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Wrong-Way Driving (WWD) Crashes on Divided Highways: Characteristics, Contributing Factors and Countermeasures

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ABSTRACT

Physically divided highways provide unidirectional traffic flow with the objective of increasing road users' safety. Wrong-way driving (WWD) is a hazardous driver error/behavior that can result in head-on collisions often causing severe injuries and fatalities. Research on wrong way driving has been conducted since the advent of the Interstate Highway System. WWD is of great interest due to its propensity to result in fatal and severe injury crashes.

Wrong-way crashes are rare and relatively infrequent but very severe . In the United States, WWD crashes result in 300 to 400 people killed each year on average, representing approximately 1 percent of the total number of traffic related fatalities that occur annually. While this is a small percentage overall, because WWD crashes involve head-on or opposite direction sideswipe crashes at high speeds, they tend to be relatively more severe than other types of crashes. However, there are many strategies and treatments that agencies can consider for implementation that are designed to address wrong-way manuevers, ranging from geometric design elements, to conventional traffic control devices, to various ITS-based solutions.

This study provides an overview and analyzes the general trend and the characteristics of the WWD crashes focusing on the high number that occurred on the US freeways. The contributing factors leading to this type of crash are identified. The study proposes systemic countermeasures to prevent or discourage wrong way occurrences, reducing wrong way crashes and driving down fatalities on freeways.

KEYWORDS: Wrong-way driving, driver behavior, drunk drivers, safety evaluation, traffic control

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INTRODUCTION

Wrong-way driving (WWD) may be defined as driving in the wrong direction (against the traffic stream) on high-speed, physically separated highways [1]. A *wrong-way driver* is defined as someone driving in the wrong direction on a physically separated motorway or on a one-way street [2]. A *wrong-way crash* is defined as a traffic crash caused by a wrong-way driver, usually resulting in head-on, angle, or side-swipe collisions [3]. For the purposes of this study, WWD is vehicular movement along a travel lane in a direction opposing the legal flow of traffic on high-speed controlled-access divided highways, including entrance and exit ramps.

Driving the wrong way has been identified as a traffic safety problem since the interstate highway system was started in the 1950s. the problem persists despite over fifty years of highway design and control improvements. Drivers who get on the highway can go the wrong way and potentially cause wrong-way crashes and fatalities. There are also many WWD incidents that do not result in a crash. In some cases WWD events are not reported and the WWD drivers might correct their direction of travel on their own. When they occur on limited access facilities, the WWD crashes usually make news headlines and strike fear into the right way drivers on the mainline who can take little action to avoid a WWD vehicle [4].

Wrong-way crashes are rare and relatively infrequent but they tend to be relatively more severe than other types of crashes. Studies performed on freeway WWD indicated that WWD crashes on freeways were more dangerous than other types of crashes because they were usually head-on collisions [5,6]. According to the US National Transportation Safety Board (NTSB), WWD freeway crashes result in 300 to 400 people killed each year on average, representing approximately 1 percent of the total number of traffic related fatalities that occur annually, and only about 3% of crashes that occur on high-speed divided highways [7]. While these are small percentages overall, it is important to try to reduce the occurrence of these crashes as much as possible.

There are many strategies and treatments that agencies can consider for implementation that are designed to address wrong-way maneuvers, ranging from geometric design elements, to conventional traffic control devices, to various ITS-based solutions. Any methods to lower the rate of wrong-way crashes will improve the safety of the highway systems [8].

This study investigates the WWD crashes with the goal of providing an insight into this problem and identifying relevant safety recommendations to prevent wrong-way collisions on such highways. The

investigation includes a focused look into the characteristics, the factors and issues affecting wrong-way collisions. The various practices for the prevention of WWD are also discussed.

MATERIALS AND METHODS

In the USA, about 50% of freeway WWD crashes were fatal or incapacitating injury [9]. 1753 people were reported to have died and thousands were injured in WWD crashes between 1996 and 2000 on all types of roadways, ranging from 300 to 900 fatalities per year indicating the significance of the problem Studies conducted by other states showed different frequencies with an average of 35 WWD fatal crashes per year in California (1965-1985); an annual average of 9 on the interstate highways in Connecticut (2004-2006); 49 fatal WWD crashes on the interstate freeways of New Mexico between 1990 and 2004; and 162 WWD crashes on freeways of North Carolina between 2000-2005. In Illinois, studies on WWD have shown that 87% of fatal crashes and 71% of A-injury crashes are head-on. On average each wrong way fatal crash resulted in 1.4 fatalities while each wrong way A-injury crash resulted in 2.1 incapacitating injuries [10]. A more detailed study on WWD crashes on Illinois freeways revealed that that a large proportion of WWD crashes occurred during the weekend from midnight to 5 a.m. About 80% of WWD crashes were located in urban areas and nearly 70% of wrong-way vehicles were passenger cars. Approximately 58% of wrong-way drivers were driving under the influence (DUI). Of those, nearly 50% were confirmed to be impaired by alcohol, about 4% were impaired by drugs, and more than 3% had been drinking [11].

RESULTS AND DISCUSSION

Analysis of the characteristics of reported freeway-related WWD crashes revealed that a high majority of WWD incidents were reported to involve drunk drivers where the majority of wrong-way drivers are those who operate their vehicles under the influence of alcohol [9]. Only 4 out of the 31 wrong- way crashes studied were caused by a person that was found to have medical issues. NTSB study [7] reported that 69% of wrong-way drivers have a Blood Alcohol Content (BAC) greater than the legal limit of 0.08 g/dL. The statistics show that most of the wrong-way driving occurs between 12 am to 5 am and peaking at 2 am which supports the study findings

Various studies in different countries such as France [12] and Japan [13] have analyzed the characteristics of WWD crashes. The results showed consensus that were summarized as below with the figures between brackets being indicative [1].

WWD crashes are more likely to occur on non-freeway roads than other crashes. They generally occur on weekends (about 43%), and during night time hours (52% between midnight and 6 a.m.) The crash locations include traveling lanes (86% with 59% of them on the most inside lane), ramps (7%) and shoulders.

The exit ramps were reported as the main entrances for WWD on highways and the partial cloverleaf interchanges experienced the majority of WWD crashes. Most of WWD crashes involved multiple vehicles(78%) and the resulting types are mostly head-on (46%) or sideswipe opposite direction crashes(22%)and 50% of crashes involved a fatality or incapacitating injury.

Most of the WW drivers involved are males (67%), particularly those in the age group of 21-35 years and greater than 65 years. Older drivers were found proportionally overrepresented in all crash types. Intoxication is a major cause of WWD; nearly 60% of wrong way drivers were intoxicated; Average BAC results for intoxicated wrong-way drivers was 0.19(80% of drivers > 0.10 while illegal limit in Illinois, for ex., is 0.08 for >21 years).

In view of the fact that WWD crashes frequently result in severe injuries and fatalities, it is necessary to investigate their contributing factors in order to reduce their risk. Much of the previous work has identified many of these factors without providing a clear methodology while some studies describing the contributing factors for both wrong-way incidents and crashes [12]. Zhou, et al. [2] investigated the main contributing factors regarding WWD on freeways but later demonstrated a methodology using the Haddon Matrix to identify the contributing factors for fatal and severe injury wrong-way crashes in Illinois. They employed the Analysis of Variance (ANOVA) and Tukey test as well as a simulation technique known as bootstrapping to rank the contributing factors [13]. In their most recent research causal tables were generated based on the police crash reports, in which the percentage of crashes caused by each factor is calculated. Based on these percentages, the contributing factors are ranked then Haddon matrix was used as before [14] .

The most significant human factors identified include younger drivers (age 16-24), older drivers (age older than 65), alcohol impairment, drug impairment, physical condition, and driving skills, knowledge, and experience. The most significant vehicle factor is the vehicle maneuver of avoiding vehicle and objects, and failing to use seat belts (especially for fatal crashes). The most significant environmental factors include road darkness. It is worth noticing that not using seatbelts were ranked within the top 10 factors in fatal and Injury crashes, but not in B-injury crashes, indicating that seatbelts contribute to reducing fatalities and A-injuries caused by wrong-way crashes.

Jadaan [1] summarized the leading contributing factors to WWD crashes as follows: Driving under the influence of alcohol/drugs; Suicidal drivers; Unintentional (confused and elderly) drivers; Wrong entries

and suspected dementia; Making U-turns on the main carriageway; Intentional WW drivers (trying to save time and /or toll money); Non commuter drivers; Lack of inappropriate signage and pavement marking; and Confusing geometric design.

Having conducted the wrong way crash analysis, general countermeasures are suggested to reduce wrong way driving incidents and to provide a consistent approach to wrong way treatments. There are no consistent guidelines for WWD mitigation at the national level in the USA or at the international level. Best practices are developed through a 4Es approach (Engineering, Education, Enforcement, Emergency response) Given the low number of WWD crashes, expensive CMs are not recommended by B/C analysis and cost-conscious CMs should therefore be developed.

The NTSB report [7] found that the majority of wrong-way drivers are those who operate their vehicles under the influence of alcohol. The other major portion of wrong-way driving involves the elderly who have an age of 70 years old or above. Therefore, the wrong-way driving prevention techniques have put priority on addressing Driving Under the Influence (DUI) wrong-way drivers.

Intervention strategies designed to reduce the prevalence of impaired driving would most likely reduce the number of fatalities because of wrong-way collisions. Proposed prevention strategies include lowering the legal limit for BAC, sobriety checkpoints, compulsory blood testing following injury from a traffic crash, swift suspension of driver's licenses from people driving while intoxicated and community traffic safety programs.

Physical barriers, including guardrails could be installed to prevent entry onto interstates from nonstandard entry points. Placing concrete barriers between lanes, particularly in areas with narrow medians, to prevent U-turns and crossovers could also reduce the number of drivers traveling against traffic. Improved lighting and signage at interstate entry points may assist drivers in choosing the correct entrance ramp, as the majority of fatalities occurred at night when visibility is reduced [15].

There are many wrong-way countermeasures, but it is not clear which of them are the best. Despite numerous CMs to mitigate WWD issues, little research was carried out to investigate the effectiveness and the level of acceptance of these CMs. A recent work by Pour-Rouholamin et al [16] studied and analyzed emerging CMs currently employed in various American jurisdictions. The results of the study identified engineering CMs (with 91.7%) as the priority choice to mitigate the WWD issues.

Considering the effectiveness of the various wrong-way prevention methods, the prevention techniques can be roughly categorized as follows [8]:

A. ***Warning signage –*** *Warning signs that would be more obvious including*

1. Red retro reflective tape on mounting poles and signs can improve visibility.
2. Signs with LED lights are more visible, but it is more expensive.
3. Barrier delineator that would be visible when traveling the wrong-way.

B. ***Geometry of interchanges***

1. Acute angles between the interchanges and the access roads can help guard against WWD.
2. Two way frontage roads are more susceptible to WWD.
3. Full Cloverleaf design has less WWD than Full Diamond or Half Cloverleaf interchange designs.

C. ***Detection system –*** *A detection system that uses advanced technology would help warn others and notify law enforcement personnel of an early instance of WWD, giving them a quicker response time.*

1. Detections of wrong-way drivers.
   a. Inductions loop.
   b. Magnetic sensors.
   c. Video Image Processors (VIP) – use video to find the car and direction of travel.
   d. Microwave radar.
2. Use changeable message signs (CMS) to alert drivers that a wrong-way driver is on the highway.
3. Pavement embedded warning lights can deter WWD.

D. ***Law enforcement –*** *Set up check points at problem areas.*

1. Police stops/check points at problem areas.
2. Methods to stop wrong-way.
   a. Tire deflation.
   b. Parallel with wrong-way driver and use signals and sirens to stop the driver.
   c. Use car to ram the wrong-way driver or create roadblock.
   d. Pin wrong-way driver's car to the median with law enforcement vehicles.
3. Wrong-way crash reporting – report entry point.
4. Require ignition interlock system (IIS) for Driving Under the Influence (DUI) offenders.

E. ***Education****- Educate the populace about the dangers of drunk driving.*

Intelligent Transportation Systems (ITS) treatments related to wrong way countermeasures may also be recommended. A number of the states, mainly Florida, are experimenting with wrong way detection devices and LED-illuminated signs to increase the conspicuity of WRONG WAY signs. Applications of existing on-board navigation systems (i.e. in-vehicle systems, portable systems, cellular devices) may be an opportunity for future development of wrong way detection and cross-system communication to notify a wrong way driver and to warn other motorists of the wrong action [17].

The results revealed some valuable findings which may be summarized as follows:

- About 50% of freeway WWD crashes were fatal or incapacitating injury, and on average each wrong way fatal crash resulted in 1.4 fatalities.
- WWD crashes were found to generally occur on weekends and during night time hours. The crash locations include mostly the inside traveling lanes with the exit ramps being the main entrances for WWD.
- Most of WWD crashes involved multiple vehicles, and the resulting types are mostly head-on.
- Most of the WW drivers involved are males and older drivers were found proportionally overrepresented in all crash types.
- Intoxication is a major cause of WWD; about two third of wrong way drivers were intoxicated with their average BAC results 0.19 much above the legal limit of 0.08.
- Beside driver errors, the leading contributing factors for WWD included road and control errors such as Lack of inappropriate signage and pavement marking; and confusing geometric design.

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