PROPOSAL FOR A NEW METHOD FOR WRONG WAY DETECTION

Siniša Babič, Marko I. Valič
University of Ljubljana, Faculty of maritime studies and transport
Pot pomorščakov 4, SI-6320 Portorož, Slovenia
babicsine@gmail.com, marko.valic@fpp.uni-lj.si
Samo Golob, Tomaž Tekavec
Sipronika d.o.o
Tržaška cesta 2, SI-1000 Ljubljana, Slovenia
samo.golob@sipronika.si, tomaz.tekavec@sipronika.si

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 they are more likely to produce serious injuries and fatalities compared to other types of freeway crashes. In the contribution results of a research involved gathering information on the issues, causes and consequences of wrong way movements on freeways is presented. A survey of passive and active methods used world-wide to reduce the number wrong way entries is made. In Slovenia this problem emerged relatively recently due to late construction of state's highway cross but it has intensified especially after recent introduction of vignettes. A review of measures made by the Slovenian motorway company is described. At the end a proposal for a new microwave method for wrong way detection is presented. This contribution is a partial result of the research project 'REMSIS' co-founded by EU incentive EUREKA and supported by the Ministry of Science and Technology of R Slovenia.

KEYWORDS: wrong-way detection, wrong-way entry, wrong-way driving, microwave detection

1 INTRODUCTION

In the states like Italy and France in which closed toll collection system via toll collection stations on entrance and exit ramps is in force, the wrong way driving on open highway practically does not exists [1]. The problem turns up in the case of open or viniette type toll collection systems with no exit/entrance toll stations, with which the control over wrong way drivers is either difficult or not exercised at all. With especially recurrent cases of wrong way driving are confronted with in the neighbouring Austria, where media in the year 2008 reported 497 such cases, and even more (519) in 2007 [2]. With high numbers of such events are engaged with in Germany, 1800 cases are reported in 2008 [1]. The key motives for wrong way driving are the following:

- badly arranged and hard to follow signalization at the entrance and exit ramps;
- unclear designations and markings of driving lanes during highway road works;
- poor visibility in unfavourable weather conditions;
- inattention of drivers, especially when driving under influence of alcohol or prohibited drugs;

- backward driving or turning maneouvers on the highway after incorrctely entering the highway or after missing an exit;
- suiside attempt;
- arrogance, a wish to prove one's courage.

In Slovenia the problem of wrong way driving emerged relatively recently due to late construction of state's highway cross and in part due to the closed toll collection system. The problem gained the attention after opening the video surveyed short tunnel Golovec on the Ljubljana ring and of the intelligent highway section Kozina–Koper (June 2004) with video detection and surveillance cameras in tunnels and in some parts on the open highway. More frequent reports in public media (radio, TV) indicate that the problem intensified after recent introduction of vignettes, thus closing the toll booth stations on exit and entry highway ramps.

There is no systematic data available. There are scattered data to be found in daily newspapers, police reports and limited information by DARS (Motorway Company in the Republic of Slovenia). Due to wrong way driving in year 2009 until Nov. 17-th there were 4 traffic accidents with total 8 deaths [3]. According to the police data there were 64 wrong way driving incidents but no death accidents in year 2008 [3,4]. In 2007 were recorded 75 wrong driving incidents with consequences of 3 death casualties and four lives were lost in 2006 due to wrong way driving [5]. Information from regional traffic management center (TMC) Kozina, 34 cases were recorded since its opening and until Dec. 2007, most of them registered in Primorska highway leg. The same source recorded about 125 cases until beginning 2010.

Vast majority of wrong way drivers correct their mistakes before causing a crash by simply turning around and heading in the right direction. None or little information is available on these ghost drivers' incidents that are resolved by themselves, because they are simply not recorded. Thus most information about wrong way driving like origin of wrong way movement and reasons for their happening (poor traffic signalization in that sector of motorway, influence of alcohol and/or drugs, age of the drivers, an intentional act or a mistake due to a misperception of installed signalization, weather conditions, etc.) we get from investigating the known wrong way driving related accidents. Based on a small sample of 'observed parameters' one cannot make a good statistics on the data from which one would be able to draw more precise conclusions about the phenomenon of wrong way driving in Slovenia.

2 WRONG WAY DRIVING COUNTERMEASURES

There are a host of potential countermeasures available to help deter or prevent wrong way movements and that type of crashes. These include devices such as embedded sensors, video and flashing lights along with spikes or other physical barrier and other conceivable means of intervention. There is no one-size-fits-all solution to this international wrong way driving problem. From a survey of the methods used four basic categories of countermeasures can be derived:

1. Modifying the geometry of motorway interchange;
2. Reinforcing traffic signage and road markings (passive systems without detection);
3. Implementing dynamic detection and alarm signs (active systems with detection);
4. Developing vehicle stopping systems coupled or not with detection devices.

2.1 Modifying the geometry of motorway interchanges

All literature reviewed indicates that about half of wrong way movements originates from interchanges like freeway exit ramp. The aim here is to discourage wrong way entries onto freeway facilities. Geometrical modifications (e.g., changes to ramps, medians, islands or other design features) primarily involve improving the legibility of motorway interchanges with non-motorway roads so that oncoming motorists can immediately evaluate the correct ramp and not making the mistake by taking the exit ramp instead of entrance ramp and reverse. This can be achieved with some geometric treatments like:

- offsetting the entrance and exit ramps in particular at interchanges where the terminals are closely spaced;
- using an island or painted median to divide parallel adjacent on- and off-ramps to discourage wrong movement;
- off-ramp throat reductions by using curbs, delineator posts or painted islands, thus making the wrong-way movement less inviting;
- channeling the off-ramp traffic in one direction only so that a potential wrong-way driver is presented with an entry barricade (e.g. curb);
- left-hand exit ramps are obsolete and should be avoided in new construction;
- to prevent wrong way driving which begins at the junction between the entry slip road and the link section (motorway facilities), a common practice is still to reinforce the guidance of the road users entering the link section, by putting road marker posts at the end of the entry slip road;
- studies on French motorways found that reducing the number of traffic islands was a very successful measure improving the legibility of motorway interchanges and minimizing the complexity of the intersection [6]. Their multiplicity could confuse drivers and lead to wrong way driving. It is therefore preferred to have only one island (Fig. 1).

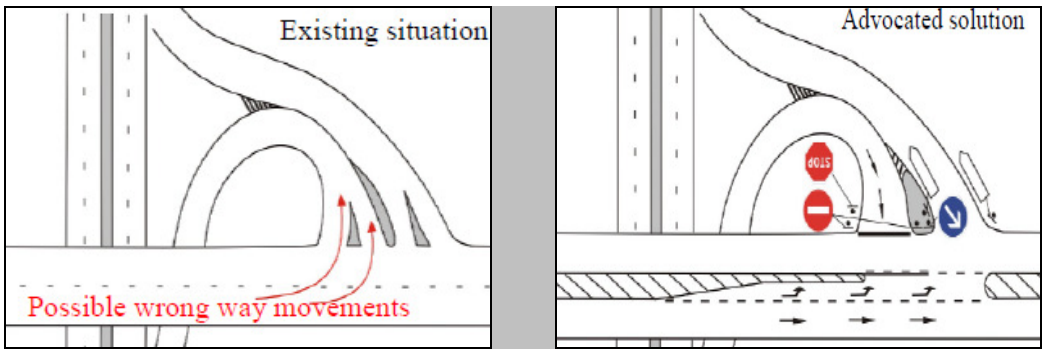

Figure 1: Existing situation and advocated solution for traffic islands

2.2 Reinforcing traffic signage and road markings

From literature search currently most efforts to resolve the wrong way driving problem is focused on reinforcing traffic signs and road markings as preventive actions implemented at the infrastructure level on motorway exit slip roads. Due to a limited number of wrong way movements (and therefore wrong way crashes) that occur on an annual basis, they are found to be the most cost effective countermeasures to reduce this kind of incidents. Reinforcing traffic signs and road markings primarily consists of:

- enlarging and lowering the 'DO NOT ENTER' signs at the intersections on both sides of the exit slip roads and the crossroads. Lowering the mounting heights makes signs more visible at night (lower signs are in the path of a car's headlights) and to impaired or older drivers, who tend to drive with their eyes low looking for visual cues from the pavement;
- lowered 'DO NOT ENTER' and 'WRONG WAY' signs mounting together on the same post;
- using signs with texts, e.g. 'WRONG WAY', DO NOT ENTER', 'NO RIGHT TURN', 'ONE WAY', 'GO BACK YOU ARE GOING WRONG WAY', etc.;
- overhead mounting 'DO NOT ENTER' and 'WRONG WAY' signs and extra overhead lighting;
- red reflective tape on the back of freeway signs;
- active road signs, like 'WRONG WAY', with red flashing beacons that is solar powered, internally-illuminated DO NOT ENTER' and 'WRONG WAY' signs or signs with flashing lights, three-dimensional signs, etc.;
- over sized wrong way pavement arrows indicating the traffic direction;
- continuous yellow edge line on the left side and white edge line on the right side of exit ramps;
- red reflective raised pavement markers on the main lanes of the highway or ramp to delineate roadways that must not be entered or used.

The above countermeasures are employed in the USA. In Europe, 'NO ENTRY' signs are systematically used on the left and the right of the carriageway on the exit ramp, with possible additional wrong way signs further along the ramp. Some countries place the 'NO ENTRY' symbol on a sign with a florescent background, systematically positioned at the end of the exit ramps. French motorway concessionary companies use painted directional arrows, road marker posts and light poles in order to visually guide the drivers coming from the entry slip roads to the link section (freeway facilities) and for better separation of traffic lanes on the two way interchange ramps.

2.3 Dynamic detection and alarm systems

Dynamic detection and alarm systems can be costly and for full coverage a great many are needed. Also, it is well recognized that there are no 100 % efficient wrong way driving detection systems. For these reasons there are very few of such systems use at present in USA and Europe. However, it is important that some exist and thus allow the detection of wrong way driving phenomenon in real time with immediate alert to a command post. A review of the literature on wrong way dynamic detection and alert subsystems is summarized in Table 1.

Table 1: Type of dynamic detection systems

Detection system	Wrong way driver alert system
- Doppler radar - Video detection - Loop detection [7] - Acoustic sensors with multiple detection zones [7] - Electromagnetic sensors	- Luminous signaling (diode panels or flashing lights) - Light barriers - Sound alarms

2.4 Developing vehicle stopping systems coupled or not with detection devices

The main goal of this last idea is to prevent ghost drivers from entering the motorway through the use of vehicle stopping systems such as physical barriers and spikes.

3 REVIEW OF COUNTERMEASURES IN SLOVENIA

Led by examples of many European countries DARS adopted on SLO motorways a big stop sign with yellow fluorescent background, red no entry symbol and black 'open hand' with text 'NAPAČNA SMER' ('WRONG WAY') underneath. These are posted on one side only (right for the offending driver) of every exit ramp close to the junction with the highway. A second measure was to paint large white arrows on the road surface near the junction exit ramp/local road, pointing the right way (contra for the ghost driver).

An experimental dynamic microwave/video wrong way detection system was installed on the exit ramp (two lanes in the same directions) Koper freeway H5-Trieste. From geometrical reasons this area is potentially a dangerous location origin for wrong way driving. The problem is the entrance to the OMV gas station from the exit ramp. Some drivers in the past mistakenly used this entrance as the exit from the gas station and thus proceeded wrong way on H5 exit ramp. The road situation and the layout of the wrong way detection system at this site is shown in Fig. 2 [8].

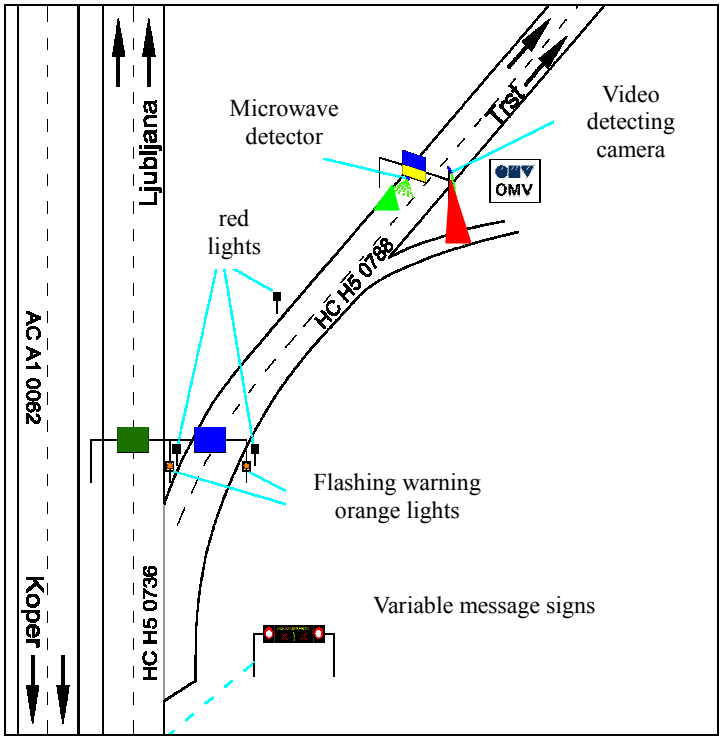

Figure 2: Layout of the wrong way detection system in the area of exit ramp H5 for Trieste

The system comprises of one microwave- and a video-detector, each set to monitor its own lane: radar the overtaking lane of H5 exit ramp (green mark) and camera (red mark) the entrance lane to the gas station. The first detects wrong way moving motorist coming from Bivje rondo and the second motorists from the gas station. A view of the dangerous area with detection zones is shown in Fig. 3 [8].

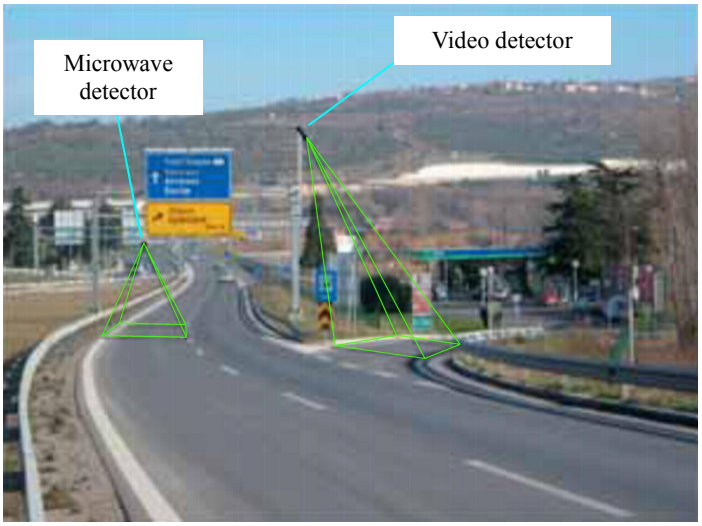

Figure 3: Microwave and video detection monitoring zones at H5 exit ramp to Trieste

The system is connected to the TMC center Kozina. A wrong way alarm is triggered immediately after a vehicle passes the wrong way under the radar detector or video camera. An appropriate simulation shows up on the large SCADA display in the TMC center. At the same time a VMS sign above H5 freeway, 300 m before Bertoki exit ramp, automatically sets the speed limit to 60 km/h and a text message 'VOZITE PREVIDNO/DRIVE CAREFULLY' (Fig. 4, left). At the exit ramp H5-Trieste two orange flashing warning lights for correct- and two red lights for wrong-driving motorists are placed (Fig. 5). Meanwhile the operator in TMC center must convince himself of the presence of wrong way driving vehicle using video surveillance system. When assured, he confirms the alarm and the message on the VMS sign automatically changes to 'VOZILO NASPROTI/WRONG WAY DRIVE' (Fig. 4, right), instructing drivers to stop due to the wrong way driving vehicle.

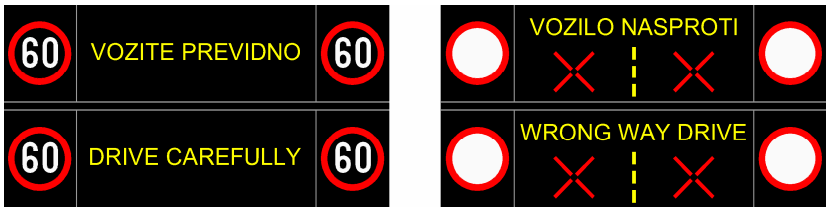

Figure 4: VMS signs in a case of wrong way incident; unconfirmed alarm (left), confirmed alarm (right)

Figure 5: Warning signalization on exit ramp (left for correct-, right for wrong-way driving motorists)

4 PROPOSAL FOR A NEW DYNAMIC WRONG WAY DETECTION SYSTEM

The newly proposed light-radar ITS system for automatic detection and reporting wrong way highway entry is composed of a microwave unit, control unit, communication interface, warning luminous signalization and power supply [9]. The detection part of the system is based on one or more Doppler radars set up on motorway exit ramp. When wrong way driving vehicle is detected, the system automatically activates special luminous signalization warning the driver about his or hers error. In the case that the driver does not pay regard to the warning sign, thus continues driving in the wrong direction, the system sends an alarm message, via a suitable communication channel at hand on the specific location, to the regional traffic control center. From here an operator can take suitable prompt actions, e.g., road closure via LED VMS signs. The possibilities of wire, wireless or optical communication are foreseen. The system could be upgraded with video surveillance for documenting the incident.

It is recommended to use several radar detectors to improve effectiveness and faster detection of wrong way entries and to eliminate or reduce the number of false alarms. These should be suitably arranged with regard to given circumstances on a specific ramp. An example of such an installation with three detectors is shown on Fig. 6. It is seen that with three detectors properly spread along the highway exit ramp, almost entire ramp can be monitored. That eliminates the possibility of false alarms almost to the zero, because if one detector makes a false alarm, there are still two left to confirm or to refute the incident. Radar detector 1 with somewhat large range (yellow) is directed toward the junction exit ramp - local road. It detects only an approaching, wrong way driving vehicle. When wrong way driving vehicle is detected by radar 1, the system automatically activates light warning signalization. From here two scenarios can happen: the driver observe or does not observe the warning sign. In the first case he stops, turns the flashing lights of his vehicle and proceeds backwards to the local road junction. His behavior is detected by radar 2. In the second case, the driver does not pay regard to the flashing warning sign and continues in the wrong direction, he will be detected with radar 3 (red). That should happen the system sends a high priority alarm message, via a suitable communication channel at hand on the location, to the regional TMC center for which prompt actions.

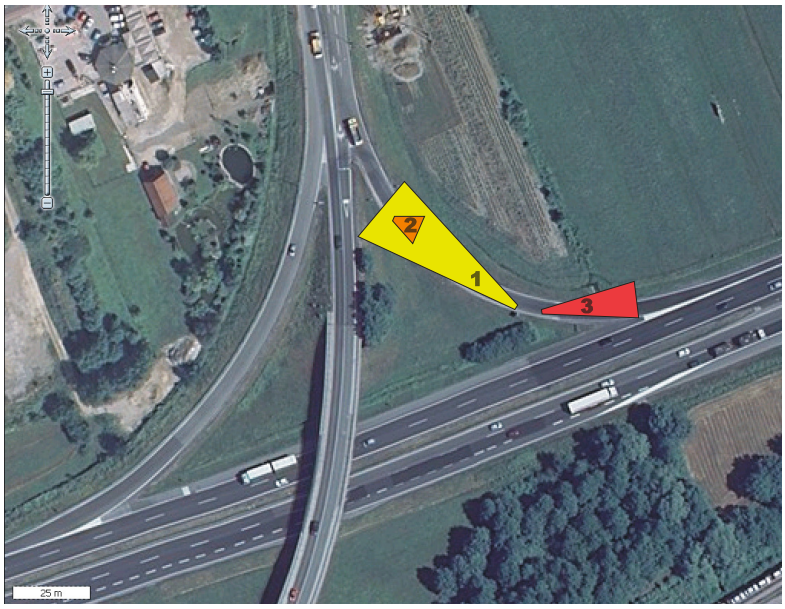

Figure 6: Example of system layout with three radar detectors

The use of a radar based wrong way detection system has the following advantages:

- non-intrusive installation (no interventions into pavement surface);
- possibility of changing the detecting zone in order to adapt to conditions of a specific location;
- detection in fog and bad weather conditions;
- possibility of wire or wireless communication with a control unit or control center;
- relatively low overall (acquisition, installation, maintenance) costs.

Apart from radar detectors the system includes a control unit which provides the following tasks:

- communication with individual radar detectors;
- carrying out wrong way entry algorithm computations;
- communication with traffic control centre;
- controlling warning luminous signalization and triggering alarms (Fig. 7);
- examining system status, power supply voltage, detecting and notifying malfunctions in performance of individual components of the system.

Apart from powering electrical network, the system should also be able to operate autonomously with its own power supply with the use of storage batteries and solar panels. An example is shown in Fig. 7. Four flashing lights are added in each corner of the large standard 'open hand' traffic sign. The appearance of the sign to the driver in standby or activated condition (day- and night- time) is also shown. The warning light signalization and the solar panel is possible to mount on the existing wrong way warning panels.

Figure 7: Installation example of the proposed light signalization wrong entry warning sign and solar panel; day time standby (left), day time activated (center), night time activated (right)

5 CONCLUSIONS

Drivers who make wrong way entries onto freeways pose a serious risk to the safety of other motorists and themselves. Wrong way crashes are relatively infrequent but they are more likely to produce serious injuries and fatalities compared to other types of freeway collisions.

The aim of this paper was to summarize the state of knowledge on the issue of wrong way driving and to propose a novel dynamic wrong way detection method with a special alert system. The main findings and results are:

- An information research on the issues, causes and consequences of wrong way movements on freeways was made.
- A survey of passive and active methods used world-wide to reduce the number wrong way entries has been done.
- In Slovenia the wrong way driving problem emerged relatively late but it has intensified after introduction of vignettes.
- A review of countermeasures taken by DARS Motorway company is given.
- A proposal for a novel microwave based wrong way detection and alert system is given. The system merits setting up a pilot project in order to make experimental assessments and technical improvements before being integrated into national roads. Attempts to get an interest in the project by responsible Slovenian authorities are in progress.

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