Effects of Advanced Driver Assistance System for Elderly's Safe Transportation

An Analysis Based on Vehicles in Japanese Market Emphasizing the Accessibility Issues of the Advanced Driver Assistance System

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***Abstract*—Japan is a representative super-aging society in the world. Generally, the quality of life is closely related with the elderly's mobility or accessibility to the necessary facilities in daily life. Therefore, how to ensure the sustainability of the elderly's mobility has been a very important issue. In our previous study, we found that driving a car play a very important role in this context. On the other hand, the smart transportation system represented by Advanced Driver Assistance System (ADAS) including Advanced Emergency Braking System (AEBS) is expected to make car driving for the elderly safe and sustainable. This paper uses the data collected in Japan to show that the AEBS is very effective to ensure safe driving for the elderly. Thus, a smart mobility society can be expected in the coming years.**

Keywords- elderly's mobility; traffic safety; Advanced Driver Assistance System (ADAS); Advanced Emergency Braking System (AEBS); diffusion of innovations.

I. INTRODUCTION

Japan is well-known as a super-aging society in the world. To make this super-aging society sustainable, the countermeasures securing mobility and accessibility of elderly people have been discussed for a long time not only in Japan but also in the world. Generally, a sustainable public transportation system is considered to be the best solution. However, it is very difficult to achieve this goal successfully. For example, in the Chukyo metropolitan area of Japan where the central city is Nagoya, from 2001 to 2011 (refer to [1]), the number of elderly people being 65 years old and over increased from 1.5 million to 2.0 million (about 1.4 times). Although the public transportation services have been promoted with some incentives for the elderly people, the rail system uses only increased from 158 thousand to 199 thousand (about 1.26 times) and the bus users even decreased from 89 thousand to 88 thousand (0.99 times). In contrast, the automobile users increased from 1.25 million to 2.46 million (about 2.0 times).

Regarding the automobile use of the elderly people, the Japanese government has released the analysis reports many times on the traffic accidents (for example [2]). The fatalities in 24 hours caused by traffic accidents in Japan have been reduced to 3904 persons in 2016 from 6415 persons in 2006. However, the elderly rate is increased from 44.3% in 2006 to 54.8% in 2016. Although we know that the major reason is that the percentage of the elderly people is increasing, more effective countermeasures are required.

As a good solution, autonomous vehicles are rapidly becoming the focus of attention to ensure the accessibility need of all people in the future (such as [3]). However, we should know that there is quite a long way to realize the fully autonomous vehicles society from now ([4] et al.). Therefore, the most important issue goes to how to ensure the safety when the elderly people drive cars by themselves. Here, the safety includes the drivers themselves and the other people.

In the world automobile market, the reality is at the stage of vehicle with Advanced Driver Assistance System (ADAS). And this stage may be considered as a primary stage of the autonomous vehicles society. According to RnR Market Research [5], most major ADAS technologies are attracting less than 10% penetration rates in 2015. However, the penetration rate of the car rear view camera has been kept on a level being higher than 30% since 2014 in Japan. That is, Japan is one of countries with the highest ADAS penetration rates in the world with respect to the automobile sales. Because the ADAS can be thought as a compensation of the physical and mental disability for the elderly drivers, the diffusion of the ADAS may help to reduce the traffic accidents to some extent.

Regarding the effects of ADAS, many previous studies have been implemented worldwide. Davidse [6] denoted that ADAS would extend the older adult's safe mobility as a driver. Winter et al. [7] concluded that Adaptive Cruise Control (ACC) and Highly Automated Driving (HAD) reduce the driving workload and improve the completion of in-vehicle tasks. The research results by Cicchino [8] showed that Forward Collision Warning (FCW), low-speed Autonomous Emergency Braking (AEB) and their combination reduces front-to-rear crash rates by 27%, 43% and 50%, respectively. The study by Son et al. [9] found that age and gender groups affect the performance of in-vehicle technology. In Italy [10], the beeping ADAS was reported having disturbed driving and distract drivers as the negative effect. Again, regarding the negative effects, the study conducted by researchers in the Netherlands [11] tells us that drivers equipped with ADAS cross intersections more often

 ISBN: 978-1-61208-622-4

with a critical time-to-collision (TTC). In Canada, the research focused on the comparison between older and younger drivers [12], concluding that advanced in-vehicle signs may increase the frequencies of stopping at intersections with relatively short yellow onsets for both younger and older drivers. As a study regarding aftermarket Collision Avoidance Technology (CAT), a research report [13] was compiled on the basis of surveys in the United States of America (USA). The effectiveness of the lane departure warning system (LDWS) was 76% and that of the FCW was 74.5%.

Taking into account the above background, we report an analysis using the traffic accident data collected in Japan. In this paper, our analysis focuses on the effects of the ADAS for safe mobility, especially with respect to the elderly.

The reminder of the paper is organized as follows: Section II briefly describes the methodology; Section III provides the detailed analysis and results discussion; Section IV gives the conclusion and brings up some suggestions for future research.

II. METHODOLOGY

As shown in Figure 1 reported by Ministry of Land, Infrastructure, Transport and Tourism [14], the penetration rates of some representative ADAS applications in Japan are depicted by Advanced Emergency Braking System (AEBS), Lane Keeping Assistance System (LKAS), LDWS and ACC. Among these representative ADAS applications, according to the research report published by TTRI [15], the AEBS is the most popular function, as shown in Figure 2. Therefore, the AEBS is set to be the representative ADAS equipment to be evaluated in this paper.

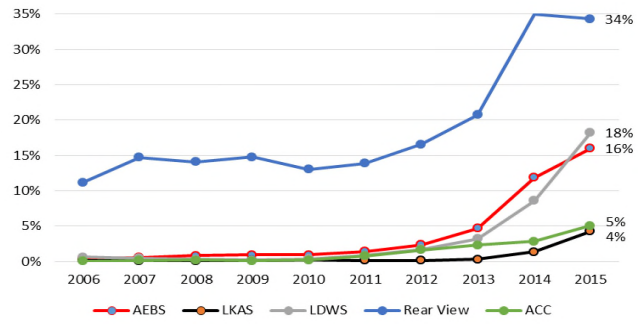

Figure 1. Diffusion of ADAS equipment in Japan [14]

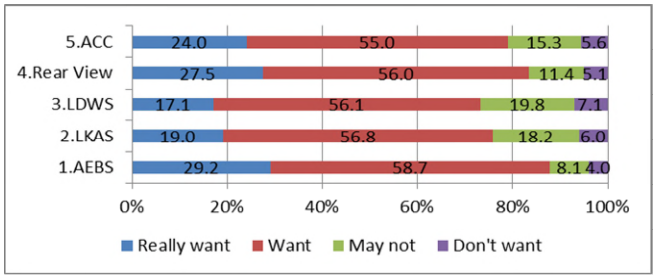

Figure 2. Use Intention of Non-ADAS Users [15].

TABLE I. EQUIPMENT RATES OF EYESIGHT [16]

Year	Country		
	Japan	*Europe*	*USA*
2015	83%	96%	31%

In Japan, among all automobile manufacturers, Subaru is the pioneer and introduced the AEBS (named Eyesight) into the vehicle market in 2008. The Eyesight was upgraded twice in the following years, and the updated version 3 released in 2014 has included the ACC, the LDWS and some more functions. We take the AEBS as the target function in this paper by considering that the AEBS is the basic function and has been in market for many years. This long term enables us to collect necessary data to evaluate the effects. In 2015, the percentage of all sold Subaru cars having Eyesight was 83% in the Japan market, as shown in Table 1. Comparing the percentages given in Figure 1, this number was much higher than the average level in Japan. This enables us to evaluate the AEBS by comparing the traffic accidents numbers and rates caused by the Subaru cars and the others. Then, a simulating analysis for the future to secure the safe mobility is given as the conclusion.

III. ANALYSIS AND RESULTS

The analysis and discussion can be divided into three steps: A. a general understanding on the possibilities of the ADAS; B. the effects of the ADAS for the elderly drivers; and C. the expected effects to reduce the traffic accident fatalities and the solution for the mobility or the accessibility of the elderly people.

A. General Understanding

Figure 3 is the first comparison between the traffic accidents rate of the newly registered Subaru cars and that caused by other newly registered cars in Japan. Here, the traffic accidents data is the data of all traffic accidents with injuries and it was purchased from the Institute for Traffic Accident Research and Data Analysis (ITARTA) that is entitled to have all traffic accidents data collected in Japan. The traffic accident rates are based on the newly sold/registered vehicles which are collected from Japan Automobile Manufacturers Association, Inc. [17]. From this figure, it is easily understood that the traffic accidents by the newly registered Subaru cars were 1.20 times comparing to other newly registered cars around 2008, but decreased since 2009 and have been only 0.6 times recently. The reason this rate has been flat is because it was also more popular for other cars to be equipped with AEBS starting in 2014, as shown in Figure 1.

In Japan, similarly to the other countries in the world, young drivers under 25 years and elderly drivers 65 years and older are normally considered to be associated with traffic accidents more than other drivers. To analyze the problem, we corrected the traffic accidents occurred in Japan (data source: [18]) and we are showing the results in Figure 4. A comparison between the Subaru cars and other cars is made by the age group, as shown in Figure 5. Here, four age groups are compared. Compared to the traffic accidents in

 ISBN: 978-1-61208-622-4

2008, the traffic accidents by the Subaru cars decreased remarkably since 2012. In contrast, a remarkable decrease of the traffic accidents by other cars starts from 2015. Among the four age groups, the elderly drivers including “64-74” and “75 and older” have shown a steeper decreases compared to young drivers “under 25” and “25-64” years of age.

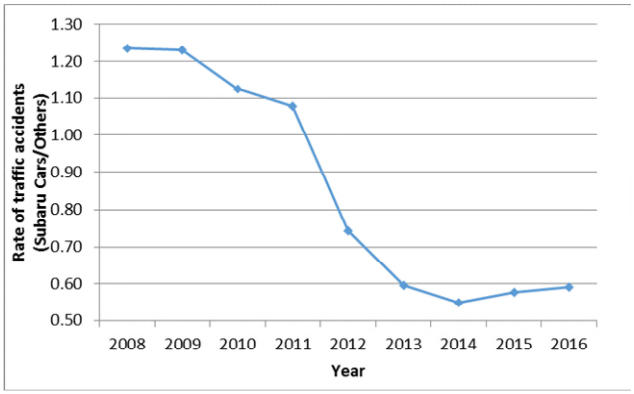

Figure 3. Rates of traffic accidents (Subaru cars/other cars)

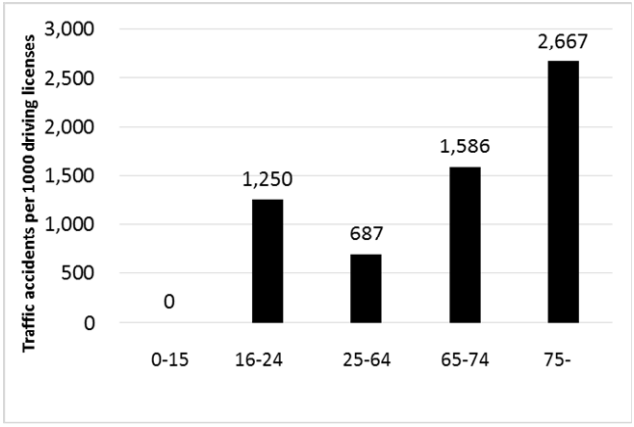

Figure 4. Corrected traffic accidents by age group in Japan

B. *Effects for Elderly Drivers*

Regarding the elderly drivers, at first, the effects are compared by the extent of the injury caused by the traffic accidents. As seen in Figure 6, the number of fatal accidents by Subaru cars during the period from 2012 through 2016 is about one-fifth compared to 2008, although there are some irregular changes over the years. Furthermore, by comparing this with the number of fatal accidents by other cars, the noticeable difference during the period from 2012 through 2015 clearly tells us that how much the AEBS contributed to this outcome. Moreover, the 2016 results of both the Subaru cars and others let us know that the AEBS effects are common with all ADAS equipped cars.

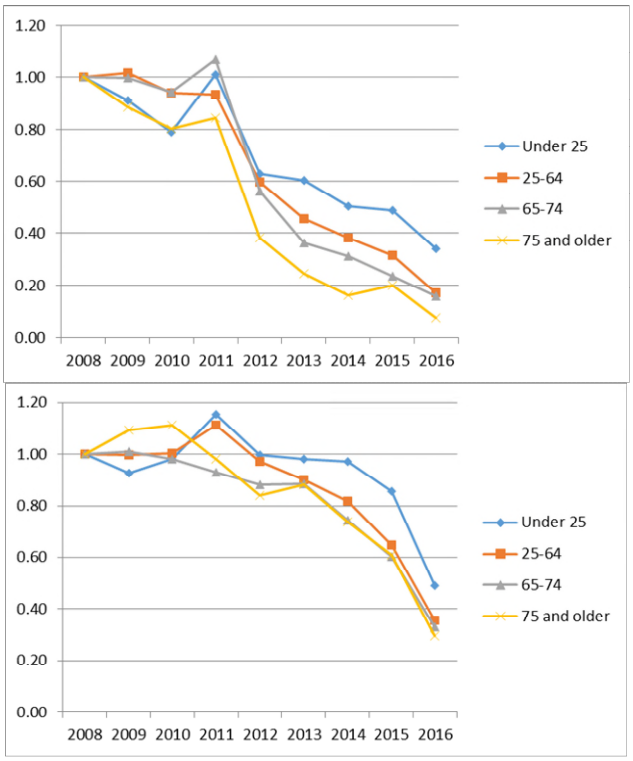

Figure 5. Change of traffic accidents over the years based on driver’s age, considering a value of 1.00 in 2008 (top: Subaru cars; bottom: other cars)

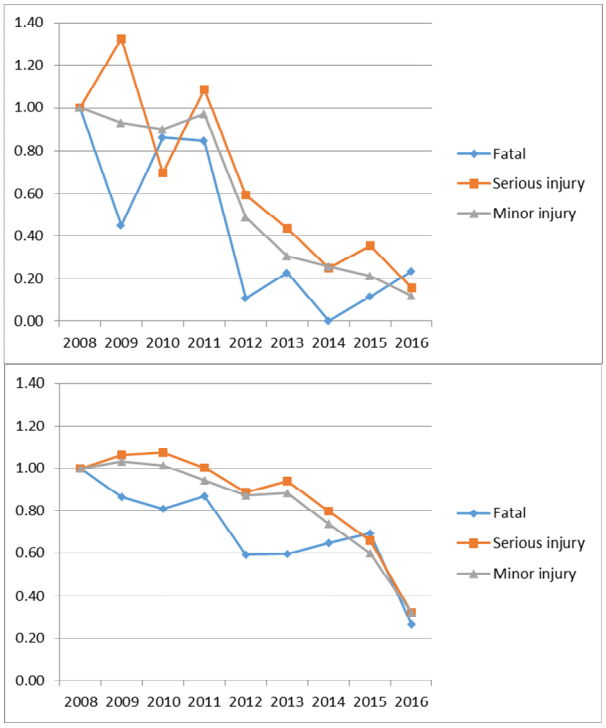

Figure 6. Changes of elderly drivers’ accidents over the years in terms of damage, considering a value of 1.00 in 2008 (top: Subaru cars; bottom: other cars)

 ISBN: 978-1-61208-622-4

Figure 7 summarizes the comparison results by traffic accident classification. Here, P2V stands for "person-to-vehicle", V2V expresses "vehicle-to-vehicle" and "V only" means "vehicle-to-infrastructure" or vehicle alone. From Figure 7, we can know that "vehicle only" accidents with injuries by Subaru cars have been reduced drastically since 2014 when the Eyesight Version 3 was released. Meanwhile, V2V accidents have been reduced in average. Similar results can be seen with other cars in 2016. These results may indicate that the AEBS help the vehicle to recognize large objects such as infrastructures and cars ahead more effectively than the appearance of pedestrians. However, the effects with the "P2V" accidents are becoming conspicuous when many automobile manufacturers equipped the AEBS and other ADAS equipment in 2016.

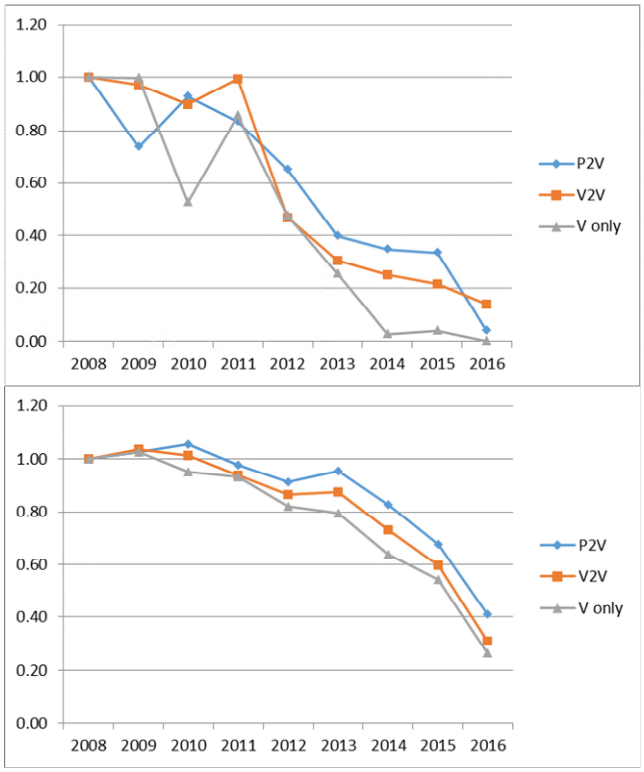

Figure 7. Changes of elderly drivers' accidents over the years in terms of accident classification, considering a value of 1.00 in 2008 (top: Subaru cars; bottom: other cars)

For traffic crash types, the comparison results are depicted in Figure 8. Although there are some irregular movements during 2009 through 2011 for Subaru cars, the remarkable and stable decreasing trends can be seen from 2012 for Subaru cars and from 2014 for other cars. In 2016, all types of traffic accidents have been reduced to less than 40% of those from 2008. Among these crash types, rear end, head-on and crossing crashes have been reduced much more than left turn or right turn crash.

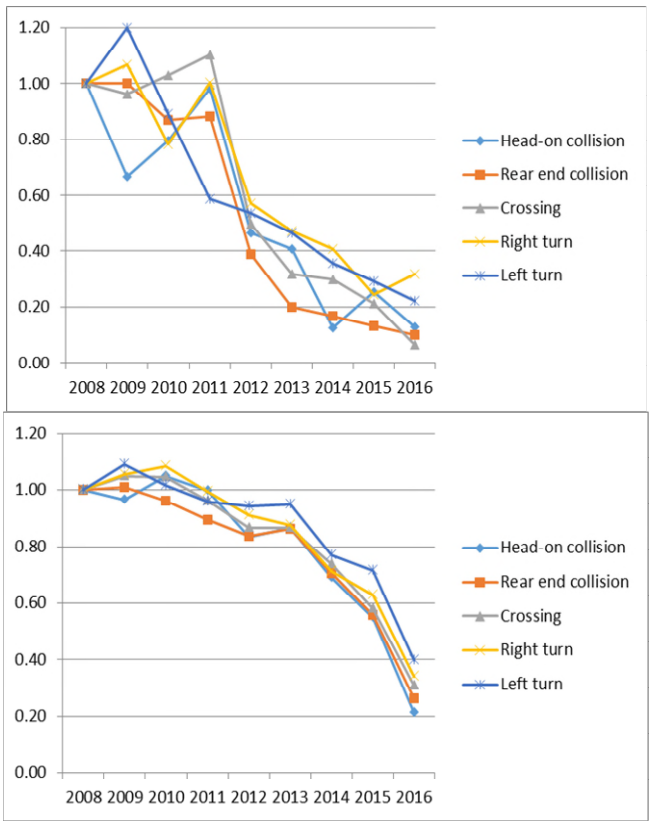

Figure 8. Changes of elderly drivers' accidents over the years in terms of crash type, considering a value of 1.00 in 2008 (top: Subaru cars; bottom: other cars)

Furthermore, the comparison is focused on weather. Figure 9 summarizes changes of the traffic accidents under different weather conditions. Because there is not enough data for Subaru cars in the foggy days, the change of the traffic accidents cannot be expressed here. In addition, a violent fluctuation with the traffic accidents in the snowy days by Subaru cars can be observed. The same can be observed with the traffic accidents in the foggy days by other cars. Therefore, we only want to conclude that the remarkable decreases have been achieved in either the sunny days or the rainy days from Figure 9. Similar to the above analysis, the positive results obtained from 2012 for Subaru cars and from 2014 for other cars support the explanation that these effects are consistent with the diffusion of the AEBS.

Lastly, the comparison is made based on the road environment. The comparison results are shown in Figure 10. As there are some violent fluctuations with "others", our discussions are only focusing on road sections and intersections. Although the traffic accidents reduction effects are well functional with both road sections and intersections, the effects with road sections seem more obvious than that with intersections in average.

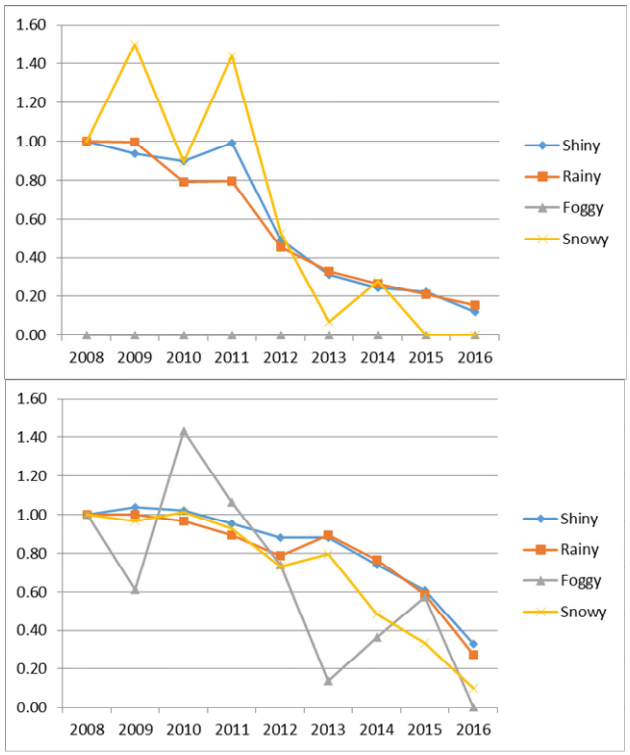

Figure 9. Changes of elderly drivers' accidents over the years in terms of weather, considering a value of 1.00 in 2008 (top: Subaru cars; bottom: other cars)

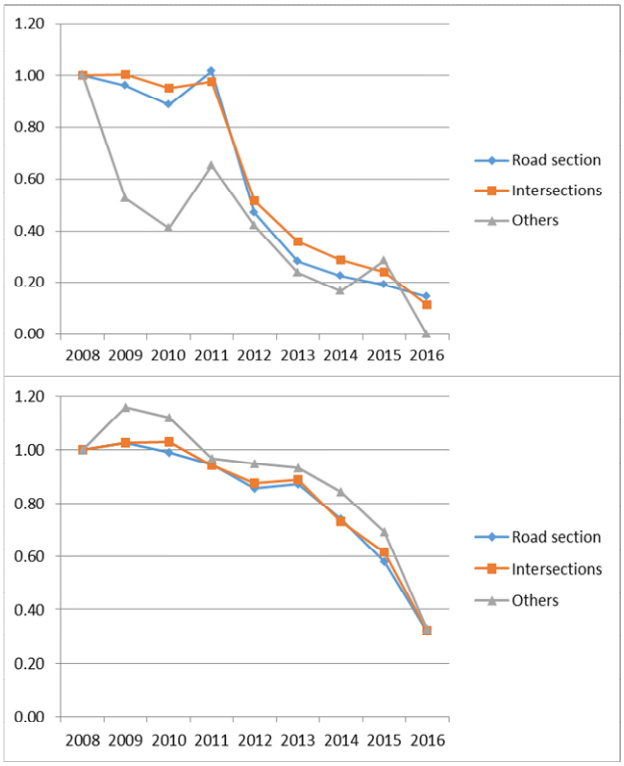

Figure 10. Changes of elderly drivers' accidents over the years based on road environment, consideirng a value of 1.00 in 2008 (top: Subaru cars; bottom: other cars)

C. *Expected Effects in the Coming Years*

If we consider the AEBS is an innovative product, its diffusion process can be discussed using the method proposed by Rogers [19]. As it is shown in Figure 11, the AEBS is getting into the "early majority" period in Japan as the diffusion rate is 16% in 2015 (Figure 1). Then, in the Tenth Fundamental Traffic Safety Program of Japan [20] released by Cabinet Office in 2016, the Japanese government emphasized that it is very important to utilize the innovative technology to reduce the number of fatalities due to traffic accidents. Therefore, it is expected that the number of AEBS users may increase rapidly in the coming years.

As mentioned in Section 1, in Japan, the 24-hour traffic fatalities (dead within 24 hours due to traffic accidents) were 3,904 persons in 2016. The goal set by the government is less than 2,500 per year around by 2020. As one important countermeasure, the AEBS and other ADAS equipment will be functional to ensure the universal mobility and accessibility.

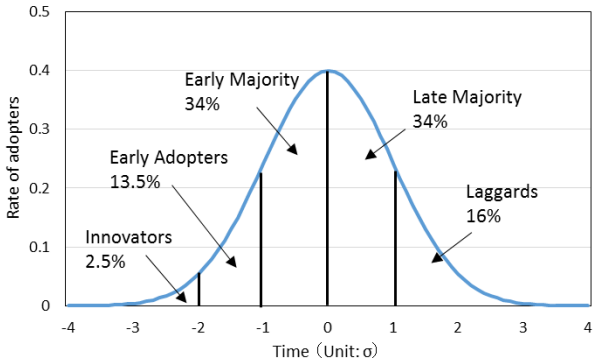

Figure 11. Adopter categories (Source: [19]).

IV. Conclusion and Future Work

In this paper, several comparative analyses on the effects of the ADAS represented by the AEBS equipment are implemented. These analyses revealed an important finding. The ADAS equipment is really effective for the drivers, especially elderly drivers, to reduce traffic accidents. As a result, cars equipped with ADAS equipment might be considered as a smart solution to realize the universal mobility and accessibility of the elderly people in the super-aging society.

As the future work, the following issues will be taken into consideration: 1) the question whether there is an incompatibility with some ADAS equipment, since many different types of equipment are existing in the car market; 2) the question whether drivers should be forced to purchase the ADAS equipment; 3) another similar comparison analysis extended to other countries.

Acknowledgements

This study was partly sponsored by a grant (H29) from Japan Safe Driving Center and JSPS KAKENHI Grants Number JP17K06612.

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 ISBN: 978-1-61208-622-4