Presentation #22-01598: Using Wrong-Way Driving Detection Data to Identify Factors that Affect Wrong-Way Driving Behavior and Compare Detection Technologies

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RESEARCH PROBLEM AND OBJECTIVES

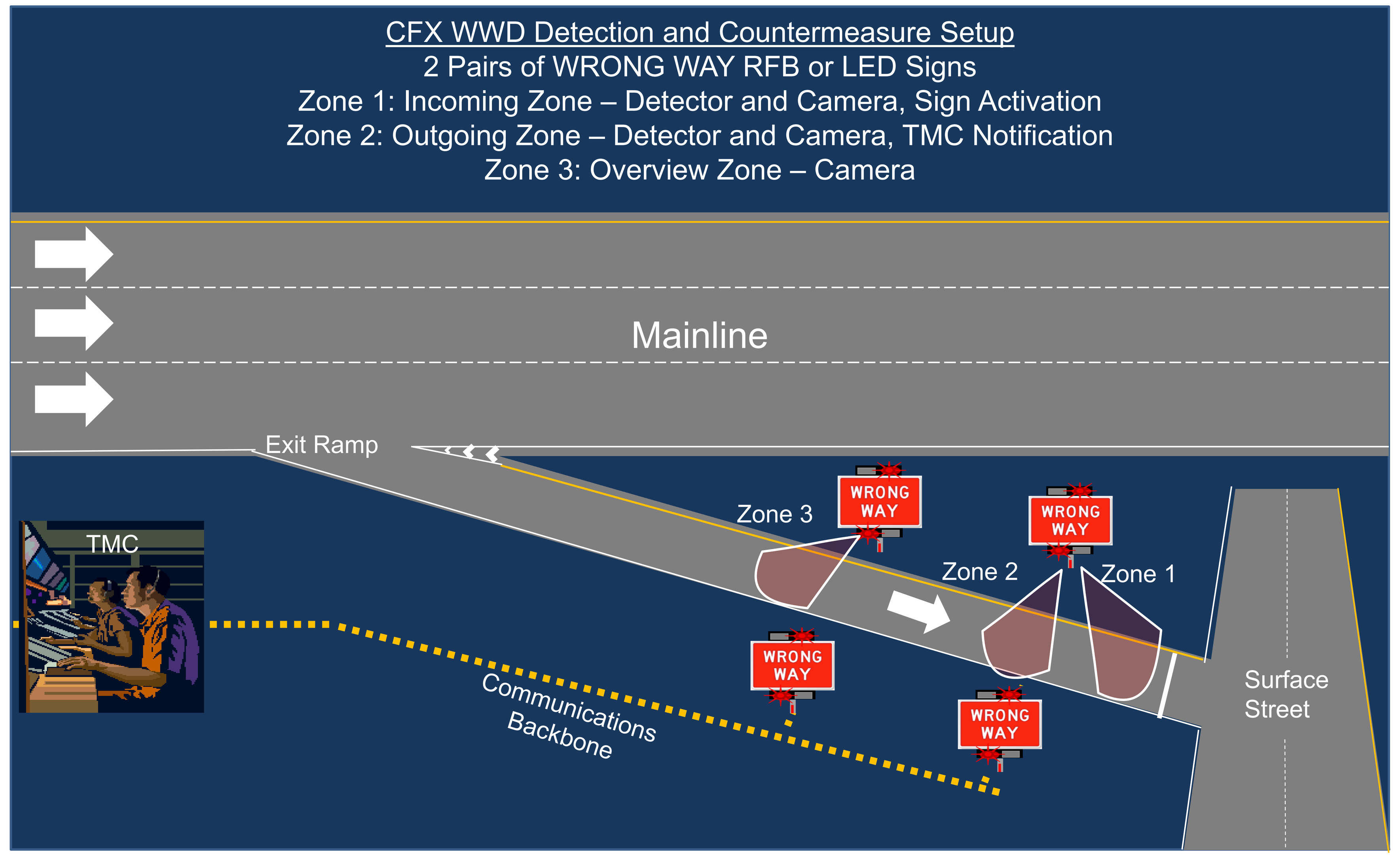
For many years, research has been done throughout the United States regarding wrong-way driving (WWD). Most of this research has focused on analyzing WWD crashes and evaluating various WWD countermeasures. No previous research has analyzed WWD detection data to identify significant factors that impact WWD frequency, understand wrong-way driver behavior, and compare various detection technologies. These detection data can be more representative of WWD behavior than crash data.

In this research, WWD detection data from 53 Central Florida Expressway Authority (CFX) exit ramps and 18 Florida's Turnpike Enterprise (FTE) exit ramps were collected and utilized to meet the following objectives:

1. Analyze WWD detection data to determine typical behaviors of wrong-way drivers.
2. Conduct a case study on ramps with a high percentage of left- or right-turn WWD entries to identify potential reasons for these behaviors.
3. Develop a model to predict the frequency of WWD detections based on the characteristics of the exit ramp and crossing street.
4. Compare WWD detection and false alarm rates at ramps equipped with radar, laser, and thermal WWD detectors to see if there are significant differences between and within each detection type.

The results of this research can help agencies better understand the WWD problem, identify treatments to reduce this problem, and determine the most effective WWD detection technologies for their roadways.

WWD DETECTION AND COUNTERMEASURE SETUP



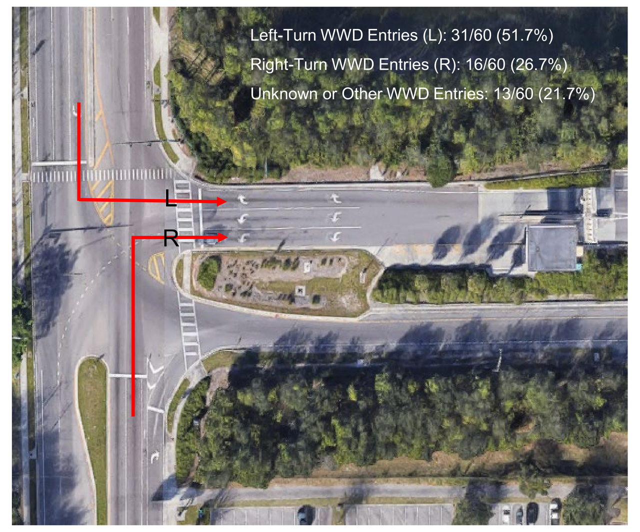
An example of the CFX WWD detection and countermeasure setup is shown below. Each CFX ramp contains 4 WRONG WAY signs with rectangular flashing beacons (RFBs) (seen below figure) or light emitting diodes (LEDs), two detectors, and three cameras. RFB signs are present at 43 CFX ramps and LED signs are present at 10 CFX ramps as of December 2021. When a WWD vehicle is detected in zone 1, the RFBs or LEDs start flashing and pictures are taken of the WWD vehicle. If the vehicle continues wrong way and is detected by zone 2, additional pictures are taken and a notification is sent to the traffic management center (TMC) via CFX's fiber optics communication backbone. Pictures are also taken in zone 3 to verify whether the vehicle continued wrong way or not. The FTE sites have a similar setup, but only have one WWD detector and camera. There have been 803 WWD detections at the CFX sites from January 2016 through April 2021 and 87 WWD detections at the FTE sites since they became active in June 2017 through April 2021.

ANALYSIS OF WRONG-WAY DRIVER BEHAVIORS

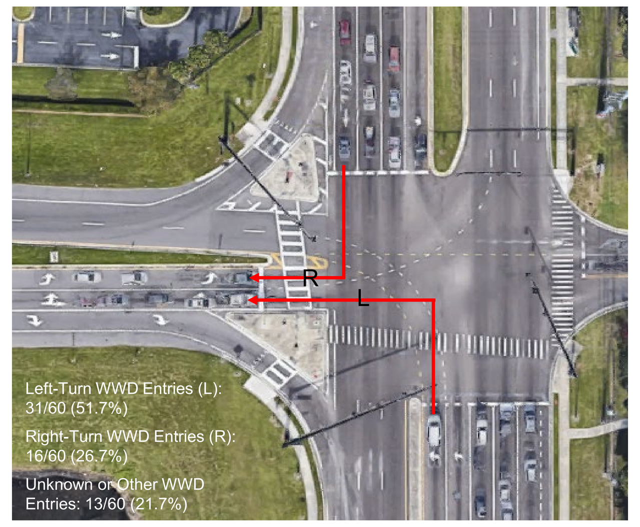
WWD detection data from 2016 through 2020 at 36 CFX sites were analyzed to identify common behaviors of wrong-way drivers and potential solutions to reduce WWD. There were 726 detected wrong-way vehicles during this period, with 562 (77.4%) confirmed to have turned around and 11 (1.5%) confirmed to have entered the mainline (including one that resulted in a non-fatal crash). Approximately two-thirds of these detections occurred at nighttime. The captured images (and videos which were available starting in August 2020) showed that 165 of these wrong-way vehicles (22.7%) turned left to go wrong way on the exit ramp and 131 vehicles (18.0%) turned right to go wrong way on the exit ramp. For the remaining vehicles, it was either not possible to determine how they entered the ramp to go wrong way or they made other maneuvers (such as crossing the median from the entrance ramp). 77.6% of left-turn WWD entries occurred at night compared to 66.4% of right-turn WWD entries; this difference was statistically significant (one-tailed p-value = 0.032) based on a χ^2 test, suggesting that improving nighttime visibility for left-turning WWD vehicles could help reduce WWD frequency.

DETAILED CASE STUDY

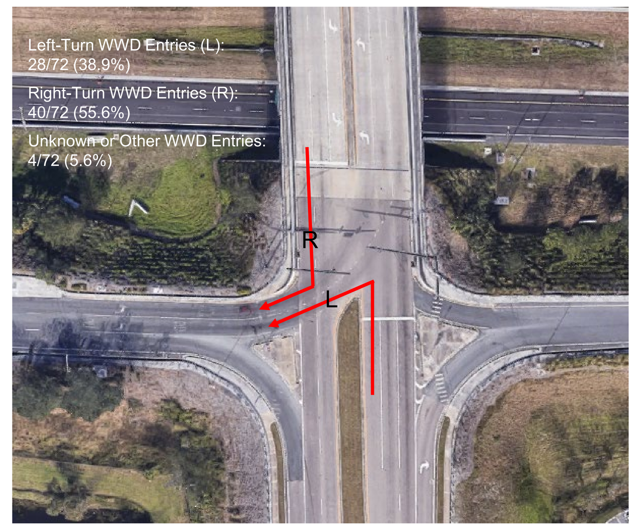
Out of the 19 exit ramps that had known left-turn or right-turn WWD entries, 5 ramps were studied in more detail. These 5 ramps all had 15 or more total WWD detections with over 50% of these detections initiated by left-turn or right-turn WWD entries. These ramps are shown below along with counts and examples of left-turn and right-turn WWD entries.



Ramp 1: SR 408 EB at Good Homes Rd.

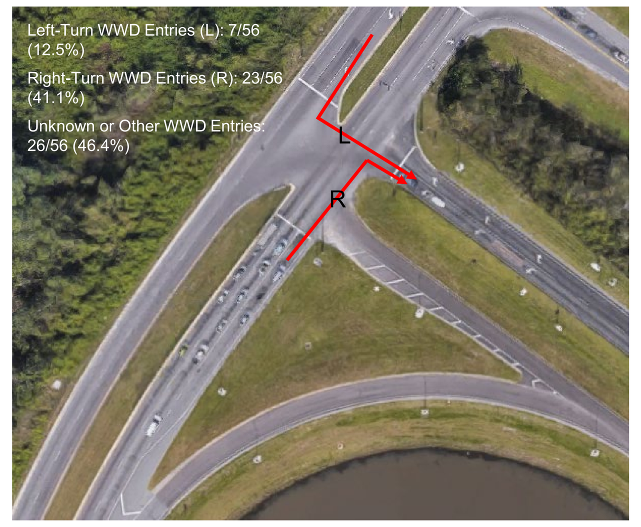


Ramp 2: SR 417 SB at US 441



Ramp 3: SR 408 EB at Dean Rd.

Ramp 4: SR 408 WB at SR 423



Ramp 5: SR 528 WB at Conway Rd.

Ramps 1 and 2 have more left-turn WWD entries than right-turn WWD entries, while the opposite is true for ramps 3, 4, and 5. Parallel entrance and exit ramps are present at ramps 1, 2, and 5, while ramps 3 and 4 have opposing entrance and exit ramps. On ramps 1 and 2, the crossing road median does extend into the ramp terminal intersection; this extension could make it harder for left-turning vehicles to go wrong way on the exit ramp. The channelizing island for right-turning vehicle on exit ramp 2 (combined with the thin median between the entrance and exit ramps) could be confusing and make some drivers think it is the median between the entrance and exit ramps, thereby increasing left-turn WWD entries. Ramps 3 and 4 also have channelizing islands on the exit ramp which could cause drivers to think they are two-way ramps and make right-turn WWD entries. Ramp 5 has more right-turn WWD entries than ramps 1 and 2, possibly due to having a right-turn lane for the entrance ramp before the ramp rather than at the ramp terminal intersection.

MODELING OF WWD DETECTIONS

To identify factors that affect WWD frequency, a model was developed to predict the number of WWD detections at a ramp based on exit ramp terminal characteristics (number of intersection approaches and minimum angle), exit ramp characteristics (annual average daily traffic (AADT), number of lanes, throat width, median presence, and toll booth presence), entrance ramp characteristics (location and toll booth presence), crossing street characteristics (AADT, number of lanes, turning lane presence, extended median presence, and distance to nearest upstream intersection), and opposing approach characteristics (presence and number of lanes). WWD detections from June 2017 through December 2020 for 33 CFX ramps and 15 FTE ramps with active WWD detection during this entire period were used in this modeling (n = 48). Poisson and negative binomial (NB) models were developed and compared using goodness of fit statistics, with the selected NB model shown below. All variables were significant at α = 0.05 significance level. This model shows that exit ramps with more lanes, a toll booth on the exit ramp, higher crossing street traffic volumes, and fewer lanes on the opposing approach are expected to have more WWD detections.

Predicted Mean Number of WWD Detections = exp[0.8028 + 0.4802(Number of Exit Ramp Lanes) + 0.5558(Exit Toll Booth Presence) + 0.0242(Crossing AADT) - 0.4154(Number of Opposing Approach Lanes)]

COMPARISON OF WWD DETECTION TECHNOLOGIES

The CFX WWD detection data was also used to compare three different WWD detection technologies: radar, laser, and thermal. WWD detections and false alarms from March 2019 through April 2021 at 24 radar sites, 9 laser sites, and 6 thermal sites were used for these comparisons. False alarms were detections where detection zone 2 was activated, but there was no WWD activity. Over this 26-month period, the average WWD detection rate per site per day was 0.009 for radar, 0.022 for laser, and 0.011 for thermal. Comparing these to the average false alarm rates of 0.003 for radar, 0.037 for laser, and 0.007 for thermal shows that the radar sites had the lowest rates and the laser sites had the highest rates, with only the laser sites having more false alarms than WWD detections. 80% of the 237 false alarms at the laser sites came from two sites. Laser false alarms were typically caused by equipment issues, weather, and traffic queues, while radar false alarms were typically caused by large vehicles and thermal false alarms were typically caused by unknown causes.

To better compare the technologies, two NB models were developed to predict the number of WWD detections and false alarms based on the technology type and number of months each site was active. These models showed that the laser sites had significantly higher WWD detection and false alarm counts compared to the radar sites. No significant differences were found between the thermal sites and the other sites (likely due to a lack of data at the thermal sites), but two sites that were changed from radar to thermal sites in February 2019 experienced false alarm rate reductions of 86.4% and 100%. The final statistical tests used were Wilcoxon signed-rank tests to see if the mean difference between the detection and false alarm rates significantly differed from zero for each detection technology. These tests showed that the radar WWD detection rate was significantly higher than the false alarm rate, indicating the accuracy of radar detection.

SUMMARY AND CONCLUSIONS

This research shows how WWD detection data can provide significant insights into WWD behavior. On the CFX exit ramps with WWD detection, left-turn WWD entries were more common than right-turn WWD entries, with significantly more left-turn entries occurring at nighttime. A detailed study of 5 ramps suggested that having an extended median on the crossing street could reduce left-turning vehicles while the presence of channelizing islands on exit ramps could increase driver confusion. Additionally, for exits with parallel entrance and exit ramps, the presence of right-turn lanes on the crossing street at the ramp terminal intersection could reduce right-turn WWD entries. The developed WWD detection model identified characteristics that could increase WWD frequency, providing agencies with a guide to proactively combat WWD. Comparing detection technologies showed that laser can have high false alert rates, possibly due to increased sensitivity to environmental conditions, while radar detection is generally accurate. Conducting these comparisons again in the future with additional thermal detection data could provide more insights into the performance of thermal detection. Overall, this first in-depth study of WWD detection data can help agencies reduce WWD and deploy effective detection technologies, saving resources and lives.

Disclaimer: This research was funded by CFX. This poster and its contents, including conclusions and results, are solely those of the authors; they do not represent opinions or policies of the funding agency.