Characteristics of and Current Countermeasures against Wrong-Way Driving on Japanese Expressways

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Abstract: On Japanese expressways, neither the number of secured wrong-way driving incidents nor the estimated number of unsecured wrong-way driving cases decreased from 2015 to 2023. It means that current countermeasures may not be effective in preventing wrong-way driving. In order to propose more efficient countermeasures, it is necessary to reveal the cause of wrong-way driving, including the secured and unsecured wrong-way driving. Because data of the unsecured cases is not available, this study first analyzes the secured cases for which expressway companies collected and made data available. As a result, it reveals that about one third of the secured cases occurred around toll plaza, and approximately 77% of the secured cases involving normal drivers (neither dementia nor MCI state) were attributed to incorrect destinations.

Keywords: Wrong-way Driving, Expressway, Traffic Accidents, Secured Case, Countermeasure

1. INTRODUCTION

Recently, wrong-way driving on Japanese expressways has become a social problem. For example, a wrong-way driving light-van had a head-on collision with a right-way driving vehicle on Tohoku Expressway in Tochigi-Prefecture of Japan. In this traffic accident, both drivers died and two children of the right-way driving vehicle were injured. Similarly, some serious accidents that are caused by wrong-way driving happened in various regions on Japanese expressways. Not only these serious wrong-way driving accidents but also a lot of wrong-way driving cases that did not cause any accidents also happen each year on Japanese expressways. Expressway companies that operate expressways have been installing various countermeasures for preventing wrong-way driving, aiming to achieve zero serious traffic accidents that are caused by wrong-way driving on expressways by 2029.

However, as detailed in Chapter.2, expressway companies recognize only cases that led to any accidents or cases that drivers were stopped by police or patrol units, as wrong-way driving cases. Hereinafter, we call these cases “secured cases”.

On the other hand, in reality, there are also cases that did not cause any accidents and were not stopped by police or patrol units, but eventually returned to right-way driving somewhere. Hereinafter, we call these cases “unsecured cases”.

As detailed in Chapter 3, the numbers of the secured and unsecured cases don’t decrease despite implementing various countermeasures for preventing wrong-way driving. This

situation indicates that the effectiveness of measures is not sufficient. Therefore, we must propose other countermeasures by understanding the root cause of wrong-way driving. To achieve this, it is essential to uncover actual status of wrong-way driving including both the secured and unsecured cases.

Regarding previous studies on wrong-way driving, many researches ([1]–[9]) have evaluated existing countermeasures or geometric structure at facilities where wrong-way driving occurred based on the secured cases. For instance, Pour-Rouholamin et al. (2015) [1] analyzed the effectiveness of implemented measures for preventing wrong-way driving by administering questionnaire surveys to representatives from 23 U.S. states where wrong-way driving have happened. They pointed out the lack of wrong-way related signs, issues with their orientation, and other issues with current measures. Das et al. (2018) [2] statistically analyzed five-year data concerning wrong-way crashes in Louisiana, USA, and sought to identify factors strongly associated with fatal wrong-way crashes, such as driver gender, the influence of alcohol, or the time of occurrence. Vaswani (1973) [3] focused on wrong-way entries from local roads onto highways in Virginia, USA. By analyzing three-year data, he identified locations prone to wrong-way entries and proposed countermeasures based on observations at each site. Carter et al. (2018) [4] analyzed crash report forms and conducted field observations at wrong-way crash sites on highway entry and exit ramps in North Carolina, USA, to propose countermeasures from the perspective of geometric structure and traffic management, including elements like pavement markings and signs. In additions, Campbell et al. (2020) [5] proposed wrong-way countermeasures by focusing on evasive maneuvers performed by right-way drivers in response to oncoming wrong-way vehicles.

However, while all of these studies provide significant insights into understanding the circumstances of wrong-way crashes and proposing countermeasures, they have not been able to uncover the root causes of wrong-way driving due to their lack of focus on wrong-way driving incidents, including the unsecured cases. Furthermore, Sandt et al. (2017) [10] revealed that the number of wrong-way driving incidents was far greater than that of reported cases based on a survey on highways in Florida, USA. This finding supports the importance of focusing on the unsecured cases.

However, it is difficult to determine the characteristics of the unsecured cases. Therefore, this study firstly focuses on the secured cases to understand where and how those cases occurs. Then, based on this understanding of facilities or structures involved in the secured cases, we aim to understand the entire feature of wrong-way driving including the unsecured cases in the future.

The Ministry of Land, Infrastructure, Transport and Tourism of Japan published a report on wrong-way driving (the secured cases only) that occurred on expressways in Japan in 2024 [11]. The data, however, both urban expressways and intercity expressways. Since the two types of expressways have different road structures such as a shape of interchanges (ICs) and cross section, it is possible that the tendency of wrong-way driving occurrence is different between them, and so far few studies have analyzed each of them separately. For this reason, this paper will report the occurrence of wrong-way driving on intercity expressways that NEXCO East, NEXCO Central and NEXCO West (hereinafter as “NEXCOs”) operates. And we will focus on the necessity of conducting wrong-way driving countermeasures. The total length of expressways that are managed by NEXCOs is 9,723km as of March 31, 2024.

2. CURRENT OCCURRENCE OF WRONG-WAY DRIVING ON EXPRESSWAYS

2.1 Current Situation of the Secured Cases

Figure 1 shows the number of wrong-way driving incidents on expressways that were secured from 2012 to 2023. The red bars mean the fatal accidents, orange ones the injury accidents, green ones the property damage only (PDO) accidents, and light blue ones represent the slight wrong-way driving incidents otherwise. These are the secured cases. Figure 1 shows that the number of the secured cases of wrong-way driving incidents has remained flat although it varies from year to year. The reason for decrease in 2020 is due to the significant decrease in traffic demand caused by COVID-19 pandemic.

2.2 Current Situation of the Unsecured Cases

In addition to the secured cases, there are also the unsecured cases. Obviously, they have a risk of causing a serious accident as the example introduced in Chapter 1 if a vehicle causes collision with other vehicles. Therefore, it is very important to grasp the actual situation of all wrong-way driving incidents, including the unsecured cases, in order to consider new countermeasures.

Because it is difficult to exactly grasp the number of the unsecured cases of wrong-way driving on expressways, this paper focuses on the number of reports by telephone and so on instead of the unsecured cases. These reports include the information of not only the secured cases but also the unsecured cases of wrong-way driving on expressways. In Figure 1, the number of the reports since 2017 (when reports data became available) is superimposed on the number of the secured cases. Although the number of the unsecured cases cannot be precisely confirmed, if we consider it as the difference between the number of reports and the number of

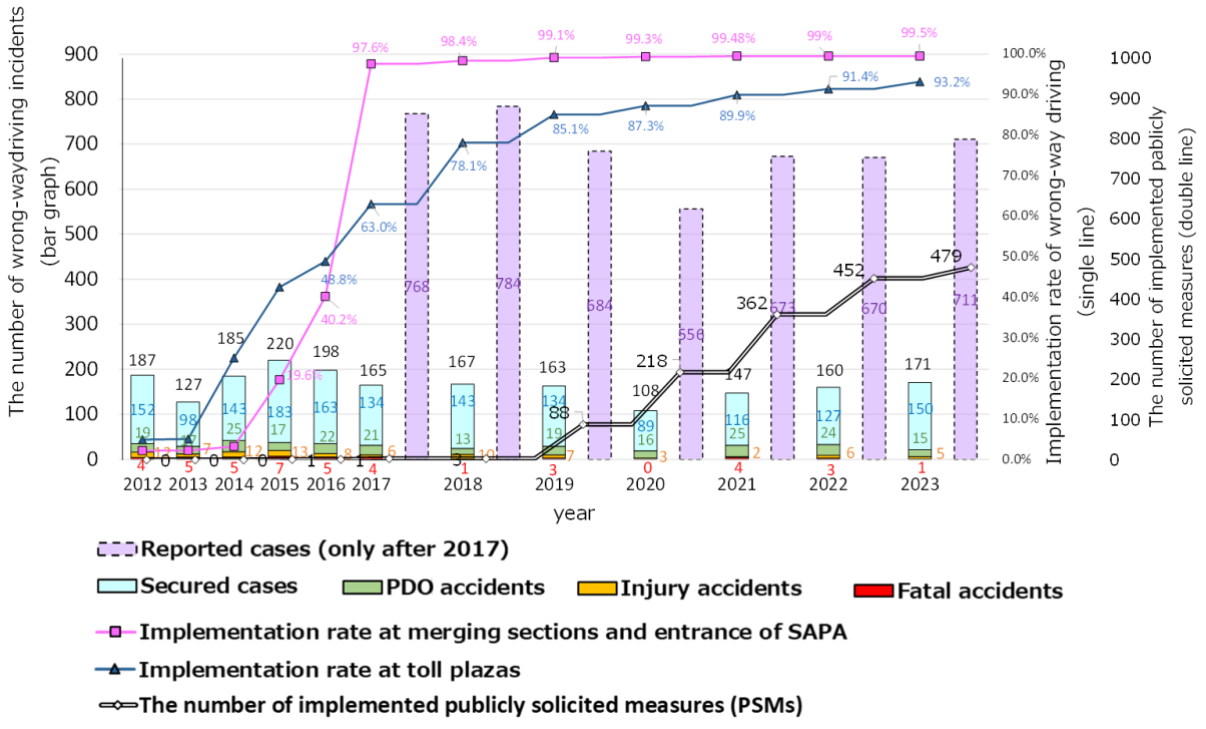


Figure 1. Number of the secured cases of wrong-way driving, reported cases, and implementation rate of measures

the secured cases, Figure 1 shows that the number of the unsecured cases has remained flat as approximately 600 per year. Therefore, it can be said that both the secured and unsecured cases of wrong-way driving on expressways have remained flat.

3. CURRENT COUNTERMEASURES TAKEN TO PREVENT WRONG-WAY DRIVING ON EXPRESSWAYS

To tackle the wrong-way driving on expressways, NEXCOs have conducted various countermeasures for preventing wrong-way driving on expressways.

3.1. Common Countermeasures Taken All over Japan (Basic Measures)

NEXCOs have implemented countermeasures as basic measures to prevent wrong-way driving at merge sections, entrance of service area and parking areas (hereinafter, as SAPAs), toll plazas, and connection area between local roads and expressways. At merge sections of mainline, the basic measures consist of no-entry signs, arrow signs, arrow markings, and rubber poles between mainline and acceleration ramp. And also at the entrance of SAPAs or merge sections between ramps of ICs or junctions (JCTs), the basic measures consist of no-entry signs, arrow markings, arrow signs and warning signs displaying “Stop! You are driving wrong-way!” as shown in Figure 2. On the other hand, at toll plazas, in the case that there are any apertures before and after toll gate, they have been blocked by physical items like barricade as basic measures. Furthermore, at connection area between local road and expressway, besides the basic measures, colored horizontal signs have also been conducted to guide drivers to expressway entrance easily.

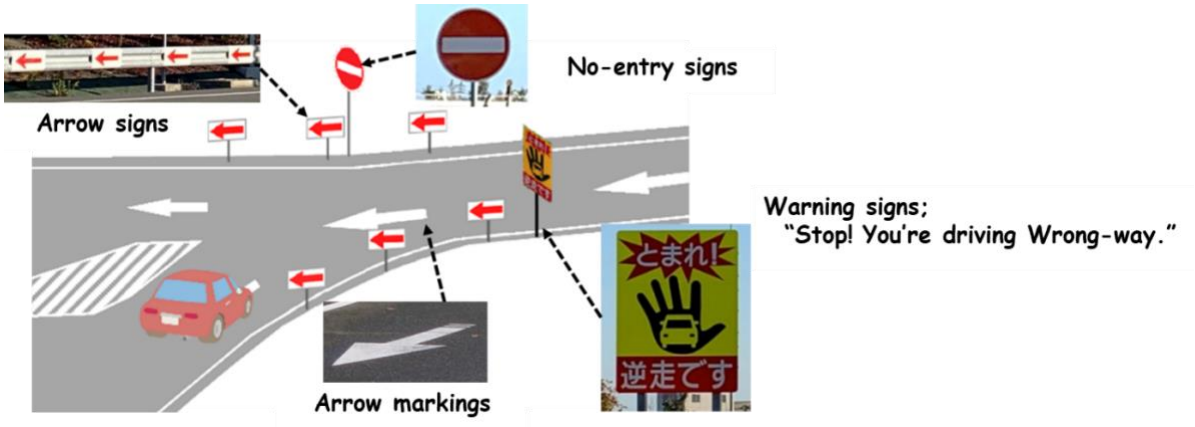


Figure 2. Basic measure at entrance of SAPAs

3.2 Publicly Solicited Measures to Prevent Wrong-way Driving

Besides the basic measures, NEXCOs have also invited applications for countermeasures against wrong-way driving and have implemented these countermeasures. This paper calls these countermeasures “publicly solicited measures (PSMs)”. They consist of five themes. Theme 1 is a technology that is installed on the road side and is visually appealing to drivers. Theme 2 is the technology to detect wrong-way driving on the road side and collects such information. Theme 3 is the technology to warn drivers who are driving the wrong-way on the car side. The technologies of these three themes were publicly solicited in 2016 [12].

Theme 4 and theme 5 were newly solicited on December 20, 2024 [13]. Theme 4 includes two technologies; (1) detecting wrong-way driving vehicles by current road management devices as CCTV cameras, (2) alerting both wrong-way driving vehicles and right-way driving vehicles based on the detected information of wrong-way driving. Theme 5 is a technology that allows a vehicle driving the wrong-way to recognize its own fault and alert and warn the driver.

Sakamoto et.al (2024) [5] focused on theme 1 of the PSMs. They made VR videos of wrong-way driving and also made right-way driving VR videos as dummy. Then they conducted subject-based experiment by showing these VR videos randomly from the viewpoint of (1) whether the subjects noticed that they were driving wrong-way or not, (2) whether the timing of noticing wrong-way driving became earlier or not (Figure 3). As a result, they reported that the effect of the PSMs was almost equal to that of basic measures. It should be noted that the experiment by Sakamoto et al. focused on an evaluation of whether the driver can notice wrong-way driving earlier, which is different from an evaluation of whether wrong-way driving can be prevented.

Adapted from Sakamoto et al. (2024)

Figure 3. Evaluation of PSMs using VR videos

3.3 Implementation of Countermeasures to Prevent Wrong-way Driving

Basic measures mentioned in Section 3.1 are those that are assumed to implement at all ICs, JCTs, SAPAs. On the other hand, the PSMs described in Section 3.2 are installed depending on the occurrence of wrong-way driving at each IC, JCT, or SAPA. Implementation of both basic measures and PSMs is shown in Figure 1. The implementation of basic measures is shown by single lines (red and blue) and that of PSMs by double line.

As shown in Figure 1, basic measures almost have already finished the implement at ICs, JCTs, and SAPAs and the number of implemented PSMs is increasing year by year. Nevertheless, the number of wrong-way driving cases does not decrease as mentioned in Chapter 2. Therefore, it seems that current countermeasures may not contribute much to reduce the number of wrong-way driving on expressways.

4. DETAILED ANALYSIS OF THE SECURED CASES OF WRONG-WAY DRIVING

As aforementioned in Chapter 1, because current wrong-way driving countermeasures could not work effectively, it is desirable to explore the root cause of wrong-way driving on expressways, including the unsecured cases, and to propose and deploy new countermeasures in the future.

Although there are few studies to reveal the fact of the unsecured cases in particular, when comparing the secured and unsecured cases, it cannot be excluded that the difference between

the secured and unsecured cases may be due to factors such as different wrong-way driving distance or different levels of familiarity with highway driving, etc. Therefore, the tendency for the secured cases does not necessarily coincide with the tendency for the unsecured cases. However, identifying the root causes for every facility where wrong-way driving incidents occur, including the unsecured cases, is challenging. Therefore, as a crucial first step in estimating the areas where the unsecured cases are likely to occur - that is, the locations where the root causes of wrong-way driving (including the unsecured cases) should be primarily investigated -, the study will first analyze the areas where the secured cases are likely to happen.

Next, if almost all of the secured cases of wrong-way driving are caused by intentional driving or dementia state drivers, this tendency could be equal to the unsecured cases, then countermeasures that expressway companies implemented on the road side may not be effective for preventing wrong-way driving. On the other hand, if most of the secured cases were caused by normal (not in dementia state or drunk) drivers' careless mistakes, countermeasures implemented by expressway companies on the road side may be effective to prevent wrong-way driving, and it becomes necessary to understand what type of countermeasures should be made (for example, to reduce wrong destination, to reduce absentminded driving, and so on). Therefore, this study analyzed drivers' health state and motivation of wrong-way driving on the secured cases of wrong-way driving.

4.1 Occurrence Locations of the Secured Cases

First, the locations, where the secured cases of wrong-way driving occurred, were categorized into six groups (IC, JCT, SAPA, mainline, others, and unknown) as shown in Figure 4. It shows that approximately half to 60% of the secured cases happened at ICs.

Next, the locations were categorized into four groups with similar structures - (A) merge/diverge section or connection area between local road and expressway, (B) toll plaza, (C) before/after toll gate, or (D) uninterrupted section as shown in Table 1.

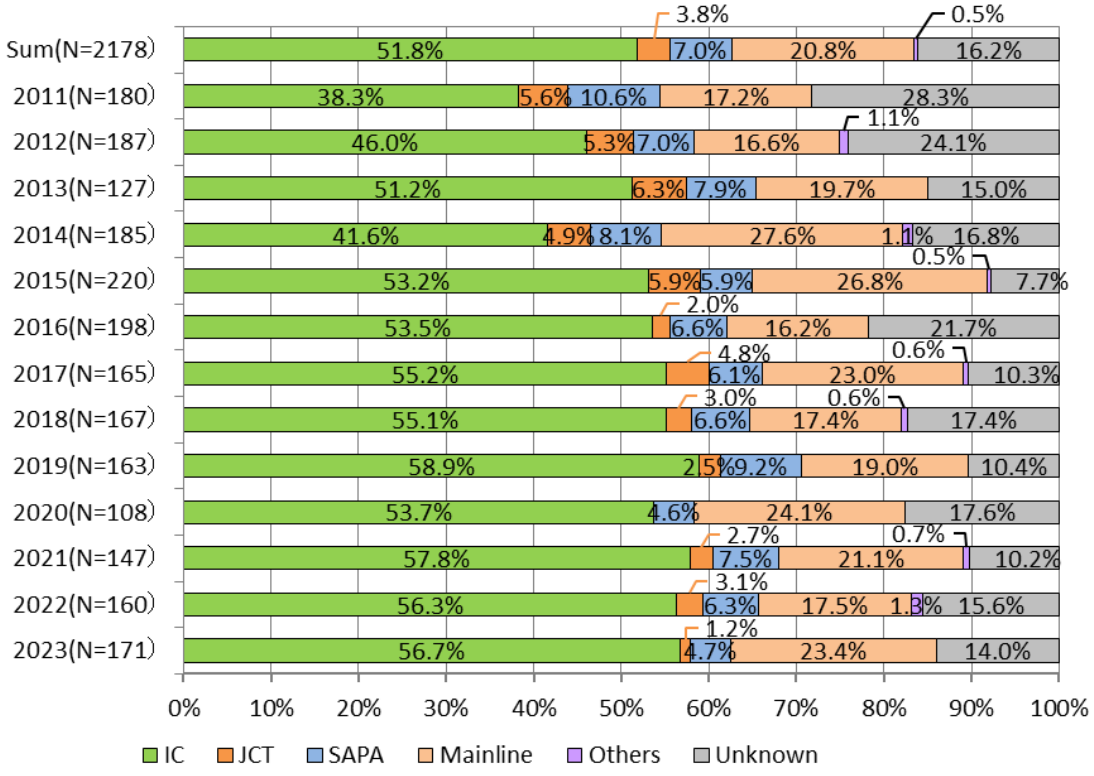
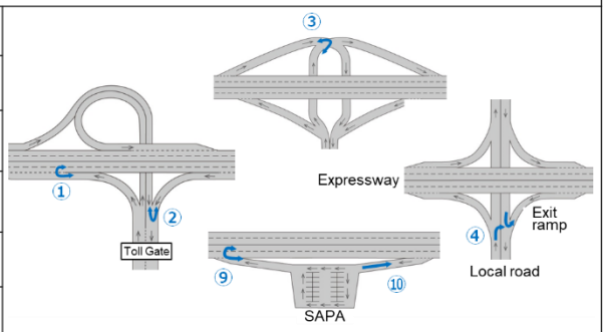


Figure 4. Occurrence locations of wrong-way driving on expressways

Table 1. The definition of division of road structures

Road Structure	Detail location	
(A) Merge/diverge sections or connection area between local roads and expressways	1. Merge section of mainline	
	2. Merge section between ramps	
	3. Planar intersection of Y-shaped interchanges	
	4. Connection area between local roads and expressways	
	9. Merge section of mainline (SAPA)	
	10. Entrance of SAPA	
(B) Toll plaza	6. Aperture at toll plaza (expressway side)	
	7. Aperture at toll plaza (local road side)	
(C) Before/after toll gate	8. Before entrance toll gate	
	11. After entrance toll gate	
	12. Before exit toll gate	
	13. After exit toll gate	
	14. Toll barrier on mainline	
(D) Uninterrupted section	5. Ramp	
	15. Mainline	

Furthermore, the road structures are further divided into 15 classifications as shown by circle numbers in Table 1. The results of the analysis, according to these 15 classifications, are presented in Figure 5. It shows that the secured cases from “15. Mainline” rank top every year. The second most was among “1. Merge section of mainline”, “4. Connection area between local roads and expressways”, “8. Before the entrance toll gate”, “11. After the entrance toll gate”, and “12. Before the exit toll gate”, although it may vary from year to year. Therefore, based on the above analysis, it can be said that the secured cases occur more frequently in the vicinity of toll plaza.

4.2. Drivers’ Attribute of the Secured Cases

In this section, attribute of drivers that were secured by wrong-way driving on expressways is analyzed. Here, as mentioned at the beginning of this chapter, differences between the secured and unsecured cases of wrong-way driving on expressways may depend on factors such as the wrong-way driving distance or driver’s familiarity with expressway driving. Therefore, it should be noted that this driver attribute analysis does not necessarily represent the actual situation of all wrong-way driving cases, including the unsecured cases.

4.2.1. Age group of wrong-way drivers of the secured cases

Figure 6 shows the result of categorizing the ages of wrong-way drivers that were secured into four age groups; under 30 years old, 30 to 65 years old, 65 to 75 years old, and 75 years old or older. From the figure, the category of drivers aged 75 and older is the most, accounting for approximately 45% of the total, with the percentage fluctuating from year to year. On the other

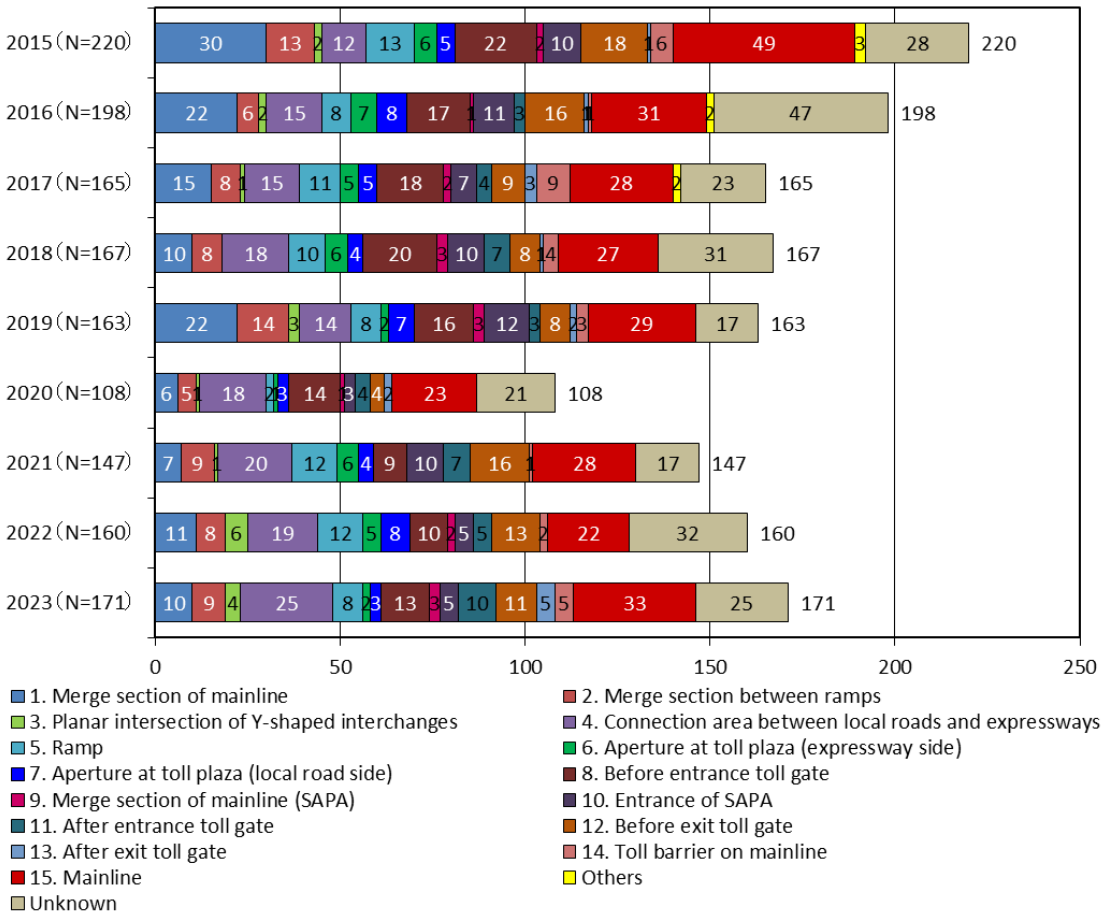


Figure 5. The secured cases of wrong-way driving occurrence based on 15 road structure classifications

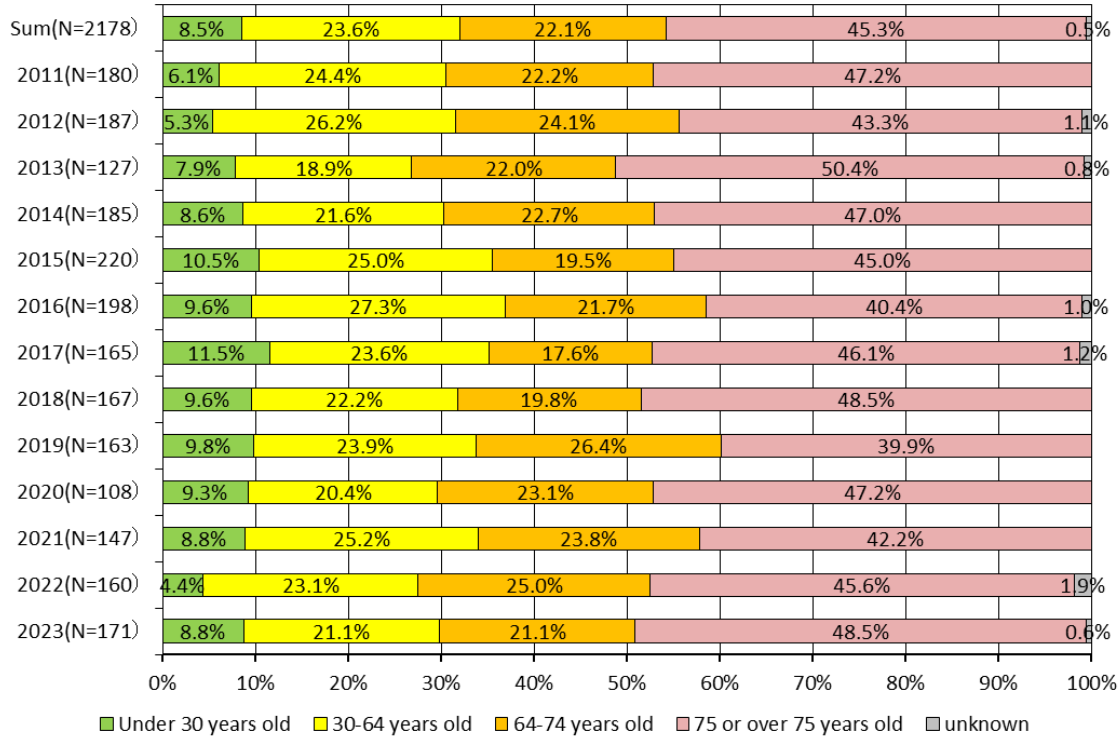
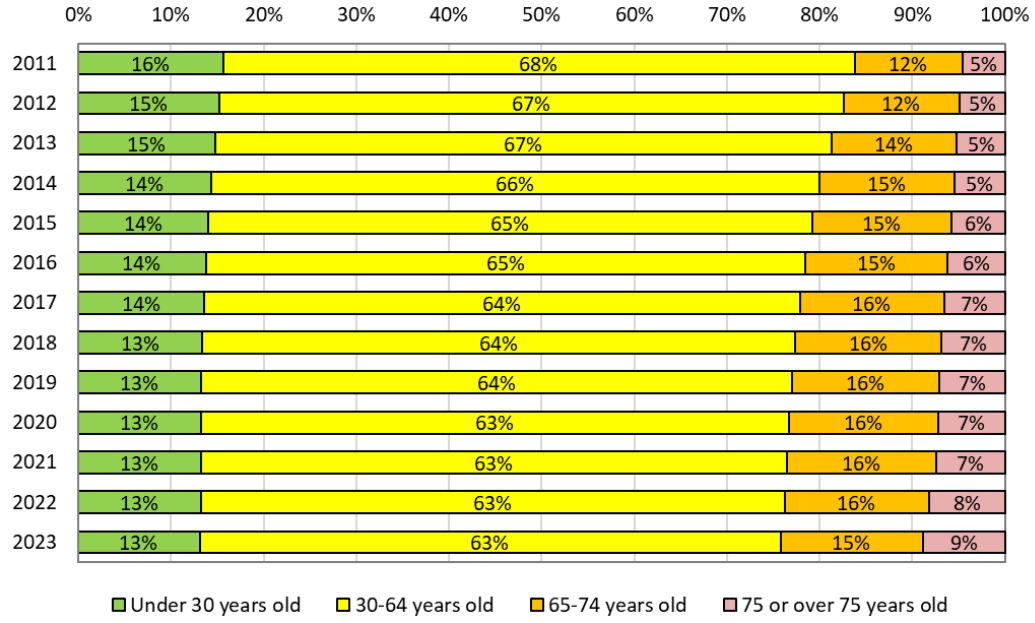


Figure 6. Age composition of wrong-way drivers of the secured cases

hand, the percentage of non-elderly drivers under the age of 65 remains approximately 30%. Here, it should be noted that this tendency is not necessarily equal to that of the unsecured cases.

By the way, from the age composition of driver license holders in Figure 7, the percentage of license holders aged 65 or older continues to rise, as if in proportion to Japan's aging population, while the percentage of non-elderly license holders under 65 continues to decline.

Therefore, if the composition rate of license holders is assumed to link to the age composition of drivers traveling on expressways, the fact that the percentage of non-elderly drivers in cases of secured wrong-way driving has remained constant, despite the fact that the percentage of non-elderly drivers under 65 years old has continued to decline, indicates that the percentage of all non-elderly drivers may be increasing among all non-elderly drivers.



Adapted from the web site of NPA (National Police Agency), Japan,
URL: https://www.npa.go.jp/publications/statistics/koutsuu/menkyo.html

Figure 7. Age composition of driver license holders in Japan

4.2.2. Health condition of wrong-way drivers of the secured cases

Figure 8 shows the health condition of wrong-way drivers of the secures cases, i.e. in bad health condition that is difficult to make a right judgment such as suspect of dementia and drunk, or in healthy condition. It shows that the largest number of drivers are healthy drivers, accounting for more than half of the total, and in some years even more than 70%.

The ratio of drivers suspected of dementia or MCI (Mild Cognitive Impairment) is not low, ranging from 25 to 40%, although the ratio of healthy drivers is relatively high.

According to Vaswani (1973) [3], approximately 40% of wrong-way entry on highways in Virginia, USA, between 1970 and 1972 were attributed to drivers who were under the influence of alcohol. Furthermore, Daniel et al. (2018) [4] reported that approximately half of wrong-way crashes on highways in North Carolina, USA, between 2000 and 2013 were also attributed to drivers who were intoxicated. These findings contrast sharply with the situation in Japan, where only approximately 2% of the secured cases, as shown in Figure 8, were attributed to drunken drivers. Therefore, this indicates the necessity of exploring the root causes of wrong-way driving specific to Japanese expressways.

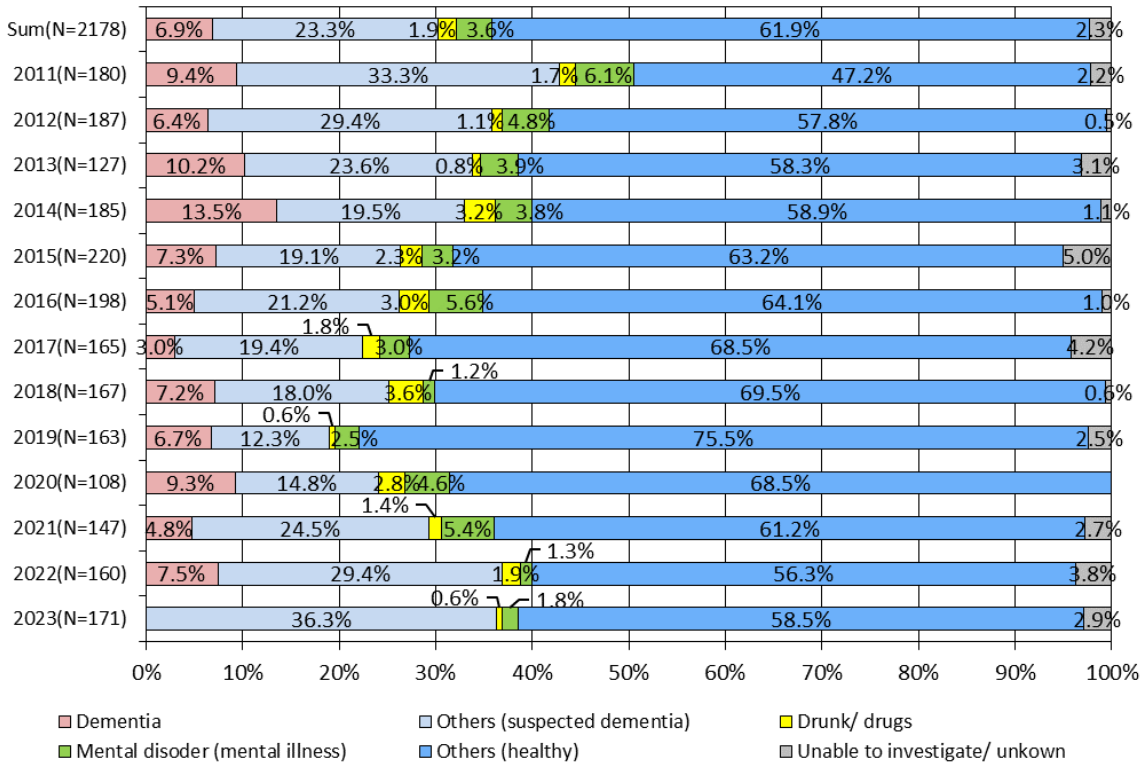


Figure 8. Health condition of wrong-way drivers of the secured cases

4.3. Drivers' Recognition at the Start of the Secured Cases

Figure 9 shows the drivers' recognition of whether they intentionally or carelessly started driving wrong-way, or whether they did not realize their wrong-way driving even when they

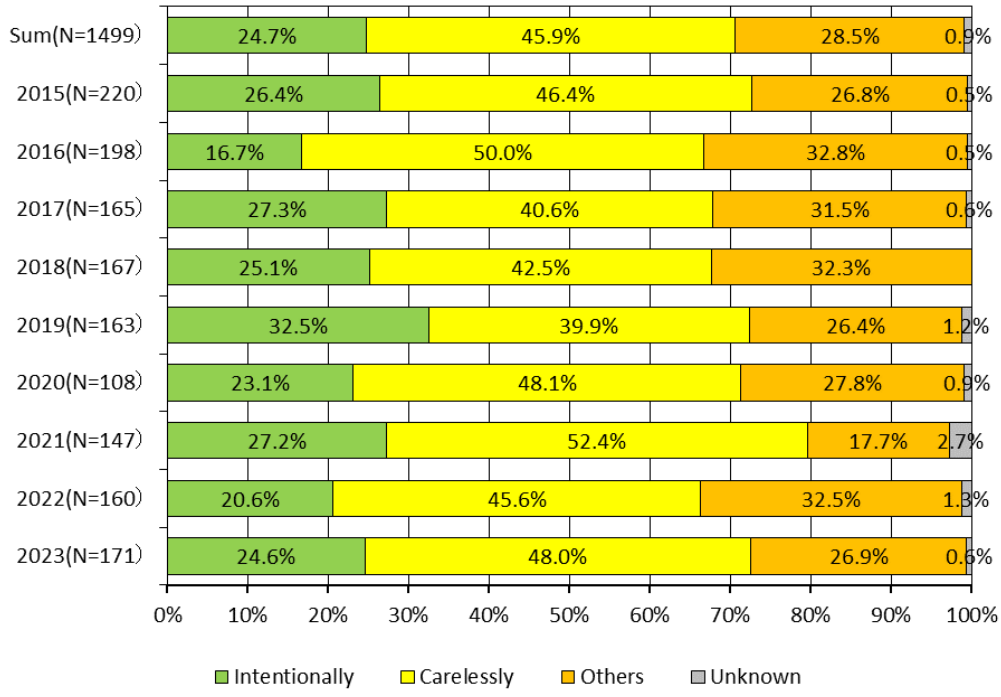


Figure 9. Drivers' recognition when starting wrong-way driving in the secured cases

were secured (expressed as “others” in Figure 9). From the figure, the ratio of drivers who carelessly started driving wrong-way is the highest, for nearly 50% in all the secured cases. The remaining intentional wrong-way driving and others, including suspected dementia and MCI, account for 20% - 30% respectively. Regarding the intentional driving, it should be noted that almost no countermeasures can prevent wrong-way driving except enforcement, because they would ignore warning signs and VMSs (Variable Message Signs) and keep driving wrong-way even if sufficient countermeasures are implemented. However, since nearly half of the secured cases are caused by driver’s carelessness or negligence, it can be expected that some measures provided by NEXCOs could prevent wrong-way driving.

Here, it is important to identify human errors that lead to wrong-way driving, especially those caused by careless driving rather than dementia or drunkenness to propose any effective countermeasures. Therefore, this study analyzed the reason for wrong-way driving by healthy drivers who were secured by wrong-way driving because of careless driving in next Section 4.4.

4.4. Cause of the Secured Cases

Figure 10 shows the cause of wrong-way driving by healthy drivers who drove carelessly wrong-way and were secured. Except for the “unawareness of driving wrong-way” and other reasons, the result shows that drivers started driving in the wrong direction mainly because of so-called “destination error” such as wrong entry or wrong diverging.

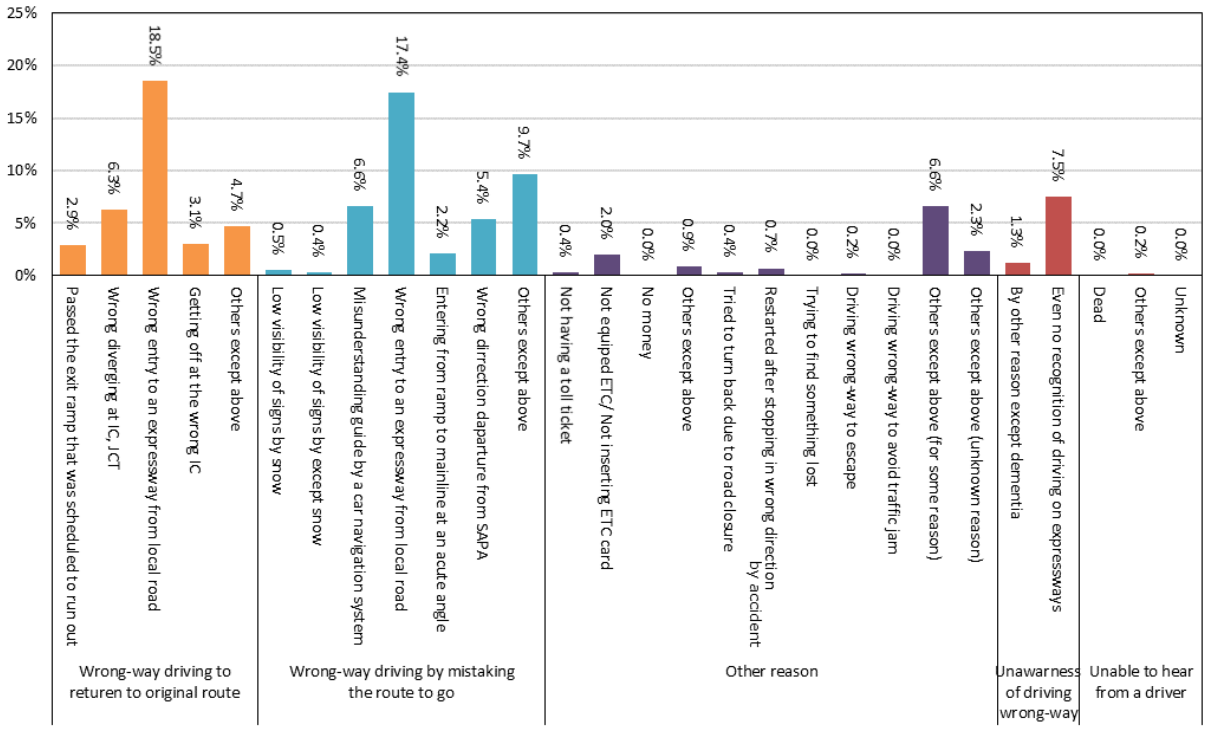


Figure 10. Cause of wrong-way driving in the secured cases

4.5. Characteristics of the Secured Cases

As the first step to grasp the actual situation of whole wrong-way driving, including the unsecured cases on intercity expressways, this paper focused on only the secured cases. As a result, although it should be noted that the tendency of the secured cases of wrong-way driving

is not necessarily the same as that of the unsecured cases, the following points can be seen from the analysis.

(1) Approximately one third of the secured cases are particularly prevalent in the vicinity of toll plaza.
(2) Approximately 60% of the secured cases are caused by healthy drivers. And, the secured cases involving drunken drivers are significantly fewer than those in the USA. In addition, the ratio of non-elderly drivers who are secured by wrong-way may be increasing among all non-elderly drivers.
(3) Nearly half of the secured cases are caused by careless driving.
(4) Approximately 77% of healthy drivers who drove carelessly and were secured is because of destination error.

Based on the above, limited to the secured cases, it can be said that if NEXCOs take measures to prevent drivers from making a destination error, it may be possible to reduce the number of wrong-way driving cases caused by carelessness of healthy drivers, thereby leading to a reduction in the total number of wrong-way driving cases. The importance of such measures can also be seen in the study by Iida et al. (2017) [14].

5. CONCLUSION AND FUTURE ISSUES

As described in Section 2.2, the current countermeasures against wrong-way driving on expressways may not be sufficient to prevent wrong-way driving, and it is necessary to clarify the root causes of wrong-way driving, including the unsecured cases. As the first step to find the locations where the root causes of wrong-way driving should be investigated and understand the actual situation of whole wrong-way driving, including the unsecured cases, we analyzed the secured case. This analysis result suggested the possibility that healthy drivers may have driven in the wrong destination in the vicinity of toll plazas, leading to wrong-way driving because of carelessness or negligence.

As a future issues, it is necessary to clarify the reality of wrong-way driving, including the unsecured cases, but, the behavior of the unsecured cases is not clear at all because they are not secured. Therefore, it is essential to obtain and statistically analyze vehicle trajectory data, for example, to clarify the actual situation of wrong-way driving, including the unsecured cases, contained within it.

Through these analyses, we hope to develop more efficient countermeasures to eradicate wrong-way driving on Japanese expressways.

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