasures, insight into various aspects of WWD countermeasures is provided.

Overview of Wrong-Way Driving Fatal Crashes in the United States, *ITE Journal*, Volume 84, Issue 8, 2014: 41-47.
Abstract at: http://trid.trb.org/view/1323133
Abstract: In this study, 8 years (2004-2011) of wrong-way driving (WWD) fatal crash data were extracted from the National Highway Traffic Safety Administration Fatality Analysis Reporting System database. The objectives of this study are to (1) provide an overview of the general trend of WWD fatal crashes in the United States; (2) discuss general characteristics of WWD fatal crashes; and (3) delineate significant contributing factors (e.g., crash location, driver gender, age, and impairment). The results will serve to inform national and state efforts to reduce WWD fatal crashes.

Cutting the Cost of Wrong-Way Driving, *ITS International*, Volume 20, Issue 3, 2014: 24-25.
Abstract at: http://trid.trb.org/view/1322456
Abstract: Wrong-way driving collisions are uncommon, but when they do occur, they are highly likely to result in fatalities or serious injury. Concerns about wrong-way driving have led transportation agencies to work to improve countermeasures. In 2012, San Antonio's Wrong-Way Driving Task Force was established. The task force identified high-risk locations and developed a geographic information system (GIS) map of all sites of reported wrong-way incidents. A pilot project was set up on a road identified as high-risk, using radar detection units and illuminated "WRONG WAY" signs. The pilot showed a reduction of wrong-way driving incidents of nearly 30%.

Wrong-Way Driving Incidents on Central Florida Toll Road Network, Phase-1 Study: An Investigation into the Extent of this Problem, Second Transportation & Development Congress 2014, American Society of Civil Engineers, 2014: 332-343.

Abstract at: http://trid.trb.org/view/1311290
Abstract: The focus of this research project was to understand the extent of wrong-way driving (WWD) incidents on Central Florida toll roads by analyzing WWD data. The universe of WWD data contains many sources on both reported and unreported WWD events. Various WWD data sources were analyzed, including crash reports, citation data, and 911 call data to determine WWD trends and areas of high occurrence. A Computer Assisted Telephone Instrument survey was conducted on 400 randomly selected toll road customers that either personally witnessed WWD or knew someone who had witnessed WWD on Central Florida highways. These customers were asked about the details of this WWD incident, if it affected how they drive, and if they reported it by calling 911. The intent of this survey was to capture information about unreported WWD events to determine the full extent of the WWD problem and understand how toll road users react to WWD and want to be alerted about it. The analysis results were used to create a systematic ranking of Central Florida toll roads with respect to WWD. The rankings indicated that SR 408 and SR 528 (in this order) are the worst roads with respect to WWD. The results indicated that WWD is a problem in Central Florida that requires attention. In addition, the survey showed that many people do not report WWD, so it is important to detect and warn drivers about WWD. In order to improve detection and reduce WWD incidents, a Phase-2 study will evaluate various WWD countermeasures to determine which are most effective for Central Florida toll roads. These countermeasures will include low-cost and medium-cost improvements and technologies.

Guidelines for Reducing Wrong-Way Crashes on Freeways, University of Illinois, Urbana-Champaign; Illinois Department of Transportation; Federal Highway Administration, 2014.
https://www.ideals.illinois.edu/bitstream/handle/2142/48998/FHWA-ICT-14-010.pdf?sequence=2
Abstract: Each year, hundreds of fatal wrong-way driving (WWD) crashes occur across the United States, and thousands of injuries are reported in traffic crashes caused by wrong-way drivers. Although WWD crashes have been a concern since the advent of access-controlled, divided roadways, the problem persists despite efforts to address it over time. The objective of this book is to provide guidance for implementing traditional and advanced safety countermeasures to achieve a significant reduction in the number of WWD incidents and crashes on freeways.

Prevention of Wrong Way Accidents on Highways: A Human Factors Approach. Transport Research Arena (TRA) 5th Conference: Transport Solutions from Research to Deployment, Institut Francais des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux (IFSTTAR), 2014.
Abstract at: http://trid.trb.org/view/1315693
Abstract: Every year, on highways, drivers taking wrong way cause accidents. Elderly drivers and young drivers are the most prevalent in the wrong-way accidents. Two main explanations of these accidents can be identified: violation (the driver takes intentionally the wrong way) or error (the driver did not identified that he/she is taking a wrong way). This paper focuses on a Human Factors evaluation of two new road signs to prevent wrong-way driving. The devices are a light barrier and the standard wrong-way signal (B1) on a yellow background (B1Y). This research, carried out in a simulator, aims at evaluating the efficiency of these road signs to prevent errors and violation on elderly and young drivers. The results of tests give a qualitative and quantitative evaluation of the wrong-way road signs and are discussed regarding their implication for road sign design and human factors evaluation.

Prevention of Wrong-way Driving on Highways Using a New Road Sign: A Field Experiment, Transport Research Arena (TRA) 5th Conference: Transport Solutions from Research to Deployment, Institut Francais des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux (IFSTTAR), 2014.
Abstract at: http://trid.trb.org/view/1315008
Abstract: Every year there are accidents caused by vehicles traveling in the wrong direction on divided roads. While few in number, these accidents are usually very serious and attract considerable media attention. For ten years now, studies and experiments have been carried out on France's freeway network, national highways and local roads. An experiment involving a new sign—a no-entry symbol on a yellow background—on exit ramps was carried out on selected roads in two French departments with the authorization of the dedicated short range communications (Road Traffic and Safety Department). The aim was to measure the impact of the new signing on the number of wrong-way incidents on the divided roads concerned. Although the number of infraction reports dropped by almost 40%, the data sample was very small and the results allow for no significant lesson drawing.

Efforts to Reduce Wrong-Way Driving: A Case Study in San Antonio, Texas, Transportation Research Board 93rd Annual Meeting, Transportation Research Board, 2014.
Abstract at: http://trid.trb.org/view/1289343
Abstract: In response to several severe wrong-way driving (WWD) crashes and a perceived increase in area-wide WWD activity, San Antonio transportation and enforcement agencies formed a task force in the spring of 2011 to discuss the issue and identify means to address the problem. The task force became a forum for agencies to discuss means of combatting WWD and led to a number of efficiency improvements in how quickly local agencies were able to respond to WWD events and how consistently those events were documented for later review. In addition, several forms of WWD signing improvement countermeasures were applied to US Highway 281, the freeway corridor in San Antonio most frequently experiencing WWD events. To date, the signing countermeasures have resulted in a reduction in WWD activity in the test corridor.

Statistical Characteristics of Wrong-Way Driving Crashes on Illinois Freeways, Transportation Research Board 93rd Annual Meeting, Transportation Research Board, 2014.
Abstract at: http://trid.trb.org/view/1289320
Abstract: This study collected and analyzed the wrong-way crashes data for a six-year time period, from 2004 to 2009, on Illinois freeways. The objective of the study was to characterize the statistical characteristics of wrong-way crashes from these three aspects: crash, vehicle, and person. The temporal distributions, geographical distribution, roadway characteristics, and crash characteristics were analyzed for wrong-way crashes. The wrong-way driver demographic information, driver physical condition, and driver injury severity were analyzed for wrong-way drivers. The vehicle characteristics, vehicle operation, and collision results were analyzed for wrong-way driving vehicles. General statistical characteristics of wrong-way crashes were analyzed, and the findings revealed that a large proportion of wrong-way crashes occurred during the weekend from midnight to 5 a.m. Approximately 80 percent of wrong-way crashes were located in urban areas. Nearly 70 percent of wrong-way vehicles were passenger cars. Approximately 60% of wrong-way drivers were driving under the influence (DUI). Of those, nearly 50% were confirmed to be impaired by alcohol, about 5% were impaired by drugs, and more than 3% had been drinking. Wrong-way entry points were analyzed for different interchange types as well. Compressed diamond interchanges, single point urban interchange (SPUI), partial cloverleaf interchanges, and freeway feeders had the highest wrong-way crash rates (wrong-way crashes per 100 interchanges per year). The contribution of this study was a new method to predict the possible wrong-way entry points and rank the high-frequency crash

locations for field reviews based on the number of recorded or estimated wrong-way freeway entries.

Is There a Right Way? *Roads & Bridges*, Volume 51, Issue 1, 2013: 40-42.
Abstract at: http://trid.trb.org/view/1240254
Abstract: This article follows the case of a pilot safety program in Milwaukee, Wisconsin to prevent wrong-way accidents. The steps to setting up the program, including a pilot study, are presented here. San Antonio's efforts on this front are also included, with attention to issues of ramp design, driving while impaired, navigation system alerts and highway signs.

Characteristics and Countermeasures against Wrong-Way Driving on Motorways in Japan, 20th ITS World Congress, ITS Japan, 2013.
Abstract at: http://trid.trb.org/view/1323736
Abstract: Drivers who make wrong-way entries onto motorways or other access-controlled highways pose a serious risk to the safety of other motorists and themselves. Wrong-way driving often leads to severe head-on crashes on motorways. Wrong-way crashes are relatively infrequent, but they are more likely to cause serious injuries and fatalities compared to other types of motorway crashes. The characteristics of both wrong-way incidents and crashes that occurred on the entire motorway network in Japan are analyzed in this study with an emphasis on wrong-way crashes. The characteristics of several typical factors resulting in wrong-way crashes are briefly identified and then directions of countermeasures for each factor are suggested. Finally some applications of recent ITS technologies to prevent wrong-way driving that have been successfully implemented on motorways in Japan are briefly introduced.

Development of a System that Prevents Wrong-Way Driving, 20th ITS World Congress, ITS Japan, 2013.
Abstract at: http://trid.trb.org/view/1323652
Abstract: In Japan, wrong-way driving by inexperienced drivers and head-on collision accidents as a result of this driving have become an issue. To solve this issue, NEXCO EAST and NEXCO Engineering Niigata jointly developed a detection and warning system to prevent wrong-way driving from occurring on highways. We installed this system on various highways in July, 2008. This system consists of a warning provision unit for drivers and the image processing unit that detects wrong-way driving. This system detected five wrong-way driving cases and stopped them by giving a warning to each driver during a six-month period at highway locations where wrong-way driving is a concern. By doing so, this system successfully prevented head-on collision accidents from occurring. When wrong-way driving is detected, this system is also capable of saving images that were shot in the past. This makes it possible to record the behavior of the driver who led to wrong-way driving, and is effective in subsequent analysis of such cases and examination of what fundamental countermeasures could be taken. This article reports on the development of this system and its operational achievements.

Investigation of Contributing Factors Regarding Wrong-Way Driving on Freeways, Civil Engineering Studies, Illinois Center for Transportation Series, University of Illinois, Urbana-Champaign; Illinois Center for Transportation; Illinois Department of Transportation; Federal Highway Administration, Issue 12-010, 2012.
Abstract at: http://trid.trb.org/view/1225870
Abstract: In Illinois, there were 217 wrong-way crashes on freeways from 2004 to 2009, resulting in 44 killed and 248 injured. This research project sought to determine the contributing factors to wrong-way crashes on freeways and to develop promising, cost-conscious countermeasures to reduce these driving errors and their related crashes. A thorough literature review was conducted to summarize the best practices on design, safety, and operational

issues related to wrong-way driving on freeways by different states in the United States and abroad. Six-year crash data from the Illinois Department of Transportation were then collected for identifying wrong-way crashes. Out of 632 possible wrong-way crashes identified from the crash database, the 217 actual wrong-way crashes were verified by reviewing hard copies of those crash reports. General statistical characteristics of wrong-way crashes were analyzed, and the findings suggested that a large proportion of wrong-way crashes occurred during the weekend from 12 midnight to 5 a.m. Approximately 60% of wrong-way drivers were DUI drivers. Of those, more than 50% were confirmed to be impaired by alcohol, 5% were impaired by drugs, and more than 3% had been drinking. Causal tables, Haddon matrices, and significance tests were used to identify factors that contribute to wrong-way crashes on Illinois freeways. Alcohol impairment, age, gender, physical condition, driver's experience and knowledge, time of day, interchange type, and urban and rural areas were found to be significant factors. A new method was developed to rank the high-frequency crash locations based on the number of recorded or estimated wrong-way freeway entries. Twelve interchanges were identified for field reviews. Site-specific and general countermeasures were identified for future implementation.

Where These Drivers Went Wrong, *Public Roads*, Volume 75, Issue 6, 2012: 33-41.
Abstract at: http://trid.trb.org/view/1142447
Abstract: Although crashes caused by wrong-way drivers are rare, they kill or severely injure drivers and passengers at a much greater rate (per crash) than other types of freeway incidents. This paper describes a study conducted by the Federal Highway Administration and the Michigan Department of Transportation (MDOT) regarding wrong-way crashes on freeways. Researchers analyzed 110 wrong-way crashes that occurred on the Michigan freeway system from 2005 to 2009. The researchers restricted their study to vehicles that were known or presumed to have entered the freeway system by traveling the wrong direction on an exit ramp. Findings show that some potential for driver confusion leading to wrong-way entry exists across the entire population, but is amplified in drivers impaired by alcohol or drugs, older drivers and drivers at night. The severity of a wrong-way crash was linked to how far the wrong-way vehicle progressed onto the system. A partial cloverleaf interchange provided the wrong-way ramp entry for 60% of the crashes for which the wrong-way entry point was known. The partial cloverleaf has a feature that appears to be the source of confusion leading to wrong-way freeway entry: a pair of freeway exit/entrance ramps that are adjacent and parallel to each other, and typically meet the crossroad at or near a 90-degree angle. The wrong-way entry mode for a driver is to turn onto the freeway exit ramp, thinking that they are entering onto the freeway entrance ramp. Most of the engineering solutions that can mitigate this problem involve positive cues to showcase the entrance ramp, and negative cues that make the exit ramp appear uninviting. Based on these findings, MDOT staff identified 161 interchanges that exhibit the suspect feature of partial cloverleaf. These interchanges are being targeted for systematic installation of low-cost countermeasures over the next 5 years. The countermeasures include: lowering the bottom height of DO NOT ENTER and WRONG WAY signs; installing reflective sheeting on the sign supports of these signs; placing stop bars at exit ramps; installing wrong-way pavement marking arrows at exit ramps; installing pavement marking extensions that will guide crossroad left-turning traffic past the exit ramp and safely onto the entrance ramp; painting the island between the exit and entrance ramp for a sufficient distance up the ramp; and placing red delineators along the exit ramp to discourage wrong-way vehicles that are headed up the exit ramp. MDOT has identified the first two of these countermeasures as being cost effective for all ramps, regardless of type. These countermeasures will be installed at the non-targeted interchanges as they come up for routine work.

Development and Operation Report of Wrong-way Driving Prevention Device, 19th ITS World Congress, ITS America, 2012.
Abstract at: http://trid.trb.org/view/1279698
Abstract: In expressways in Japan, the act of wrong-way driving among inexperienced drivers and head-on collision accidents that occur as a result are viewed as a significant problem. As a solution to this problem, NEXCO East and NEXCO Engineering Niigata developed a sensing and warning device, which prevents wrong-way driving on expressways, and installed the device in several locations in July 2008. This device consists of a warning device for drivers and an image processing device which senses the act of wrong-way driving. This device was installed in locations where there were concerns of wrong-way driving among inexperienced drivers. Within 6 months from installation, the device sensed five (5) examples of wrong-way driving, warned the drivers to stop driving the wrong way, and successfully prevented head-on collision accidents. In addition, this device is able to store images photographed in the past as it senses the act of wrong-way driving. This is extremely effective for ex-post analysis as well as for devising fundamental measures to prevent the act of wrong-way driving, as it can objectively record the driver's behaviors that lead up to the act of wrong-way driving. This article is a report regarding the development of this device and its achievement in operation.

Wrong Way Caution System for Motorways Based on Car Navigation System, 19th ITS World Congress, ITS America, 2012.
Abstract at: http://trid.trb.org/view/1268199
Abstract: This paper presents a method for detecting wrong-way travel on motorways and a method for warning drivers by using the car navigation system. In Japan, approximately 1,000 wrong-way driving incidents are reported annually. Senior drivers older than 65 years old are involved in almost half of these incidents. This phenomenon has become an object of public concern as Japanese society continues to age. To tackle this issue the authors have developed a wrong-way travel detection method for motorways using highly accurate location and communication-based map update technologies on the authors' car navigation system products.

Cross-Cultural Comparison of Drivers' Tendency to Commit Different Aberrant Driving Behaviours, Transportation Research Part F: Traffic Psychology and Behaviour, Volume 14, Issue 5, 2011: 390-399.
Abstract at: http://trid.trb.org/view/1108842
Abstract: The first aim of the present study was to identify key items which are rated differently by drivers from Finland, Sweden, Greece and Turkey. The second aim was to examine how these key items relate to drivers' self-reported accident involvement. Similar comparisons have previously been conducted in Europe but these have only included items classified as violations and errors, but not lapses. A sample of Finnish (N = 200), Swedish (N = 200), Greek (N = 200) and Turkish (N = 200) drivers completed the driver behaviour questionnaire (DBQ) and reported their accident involvement during the previous 3 years. The results showed that nine key items (which drivers from different countries rated differently) could be identified. These items included two aggressive violations, four ordinary violations and three lapses, but no errors. Out of these nine items, five items (Become angered by a certain type of driver and indicate your hostility by whatever means you can, Disregard the speed limit on a motorway, Overtake a slow driver on the inside, Pull out of a junction so far that the driver with right of way has to stop and let you out and Get into the wrong lane approaching a roundabout or a junction) could explain differences in drivers' self-reported yearly accident involvement when all four countries were taken together. At the same time, none of the items could explain differences in self-reported yearly accident involvement in Finland and Sweden while one of the items (Overtake a slow driver on the inside) could explain differences in self-reported yearly accident involvement in Greece and two of the items (Become angered by a certain type of driver and indicate your hostility by whatever

means you can and Disregard the speed limit on a residential road) could explain differences in self-reported yearly accident involvement in Turkey. This shows that different countries have different problems with regard to aberrant driving behaviours which need to be taken into account when promoting traffic safety interventions and the driver behaviour questionnaire (DBQ) can be used to diagnose risk areas and to better inform road safety practitioners within and between countries.

Development of the Device to Prevent Wrong-Way Driving, 18th ITS World Congress, ITS America, 2011.
Abstract at: http://trid.trb.org/view/1255608
Abstract: In expressways in Japan, the act of wrong-way driving among inexperienced drivers and head-on collision accidents which occur as a result are viewed as a problem. As a solution to this problem, NEXCO East and NEXCO Engineering Niigata developed a sensing and warning device which prevents wrong-way driving on expressways, and installed them on sites. This device consists of an image processing device which senses the act of wrong-way driving and a warning device towards drivers. This device was installed in locations where wrong-way driving among inexperienced drivers was a concern. Within 6 months from installation, the device sensed 5 cases of wrong-way driving, warned the driver to stop driving the wrong way, and successfully prevented head-on collision accidents. In addition, this device is able to store photographed images of the past as it senses the act of wrong-way driving. This is extremely effective for ex-post analysis as well as for devising fundamental measures to prevent the act of wrong-way driving as the driver's behaviors which lead to the act of wrong-way driving can be objectively recorded. This article is a report regarding the development of this device and its achievement in operation.

A Wrong Way Ramp Detection System, First International Conference on Transportation Information and Safety (ICTIS), American Society of Civil Engineers, 2011: 1166-1172.
Abstract at: http://trid.trb.org/view/1111893
Abstract: A Wrong-Way Ramp (WWR) detection system is described. The system is based on (i) in-ground magnetometer sensor grids which wirelessly communicate vehicle detection events to an access point; (ii) algorithms identifying wrong-way events with a high detection rate and low false alarm rate for a variety of vehicle and driver behaviors; (iii) video monitoring and notification; and (iv) driver alerts. The system design, test issues and resolutions, and field results are presented.

Fatal Wrong-Way Collisions on New Mexico's Interstate Highways, 1990–2004, *Journal of Forensic Sciences*, Volume 55, Issue 2, 2010: 432-437.
Abstract at: http://trid.trb.org/view/926076
Abstract: Medical examiner files from 1990 through 2004 were reviewed to identify fatalities caused by drivers traveling the wrong direction on interstate highways and identify risk factors and prevention strategies. Other fatal nonpedestrian interstate motor vehicle crashes served as a comparison group. Data abstracted included decedent demographics, driver/passenger status, seatbelt use, blood alcohol concentration, weather and light at time of occurrence, and types of vehicles involved. Of 1,171 total fatalities, 79 (6.7%) interstate motor vehicle fatalities were because of drivers traveling against the posted direction in 49 crashes, with 1 to 5 fatalities/crash. Wrong-way collisions were significantly more likely to occur during darkness ($p < 0.0001$) and involve legally intoxicated drivers ($p < 0.0001$). In 29/49 (60%) wrong-way crashes, alcohol was a factor. Prevention strategies aimed at reducing the incidence of driving while intoxicated, as well as improved lighting and signage at ramps, could help reduce the occurrence of fatal wrong-way collisions on interstates.

Countermeasures against Traffic Accidents by Wrong-Way Driving, 17th ITS World Congress, ITS Japan; ITS America; ERTICO, 2010.
Abstract at: http://trid.trb.org/view/1118519
Abstract: Wrong-way driving on expressways is an event with strong social impact, as it causes serious traffic accidents with causalities including innocent drivers. Recently, increasing numbers of accidents have been reported in mass media such as newspapers. Under these circumstances, we analyzed current statistical records of wrong-way driving case on expressways operated by West Nippon Expressway Company Ltd. (NEXCO-West). This paper describes the results of the statistical analysis and various efforts to reduce the number of wrong-way driving on expressways.

Wrong-Way Driving on Freeways: Problems, Issues, and Countermeasures, Transportation Research Board 87th Annual Meeting, Transportation Research Board, 2008.
Abstract at: http://trid.trb.org/view/848449
Abstract: Drivers who make wrong-way entries onto freeways pose a serious risk to the safety of other motorists and themselves. Wrong-way driving often leads to head-on collisions. Wrong-way crashes are relatively infrequent but are more likely to produce serious injuries and fatalities compared to other types of crashes and often result in significant media attention. Driving the wrong-way on freeways has been a nagging traffic safety problem since the interstate highway system was started in the 1950s. On average, approximately 350 people are killed each year nationwide in wrong-way freeway crashes according to data from the Fatality Analysis Reporting System (FARS). Despite over forty years of highway design, marking, and signing improvements at freeway interchanges, the problem still persists and annual fatalities are rising. In response to this issue, the Texas Department of Transportation sponsored a research project to evaluate the most effective traditional and innovative countermeasures throughout the United States to reduce wrong-way movements. Data from previous studies and a detailed study of 4 years of wrong-way crashes on freeways Texas was used to develop a typical wrong-way crash profile. The paper documents best practices nationwide and provides recommended guidelines for use of the most effective wrong-way countermeasures. A checklist for engineers and field crews to use for reviewing wrong-way entry issues or suspected problem locations is also provided.

Prevention of Wrong-Way Driving on Freeways, *Promet Traffic-Traffico*, Volume 19, Issue 5, 2007: 311-321.
Abstract at: http://trid.trb.org/view/841930
Abstract: Accidents on freeways often end tragically due to high vehicle speeds. Wrong-way driving is also a main cause of accidents on freeways. This paper presents and discusses research based on analysis of traffic accident data caused by wrong-way driving on freeways, while concurrently considering valid technical specifications for the design of roadway connection and junction elements. The thesis presents possible countermeasures for prevention of wrong-way driving and consequential decreases in the number of traffic accidents. The proposed prevention countermeasures to wrong-way driving on freeways could greatly reduce incorrect vehicle movements and enhance traffic safety on these roads.

Heading In The Wrong Direction: Descriptive Research on Wrong-Way Driving on Dutch Motorways: Background, Causes, Liability and Measures, Institute for Road Safety Research, SWOV, Issue D-2000-6, 2000.
Abstract at: http://trid.trb.org/view/673041
Abstract: Wrong-way driving causes a small number of serious accidents. In this research, the original accident registration sets and the more elaborate official police reports of wrong-way accidents on Dutch motorways were analyzed. The accident reports especially proved to give

more insight into the way wrong-way driving begins. Included in the supplementary research was the examination of the factors associated with road design and driver behavior that could have played a role in wrong-way driving. Therefore, junctions where drivers started wrong-way movements were visited. The supplementary research also examined legal liability in accidents involving wrong-way driving and the effectiveness of (new) measures to prevent wrong-way driving. Analysis of the official police reports showed that about half of the episodes of wrong-way driving began when drivers entered exits, while the other half began when drivers turned their cars (mainly on the main carriageway) or were engaged in similar maneuvers. The supplementary research focused on situations in which exits were entered unintentionally. This error, made by the largest group, is the simplest to prevent due to its involuntary nature and the locations where it occurs. If the indications found about the characteristics of exits that have been the scene of wrong-way entries are confirmed in further research, complying with the existing specifications for the signing and visibility of these junctions and the maintenance of line markings are amongst the most important measures to be taken to prevent wrong-way driving.

Wrong-Way Drivers and Head-on Collisions on Motorways: Number and Development of their Threat to Road Safety, In The Period up To 1998, Institute for Road Safety Research, SWOV, Issue R-2000-16, 2000.
Abstract at: http://trid.trb.org/view/672244
Abstract: This report contains the results of a study into wrong-way drivers. This Dutch study is a sequel to earlier studies in 1981(See ITRD 258645) and 1997 (See ITRD 491577). The purpose of the study was to gain insight into recent developments in the number of motorway accidents and reports to police stations. At the same time, the quality of the available information about wrong-way driver accidents was examined. Apart from an update of the 1997 study, the report also contains data on other (head-on) collisions on motorways, in which one of those involved were driving in opposite directions. New is the use of detailed official police reports. This data added more insight as to how wrong-way driving occurred. The study used the 1983-1998 accident databases. In order to make a comparison, a selection of all motorway accidents was made. However, this was only possible for 1991-1997. Analysis of the wrong-way driving accidents and victims presents a picture more or less the same as in the 1997 study.

Wrong-Way Drivers on Motorways. Part II: Literature Study, Institute for Road Safety Research, SWOV, Issue R-98-33 II, 1998.
Abstract at: http://trid.trb.org/view/537927
Abstract: In this report an overview is given of the available literature and other sources of information about the extent of wrong-way driving in a number of countries as compared to the total number of accidents/casualties on motorways or (if not available) to national figures concerning accidents/casualties. The following countries are included: Germany, Denmark, United Kingdom, Portugal, Sweden, France, and United States. For the first part see IRRD 491577.

Wrong-Way Drivers on Motorways. Part I: The Extent And Development Of The Number Of Wrong-Way Drivers, And The Road Accidents And Road Casualties Involving Wrong-Way Drivers Prior To The End Of 1996, Institute for Road Safety Research, SWOV, Issue R-98-33 I, 1998.
Abstract at: http://trid.trb.org/view/537926
Abstract: This report contains the results of a study into wrong-way driving on motorways and is a follow-up to a previous study conducted in 1981 (See IRRD 258645). The objective of the current study was to gain an insight into source files available in the Netherlands that contain information about wrong-way accidents and to determine the quality of that information. The extent, nature and development of wrong-way driving in the Netherlands since 1980 as based

on these source files are also discussed. During the 1991 to 1996 period, about 0.1% of all registered road accidents on motorways resulted from wrong-way driving. This percentage indicates that an annual average of 22 wrong-way accidents occurred during this time. Accidents involving wrong-way driving are serious in nature. During the dark, the percentage of wrong-way driving accidents of the total number of accidents on motorways is greater than during the day. Starting at age 55, the percentage of wrong-way drivers involved in road accidents on motorways increases. Alcohol use by wrong-way drivers occurs relatively often, with the exception of the group of drivers aged 70 and older. Regarding the location at which drivers start driving in the wrong direction, little data is available. For the second part see IRRD 491578.

Optimizing Arrow Pavement Marking Against Wrong-Way Driving, Tno Technische Menskunde Tm, Issue TM-97-C035, 1997.
Abstract at: http://trid.trb.org/view/537937
Abstract: Wrong-way driving is still a negative factor in traffic safety. Entering an exit on motorways from a secondary road results in the largest proportion of wrong-way drivers. Several times it has been suggested to place pavement arrow markings on exits to indicate the driving direction in order to prevent wrong-way driving. Under contract with the Netherlands Transport Research Centre (AVV) of the Department of Public Works, the TNO Human Factors Research Institute designed a pavement arrow marking. This marking is expected to be most optimal in reducing the number of wrong-way driving incidents. Attention is paid to the shape of the arrow, its size, the location in longitudinal and transverse profile, and the possible hindrance for traffic that uses the exit in the correct direction. Based on a brainstorm with experts in the area of visual perception, traffic and psychology, an arrow has been selected that bears a resemblance to the standard arrow, but that appears larger and is more pointed, partly due to the characteristic head of the arrow. This arrow is assumed to be the most effective in drawing the attention of wrong-way drivers, since the arrow will keep its characteristic shape under most circumstances. The arrow scores well in terms of conspicuity, characteristic arrow features, distinctness, and clarity.

Automatic Incident Detection: Wrong-Way Vehicle Detection Using Image Processing, Intelligent Transportation: Realizing the Future. Abstracts of the Third World Congress on Intelligent Transport Systems, ITS America, 1996.
Abstract at: http://trid.trb.org/view/574555
Abstract: This paper presents a new function added in an automatic incident detection system. It concerns an algorithm based on image processing able to detect the wrong-way vehicle on the motorway. The algorithm is working in most outdoor conditions (day, night, rain). The principle of the method consists in analysis of the moving vehicles. Each vehicle is tracked in the image and its trajectory is then built. The trajectory is a good criteria to qualify the circulating vehicle direction but in practice, parts of the trajectory include some error due to physical parameters (noise, deformation of objects due to the perspective view, etc.) or to natural phenomena (shadows, glints). A proposed paper presents the following points: a survey of the main difficulties met in the motion detection field and automatic incident detection; the principle of the method developed by the INRETS; the advantages and drawbacks of the method; and results obtained in field experimentation.