A COMPREHENSIVE EVALUATION OF CAR SAFETY EVOLUTION USING MODEL CHANGE YEAR CLASSIFICATIONS AND TRAFFIC ACCIDENT DATA IN JAPAN

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ABSTRACT

To reduce the number of traffic accidents and injuries caused by vehicles, crash safety performances for saving occupants and pedestrians have been improved, and also various advanced driver assistance systems have been introduced for a wide range of vehicles in recent years. The aim of this study was to elaborate on whether newer generations of car models have fewer casualty accidents due to such safety evolutions from a broader perspective. As for the classification of the cars, 411 models of standard passenger cars including SUVs were grouped into four categories by the year of full-model change (Mo.CY) which meant either fully remodeled or newly introduced to the Japanese market. Specifically, the classification were as follows; G1 (Generation 1): 2000-2002 Mo.CY, G2: 2003-2010, G3: 2011-2015, G4: 2016-2019.

Regarding accident data, fatal, serious, and minor injury accidents reported to the police in Japan between 2017 and 2020 were utilized. This applied in common to the four Mo.CY groups.

As the evaluation index, the numbers of accidents per 100,000 vehicles registered per year were used. Then it was assessed whether there was a difference among the groups of Mo.CY, i.e., whether the newer vehicle group has fewer accidents.

This evaluation was conducted from a comprehensive viewpoint including many safety systems and crash safety performance improvements, rather than strictly assessing the effectiveness of a specific safety system.

In conclusion, analyzing accident data for the same period of 2017 to 2020, the number of accidents for the newer Mo.CY groups in several types of accidents was lower than that for old ones.

Regarding fatal accidents, pedestrian and single-vehicle accidents accounted for a large percentage in the G1 group. Specifically, the analysis proved that the number of fatal accidents per 100,000 registered vehicles has dramatically decreased by 55% for pedestrians, and 69% for single-vehicle accidents from G1 to G4. In addition, the casualty accidents for rear-end collisions have greatly reduced by 64% from G1 to G4.

That was because the newer cars had more various safety features and better-improved passive safety performance. It was also clarified that the degrees of accident reduction depended on the severity of injury and the type of accident.

The method presented here, utilizing Japanese elaborate statistical accident data, demonstrated that it was possible to quantify the overall benefits of safety features and performances, or car safety evolution. Therefore it could lead to a better understanding of real-world performance and a way to go for a safer world.

INTRODUCTION

To decrease traffic accidents and injuries caused by vehicles, crash safety performances for occupants and pedestrians have been improved, and various advanced driver assistance systems have been introduced for a wide range of vehicles recently. New Car Assessment Program (NCAP) have been conducted in the U.S., Europe, Japan, etc., to evaluate such safety performance and systems. Several studies have been conducted to clarify how to contribute to the reduction of accidents and injuries [1] [2] [3].

In Japan, all police-reported accident data, not sampled, are recorded with model and type information, which is linked to the number of registered vehicles by model. Such an integrated accident database compiled by ITARDA would be extremely helpful for statistical analysis. The analysis enabled us to elaborate on whether a newer group of car models have fewer accidents and injuries from a broader perspective. The clarification of accident reduction by the severity of injury and type of accident could contribute to update of the traffic accident reduction strategies similar to those in the United States [4].

METHOD AND DATA SOURCES

The method used in this study contains five steps: vehicle model selection and grouping; counting accident data; counting numbers of registered vehicles; evaluation index calculation; results analysis.

Vehicle model selection and grouping

Firstly, the models fully remodeled or newly introduced on the Japanese market in 2000 or later were selected. As a result, 411 models of standard passenger cars including SUVs were chosen. The models were grouped into four categories by the year of full-model change (Mo.CY) as follows; G1 (Generation 1): 2000-2002 Mo.CY, G2: 2003-2010, G3: 2011-2015, G4: 2016-2019. The reasons why they were separated by those years are described below. The evaluation of ODB (Offset Deformable Barrier Frontal Test) was started in 2000 in JNCAP, and the initial group of vehicles with such basic performance was used for the comparison basis. Since this study initially started with pedestrian accident analysis, Mo.CY were segmented at the years of 2003 (when pedestrian head protection performance evaluation started in JNCAP), 2011 (pedestrian leg protection performance), and 2016 (pedestrian damage mitigation brakes.) However, these delimited years were kind of a guideline, not an absolute requirement. The fact that the year is not "model year" but "full-model change year" was significant. That is because the year means to be related to when a model was developed, not produced.

Counting accident data

In the second step, fatal, serious, and minor injury accident data related to each model between 2017 and 2020 in Japan were utilized. This applied in common to the four Mo. CY groups. The accident data reported to the police was obtained from National Police Agency and compiled by ITARDA. In this study, the targeted vehicle was focused on the primary-party in the accidents.

The injury severities in the accident database are defined as follows:

- Fatality: a death occurs within 24 hours of the accident and as a result of the accident
- Serious Injury: victim is treated for 30 or more days from the date of accident, including a death after more than 24 hours

- Minor Injury: victim is treated for less than 30 days from the date of accident

Counting numbers of registered vehicles

In the third step, the total number of registered vehicles from 2017 to 2020 for each group were counted. As data sources, the numbers of registered vehicles for each model as of the end of the year were got from Road Transport Bureau of Ministry of Land, Infrastructure, Transport and Tourism and compiled by ITARDA. To determine the effective number of registrations for the relevant year, the average of the number of registrations at the end of the previous year and that at the end of the current year was calculated. In the next step, the calculated number of registrations for each year was then added up for the four years: 2017-2020. In the final step, the numbers of registrations of each model for the four years were summed up among each Mo.CY group.

Evaluation index calculation

The fourth step calculated the evaluation index through dividing the number of accidents by the number of vehicles registered during the four years period. As the evaluation index, the numbers of accidents per 100,000 vehicles registered per year for each group were adopted.

Results analysis

In the final step, the evaluation index have been scrutinized by the severity of accidents and the type of accidents.

RESULTS

Table 1 showed the number of models for each group, varying from 63 to 164. Table 1 also included the total registered vehicle number for each group for four years. The number is from a minimum of about 8 million to a maximum of over 63 million. They were used as denominators when deriving the per-unit indicator. These sample sizes were quite large enough and nationally representative since the total registered number here accounted for about 80 percent of standard passenger car fleet in the Japanese market.

Table 1.

Classification of vehicle models, number of models and total registered number for each group

Group No.	**G1**	**G2**	**G3**	**G4**	**Total G1-G4**
Mo.CY	2000-2002	2003-2010	2011-2015	2016-2019	2000-2019
Number of models	86	164	98	63	411
Total of registered vehicle number for 4 years: 2017-2020	16,177,592	63,757,014	39,609,658	8,044,915	127,589,179

Table 2 displayed the number of fatal accidents by type of accident for each Mo.CY group. The similar tables for fatal and serious accident and for casualty one were shown in APPENDICES.

First of all, the total accident numbers in the bottom row of Table 2 were divided by the registered number in Table 1 for each group. Then the indicators "per 100,000 registered vehicles" were calculated.

Table 2.

Number of fatal accidents for each Mo.CY group and each type of accident

(Years of accident: 2017-2020, subject car: the primary-party)

	Number of fatal accidents for each Mo.CY group			
Type of accident	G1:2000-2002	G2:2003-2010	G3:2011-2015	G4:2016-2019
pedestrian	227	777	351	52
head-on	55	162	74	13
rear-end	19	69	27	9
crossing	43	160	89	18
turning right	36	95	53	8
turning left	0	8	6	1
single-car	141	272	108	23
others	13	68	27	4
Total	534	1,611	735	128

The results were shown in Figure 1, and there was a large difference between G1 and G2 in fatal case (left). On the other hand, in casualty cases (right), there was no difference between G1 and G2 but is a large difference between G3 and G4. Looking over these graphs it was found that the newer Mo.CY groups have lower accident possibilities than the older ones. In these figures, vertical lines indicated 95% confidence intervals and were used as a reference for determining whether there was a significant difference.

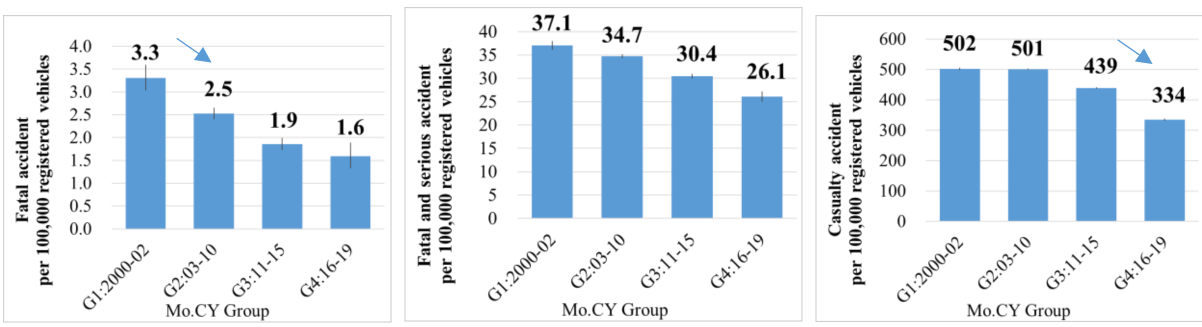

Figure 1. Number of accidents per 100,000 registered vehicles by Mo.CY group

(Years of accident: 2017-2020)

Fatal (left), fatal and serious (center), casualty (right) accident.

Next, Figure 2 (left) described a detailed look at type of accident in fatal accidents from Figure 1 (left).

In G1, pedestrian and single-car accidents were the most common types of accidents.

Comparing G1 to G4 for each type of accident, only those two types of accident had a significant difference. Therefore, the reduction tendency of both pedestrian and single-car accidents were shown in Figure2 (right), articulating a 55 percent decrease in pedestrian accidents and a 69 percent decrease in single-car accidents.

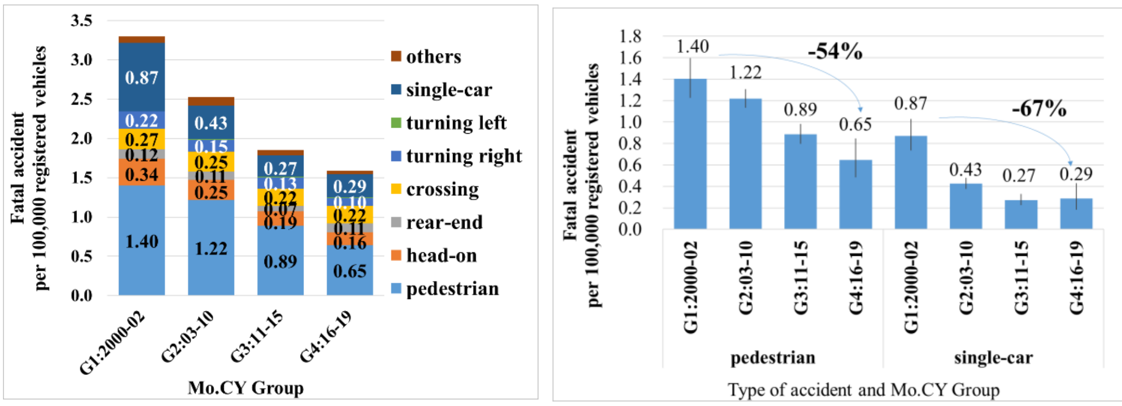

Figure 2. Number of <u>fatal</u> accidents per 100,000 registered vehicles by Mo.CY group

(Years of accident: 2017-2020)

Accumulated bar by type of accident (left), evolution for pedestrian and single-car collision (right).

Figure 3 illustrated the number of fatal and serious injury accidents per 100,000 registered vehicles by type of accident and Mo.CY group. It was illustrated that pedestrian and crossing collision were dominant types of accidents. There were some reductions for several types of accidents with comparison among Mo.CY Groups during the same period of the year of 2017-2020.

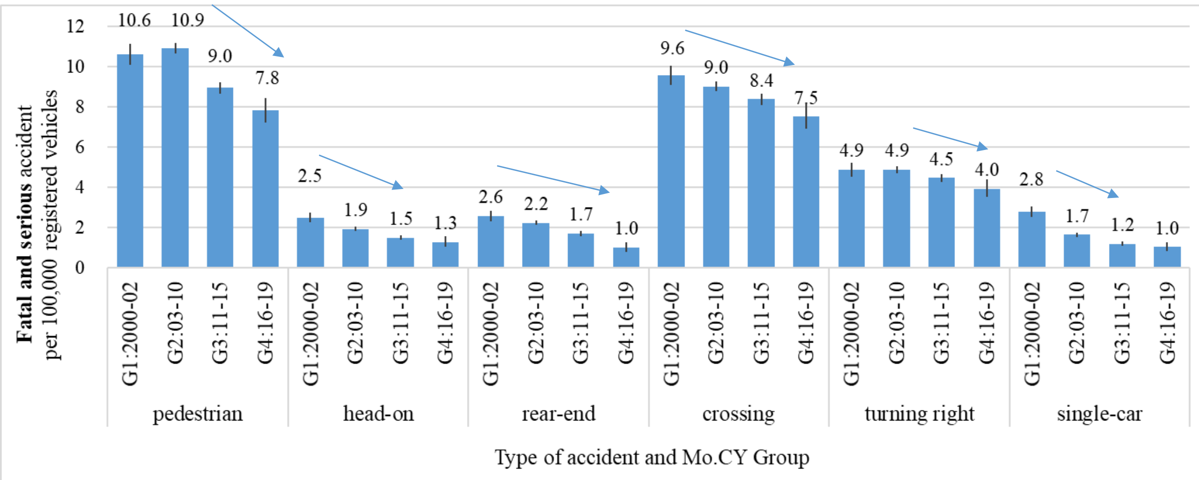

Figure 3. Number of <u>fatal and serious</u> accidents per 100,000 registered vehicles by Mo.CY group

(Years of accident: 2017-2020).

Figure 4 described the number of casualty accidents per 100,000 registered vehicles by type of accident and Mo.CY group. It was demonstrated that rear-end and crossing collisions were dominant types of accidents. A dramatically sharp drop for rear-end collision was clarified. Since rear-end collisions which were the most common type of accident have decreased, crossing collisions have become the most frequent type of accident in G4.

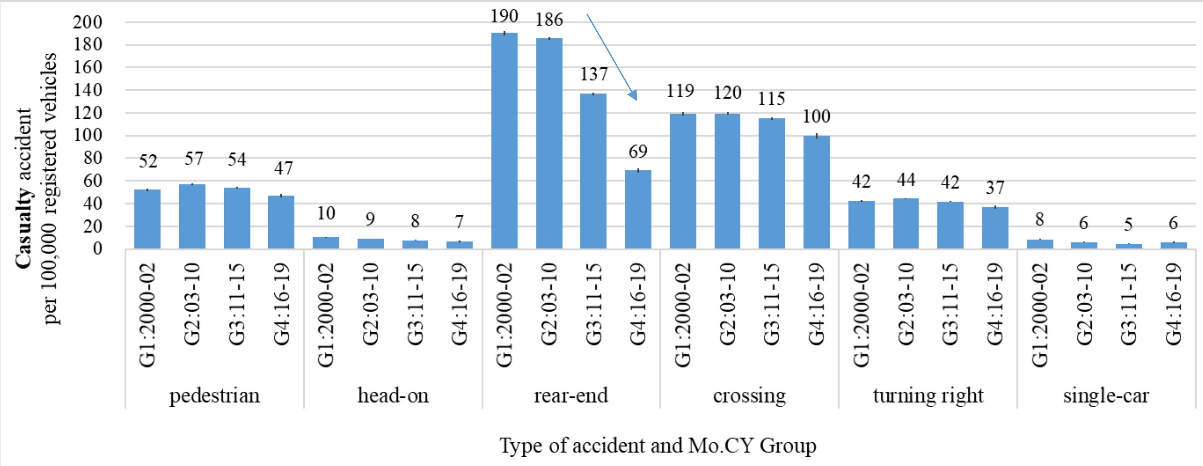

Figure 4. Number of casualty accidents per 100,000 registered vehicles by Mo.CY group (Years of accident: 2017-2020).

Figure 5 summarized the reduction rates from G1 to G4 by type of accident for three severity levels of injury. The collision when turning left and the fatal type of accidents except for pedestrian and single-car had no significant difference between G1 and G4. Therefore, they were omitted from the graph.

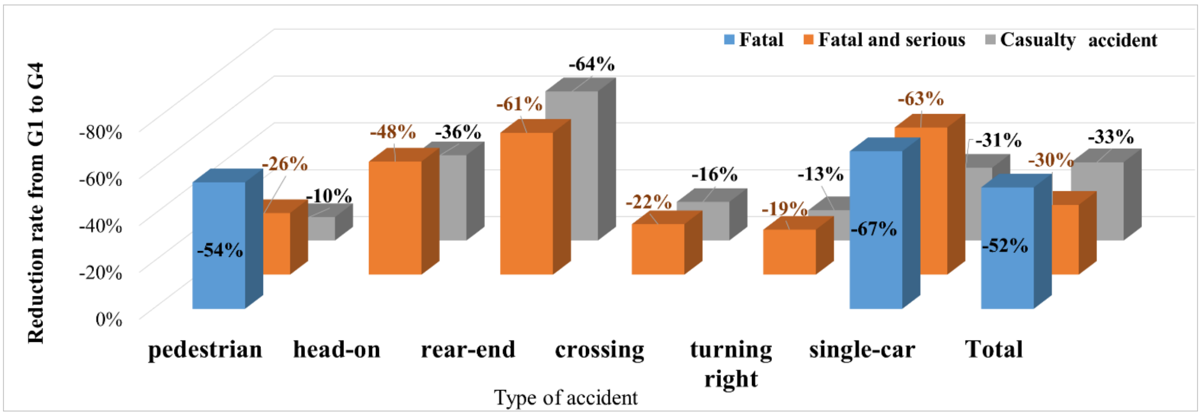

Figure 5. Reduction rates from G1 to G4 by type of accident for three severity levels of injury (Years of accident: 2017-2020).

In addition, Figure 6 indicated absolute values of reduction per 100,000 registered vehicles. As shown in Figure 5 and Figure 6, it demonstrated that each reduction rate depended on the degree of injury and type of accident.

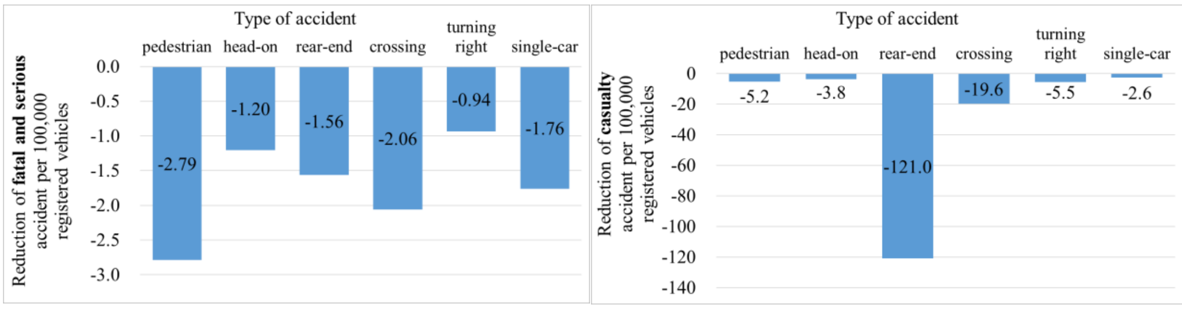

Figure 6. Reduction values per 100,000 registered vehicles from G1 to G4 by type of accident Fatal and serious (left), casualty accident (right) (Years of accident: 2017-2020).

DISCUSSION AND LIMITATIONS

The status of accident reduction has been carefully and quantitatively scrutinized so far. Here, the presumed factors for these reductions would be discussed.

Regarding pedestrian fatality reduction, one of the factors could be the improvement of pedestrian head protection performance which JNCAP started to evaluate in 2003. That was because the primary part of injury in pedestrian fatalities was the head. In addition, the primary part of crash of vehicle against pedestrian in fatal case was the front as is well known.

As to head-on collision, in addition to the improvement of crash safety performance in Offset Deformable Barrier (ODB) frontal crash mode, the spread of Lane Departure Warning (LDW) system or Lane Departure Prevention System (LDPS) could play a leading role.

The largest decline in rear-end collisions including minor injury accidents, as shown in Figure 6 (right), could be attributed to the spread of Autonomous Emergency Braking (AEB) system. It can be said that AEB would be the most successful safety system.

For single-vehicle accidents, the spread of Electric Stability Control (ESC) system, LDW, and LDPS could contribute to the decrease in accidents.

However, all of these factors as mentioned above were presumptive ones. No causal relationship was quantified here. It would be difficult to extract the effectiveness of each system independently. For this purpose, further study should be needed, and at that time the differences in many accident conditions, such as collision velocity and drivers' age in different Mo.CY groups should be taken into account. Also, both the absolute number and the rate of reduction should be scrutinized to determine areas of future focus. The aim of this study was nonetheless successfully conducted to clarify that the newer generations of car models have fewer accidents and injuries from a broad perspective.

CONCLUSIONS

The 411 models of standard passenger cars including SUVs were grouped into four categories by the year of full-model change (Mo.CY). The number of accidents per 100,000 vehicles for a total of four years from 2017 to 2020 were compared to each other. The results showed the following improvements in vehicle safety for example.
Comparison between G1 (2000-2002) and G4 (2016-2019)

- Fatal accidents, 54% reduction for pedestrian accidents, 67% reduction for single-car ones
- Casualty accidents, as much as 64% reduction for rear-end collisions

The method presented in the study, utilizing Japanese elaborate statistical accident data, demonstrated that it was possible to quantify the overall benefits of safety features and performances based on the field data. Therefore, it could lead to a better understanding of real-world performance.

The results presented in this paper demonstrated the fruits of the great endeavors of many people including automotive engineers and others involved.

Moreover, the outcomes here could also mean a starting point for further research and measures toward vision zero.

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APPENDICES

Table 3.

Number of fatal and serious accidents for each Mo.CY group and each type of accident

(Years of accident: 2017-2020, subject car: the primary-party)

	Number of fatal and serious accidents for each Mo.CY group			
Type of accident	G1:2000-2002	G2:2003-2010	G3:2011-2015	G4:2016-2019
pedestrian	1,718	6,961	3,548	630
head-on	404	1,241	599	104
rear-end	418	1,431	679	82
crossing	1,550	5,759	3,327	605
turning right	791	3,125	1,773	318
turning left	220	882	696	101
single-car	454	1,059	481	84
others	444	1,691	958	172
Total	5,999	22,149	12,061	2,096

Table 4.

Number of casualty accidents for each Mo.CY group and each type of accident

(Years of accident: 2017-2020, subject car: the primary-party)

	Number of casualty accidents for each Mo.CY group			
Type of accident	G1:2000-2002	G2:2003-2010	G3:2011-2015	G4:2016-2019
pedestrian	8,428	36,525	21,287	3,774
head-on	1,669	5,772	3,069	528
rear-end	30,770	118,442	54,264	5,571
crossing	19,317	76,192	45,618	8,026
turning right	6,872	28,244	16,622	2,977
turning left	3,592	14,274	9,800	1,690
single-car	1,350	3,962	1,851	463
others	9,203	36,042	21,369	3,870
Total	81,201	319,453	173,880	26,899