Evaluation of Traffic Fatality Countermeasures Implemented in Japan from 1992 to 2007

Kenji HAGITA
Senior Researcher
Traffic Science Division,
National Research Institute of Police Science
6-3-1, Kashiwa-no-ha, Kashiwa City, Chiba
277-0882 Japan
Fax: +81-4-7133-9187
E-mail: hagita@nrips.go.jp

Munemasa SHIMAMURA
Associate Professor
Faculty of Risk and Crisis Management,
Chiba Institute of Science
15-8 Shiomicho, Choshi City, Chiba
288-0025 Japan
Tel:+81-479-30-4714, Fax:+81-479-30-4750
E-mail:shimamura@cis.ac.jp

Hiroki HASHIMOTO
Researcher
Advanced Road Design and Safety Division,
National Institute for Land and Infrastructure Management
Asahi-1, Tsukuba City, Ibaraki
305-0804, Japan
Fax: +81-29-864-2873
E-mail: hashimoto-h92ta@nilim.go.jp

Toru HAGIWARA
Associate Professor
Laboratory of Infrastructure Planning and Design, Graduate School of Engineering,
Hokkaido University
Kita 13, Nishi 8, Kita-ku, Sapporo City
060-8628, Japan
Fax +81-11-706-6214
E-mail: hagiwara@eng.hokudai.ac.jp

Hidekatsu HAMAOKA
Associate Professor
Department of Civil and Environmental Engineering, Akita University
Tegata gakuen-machi 1-1, Akita City, Akita
010-8502, Japan
Fax: +81-18-889-2975
E-mail: hamaoka@ce.akita-u.ac.jp

Abstract: This study aims to evaluate the comprehensive safety programs that were launched around 1990 in Japan in terms of its effectiveness in reducing traffic fatalities. Traffic fatalities (hereinafter: “fatalities”) in Japan recorded by the National Police Agency (NPA) declined from 11,415 in 1992 to 5,744 in 2007. For this period, comprehensive traffic safety programs were carried out by police agencies, road authorities, automobile manufacturers and other organizations in Japan. Severe penalties for drink-driving, vehicle speed, rate of seatbelt use, road infrastructure improvements and so on are adopted as performance indicators to evaluate effect of countermeasure. We estimated the effect of each fatality-reduction countermeasure on the number of fatalities respectively. The comprehensive nationwide traffic safety program was shown to be highly effective in reducing traffic fatalities in Japan. Especially, it was inferred that increasing seatbelt use rate and vehicle speed reduction are most effective.

Key Words: traffic accident, fatality, traffic fatality countermeasure, evaluation

1. INTRODUCTION

Traffic fatalities (hereinafter: “fatalities”) in Japan recorded by the National Police Agency (NPA) declined from 11,415 in 1992 to 5,744 in 2007 “ITARDA (2009)”. A fatality is defined as the death of a person within 24 hours after a traffic accident. Figure 1 breaks down the number of fatalities for four crash types between 1992 and 2007. Fatalities decreased for all four crash types. The decrease for the category “car-to-car and single-car accidents” is particularly dramatic.

The Government of Japan took a comprehensive approach to decreasing the number of fatalities. This approach included enhancing drivers’ education, strengthening enforcements (particularly severe penalties for drink-driving and enforcement for exceeding the speed limit), increasing the
active and passive safety of vehicles, improving road facilities, reducing traffic blackspots, and improving the emergency system. These approaches have been implemented simultaneously since around 1990 to decrease the number of fatalities. The comprehensive approach to improving traffic safety in Japan has resulted in a large reduction in fatalities. The *Towards Zero* report (OECD 2008) documents the numbers of fatalities between 1995 and 2007 in Australia, the Netherlands, New Zealand and Sweden. In Australia, New Zealand and Sweden, fatalities decreased by about 20% over that period. However, in the Netherlands and Japan, fatalities decreased by about 50% over the same period. The Netherlands, Sweden, Switzerland, Norway, the United Kingdom, Denmark and Japan attained rates below 6.0 fatalities per 100,000 inhabitants by 2006. In many Asian countries, traffic safety problems are key issue to be resolved because the mileage of vehicles is rapidly increasing. As these countries weigh appropriate countermeasures, Japan's success in cutting fatalities in the past 15 years can serve as guidance.

![Figure 1 Fatalities broken down by four crash types in Japan (1992-2007)](image)

The NPA has reported the effects on traffic safety of advanced traffic control systems and improvements to traffic signal (NPA, 2008; NPA, 2005; NPA, 2008). The National agency for Automotive Safety & Victim’s Aid (NASVA) conducts various safety tests every year and measures collision safety performance for commercially available vehicles “NASVA(2005)”. NASVA(2005) reported the effect of passive systems (crash protection) and active systems (crash avoidance) on fatalities in 2005. Hagita et al (2006) evaluated the traffic accident reduction effectiveness of a program, launched in 2002, to make drink-driving regulations stricter. They compared the number of fatalities before and after the revised *Road Traffic Law* were enforced, and estimated the effect of the revised *Law* on the number of fatalities.

However, it is not entirely clear which fatality-reduction measures are the main causes for the decrease in fatalities, and why there is such a steep decrease in the number of car-to-car and single-car fatalities (Figure 1). In addition, few studies have compared the relative effectiveness of fatality-reduction measures. We would like to determine the relationship between countermeasures and safety performance. It is also expected that this information could contribute to the drafting of effective and comprehensive plans in countries with lower levels of road traffic safety performance. Thus, the objectives of the study are to evaluate each major fatality-reduction measure in terms of its contribution to the decrease in fatalities, and to identify which of these countermeasures has been responsible for the greatest decline in fatalities in Japan.

To determine the effectiveness of each countermeasure, we estimated the number of fatalities related to the target factor before and after the fatality-reduction measure was implemented. These estimations are not simple forward projections of past reduction rates but are based on a comprehensive understanding of all the basic trends likely to affect traffic safety. Other factors
associated with the target factor affect the number of fatalities. Also, the number of fatalities is influenced by demographic and socioeconomic changes. During the 15 years from 1992 to 2007, we have had changes in the economy, population demographics, the traffic system and so on. These should also be taken into account; however, it is difficult to quantify the effects of these on traffic fatality-reduction. We assumed that the number of fatalities related to the target factor before and after the fatality-reduction measure could represent effect of the target factor on traffic safety.

Based on these considerations, the following sections evaluate the effect of each factor in terms of the decrease in fatalities. Section 2 evaluates the effect of drivers’ education implemented by the drivers’ license system of Japan from 1990. Section 3 evaluates the effect of severe enforcement implemented by the NPA. Section 4 evaluates the effect of the increase in the use rate of seatbelts and helmets. Section 5 evaluates the effect of the increase in vehicle speed.

2. EVALUATION OF SAFETY EDUCATIONAL PROGRAMS FOR DRIVERS

2.1 Effect of training program for moped drivers

The driver’s license system of Japan has various safety educational programs for drivers to reduce the number of traffic accidents. All drivers in Japan, for example, must receive some kind of refresher course when they renew their driver’s license every three or five years. The renewal period depends on the driver’s penalty points of accidents and traffic violations, age, and driving experience.

For the purpose of reducing moped traffic accidents, training program for moped drivers has been given since 1992. Before 1992, the only licensing requirement for moped drivers was a paper test, and moped licenses were available to drivers as young as 16. Since 1992, all moped license applicants have had to complete driver’s training program for moped license applicants before and after passing the paper test. Figure 3 shows the number of fatalities caused by novice moped drivers (i.e., those who had been licensed for less than a year) for each year from 1990 to 2007. Driver who has car license is permitted to drive moped. So, these include fatalities caused by novice moped drivers who have a car driver’s license instead of moped license. According to this figure, fatalities caused by novice moped drivers have tended to decrease since moped license applicants were required to complete driver’s training program for moped license applicants.

![Figure 2 Fatalities caused by novice moped drivers in Japan](image-url)
2.2 Effect of educational program for elderly drivers
For the purpose of reducing accidents caused by elderly drivers, educational program for elderly drivers has been given since 1998. Drivers age 70 or over must renew their driver’s license every three years, and drivers age 75 or over must complete elderly driver educational program. In 2002, the age for the elderly driver educational program was reduced from 75 years to 70 years. Figure 4 shows fatalities for each year from 1996 to 2007 caused by the drivers age 70 or over. Fatalities caused by drivers aged 75 or over show a continuous increase. However, fatalities caused by drivers aged 70 to 74 years show little change or a slight decreasing tendency since 2002.

3. EVALUATION OF SEVERE ENFORCEMENT

3.1 Effect of novice driver probationary period
For the purpose of reducing fatalities caused by novice drivers, the drivers’ license system of Japan has adopted a novice driver probationary period to prevent accidents caused by novice drivers who had been licensed for less than a year since 1990. A novice driver who receives 3 penalty points for traffic violations within the first year after licensing must complete the novice driver educational program. After this, a novice driver who receives another 3 penalty points must retake the driving license test. This is system of novice driver probationary period, which is much stricter on novice drivers than on more experienced drivers. Figure 2 shows the number of fatalities for each year from 1986 to 2007 caused by novice drivers (i.e., drivers who had been licensed for less than a year). Since the system started, fatalities caused by novice drivers have declined rapidly.
3.2 Effect of more severe penalties for drink-driving
The NPA increased the severity of penalties for drink-driving in 2002 and again in 2007. Breath Alcohol Concentration (BrAC) is used to measure alcohol concentration instead of Blood Alcohol Concentrations (BAC) in Japan. Table 1 indicates the penalties for drink-driving before and after The Road Traffic Law was amended in 2002 and 2007. The maximum permissible BrAC was reduced from 0.25 mg/l to 0.15 mg/l in 2002. Penalties for drink-driving were also made more severe. For example, the driver’s license is suspended when the BrAC exceeds 0.15 mg/l from 2002.

In 2007, penalties for drink-driving were made more severe than those in 2002. A driver who refuses to take a breath test implemented by the police will receive a very severe penalty. In addition, the penalties extended to those abetting the driver in drinking (e.g., restaurant managers, liquor shop managers, passengers aware of the driver’s status, etc.). Figure 5 shows fatalities due to drink-driving for each year from 1992 to 2007. These data include fatalities caused by drivers who tested positive for alcohol even when their BrAC is less than 0.15 mg/l. Fatalities caused by drink-driving numbered 1,319 in 2001. By 2004, shortly after the 2002 amendment of The Road Traffic Law, they had fallen to 791. In 2007, immediately after the 2007 amendment of The Road Traffic Law, fatalities fell to 475.

Table 1 Penalties for drink-driving in Japan, before and after The Road-Traffic-Law was amended

<table>
<thead>
<tr>
<th>Criminal penalties</th>
<th>Before Amendment</th>
<th>After 2002 Amendment</th>
<th>After 2007 Amendment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive While Intoxicate</td>
<td>Imprisonment less than 2 years or Fine less than 100,000yen</td>
<td>Imprisonment less than 3 years or Fine less than 500,000yen</td>
<td>Imprisonment less than 5 years or Fine less than 1,000,000yen</td>
</tr>
<tr>
<td>Drink-Driving</td>
<td>Imprisonment less than 3 months or Fine less than 50,000yen</td>
<td>Imprisonment less than 1 years or Fine less than 300,000yen</td>
<td>Imprisonment less than 3 years or Fine less than 500,000yen</td>
</tr>
<tr>
<td>BrAC Legal Limit</td>
<td>0.25 mg/l</td>
<td>0.15 mg/l</td>
<td>0.15 mg/l</td>
</tr>
<tr>
<td>Breathalyzer Refusal</td>
<td>Fine less than 50,000yen</td>
<td>Fine less than 300,000yen (2004 Amendment)</td>
<td>Imprisonment less than 3 month or Fine less than 500,000yen</td>
</tr>
<tr>
<td>Hit-and-Run</td>
<td>Imprisonment less than 5 years or Fine less than 500,000yen</td>
<td>Imprisonment less than 10 years or Fine less than 1,000,000yen</td>
<td>Imprisonment less than 5 years or Fine less than 1,000,000yen</td>
</tr>
<tr>
<td>Accessory to Drink-Driving</td>
<td>No penalty</td>
<td>No penalty</td>
<td>No penalty</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Administrative penalties</th>
<th>Before Amendment</th>
<th>After 2002 Amendment</th>
<th>After 2007 Amendment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive While Intoxicate</td>
<td>15 Penalty Points (Cancellation of driver's license)</td>
<td>25 Penalty Points (2-year-cancellation of Driver's License)</td>
<td></td>
</tr>
<tr>
<td>Drink-Driving (0.25 mg/l ~)</td>
<td>6 Penalty Points (Suspension of Driver's License)</td>
<td>13 Penalty Points (Suspension of Driver's License)</td>
<td></td>
</tr>
<tr>
<td>Drink-Driving (0.15 mg/l ~)</td>
<td>No penalty</td>
<td>6 Penalty Points (Suspension of Driver's License)</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5 Fatalities caused by drink-driving
4. EV ALUATION OF THE USE OF OCCUPANT PROTECTION DEVICES

4.1 Effect of seatbelt use
The rate of seatbelt use has been increasing steadily. This section estimates the reduction in fatalities for 2007 compared with those in 1992 afforded by increased seatbelt use. In order to understand effectiveness of seatbelt use accurately, we confined crash types and crash conditions for this analysis to the following:
1) Passenger cars and trucks (Both drivers and passengers are analyzed.)
2) Vehicles involved in head-on collisions
3) Vehicles that collided with a passenger car, a truck, or a special vehicle such as a farm tractor or a vehicle with caterpillar tread; or, those involved in accidents without any other vehicles or pedestrians
4) Vehicles that do not meet an accident at expressway
5) Those that were not involved in multi-vehicle collisions
Figure 6 shows the seatbelt use rate for all occupants involved in all crash types and crash conditions described above. Also, a seatbelt use rate is defined as the number of all occupants without seatbelts divide by the number of all occupants with seatbelts. The seatbelt use rate in 1992 was 74.2%. It rose to 98.5% in 2007, an increase of 24.3 percentage points. Table 2 shows the all injured occupants with/without seatbelts in 1992 and 2007 respectively. Table 3 shows the number of all occupants and the number of fatal occupants throughout 1992-2007 and fatality rate with or without seatbelt.

Figure 6  Seatbelt use rate in accidents

<table>
<thead>
<tr>
<th>Year</th>
<th>Fatalities</th>
<th>All occupants</th>
<th>Fatality rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>92</td>
<td>6,217</td>
<td>6,241,137</td>
<td>0.100</td>
</tr>
<tr>
<td>07</td>
<td>14,532</td>
<td>635,382</td>
<td>2.287</td>
</tr>
</tbody>
</table>

Table 2 All occupants with and without seatbelt

<table>
<thead>
<tr>
<th>Year</th>
<th>All occupants (with seatbelt)</th>
<th>All occupants (without seatbelt)</th>
<th>Seatbelt use rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>92</td>
<td>252,245</td>
<td>87,830</td>
<td>74.2</td>
</tr>
<tr>
<td>07</td>
<td>415,084</td>
<td>6,334</td>
<td>98.5</td>
</tr>
</tbody>
</table>

Table 3 All occupants and fatal occupants with and without seatbelt (throughout 1992-2007)
Using the information shown in Table 2 and Table 4, fatalities for 2007 were estimated based on the assumption that the seatbelt use rate was the same as that of 1992. If the seatbelt use rate $RU_{belt}$ and the number of all occupants are given, the number of occupants with seatbelt is calculated by

$$I_{\text{withbelt}} = I \times RU_{belt}$$  \hspace{1cm} (3)$$

where $I_{\text{withbelt}}$ : the number of occupants with seatbelt  \hspace{1cm} I : the number of all occupants and $RU_{belt}$ : the seatbelt use rate.

Also, the number of occupants without seatbelts is calculated by

$$I_{\text{withoutbelt}} = I \times (1 - RU_{belt})$$  \hspace{1cm} (4)$$

where $I_{\text{withoutbelt}}$ : the number of occupants without seatbelt.

Based on the seatbelt use rate $RU_{belt}$ and the fatality rate of occupants with seatbelt $RF_{\text{withbelt}}$, we estimated the number of fatality in 2007.

Fatalities in 2007 = $I_{07} \cdot RU_{belt92} \cdot RF_{\text{withbelt}} + I_{07} \cdot (1 - RU_{belt92}) \cdot RF_{\text{withoutbelt}}$

$$= 421,418 \times 0.742 \times 0.100 + 421,418 \times (1 - 0.742) \times 2.287 = 2,801$$  \hspace{1cm} (5)$$

where $I_{07}$ : all occupants in 2007, $RU_{belt92}$ : the seatbelt use rate in 1992, $RF_{\text{withbelt}}$ : the fatality rate with seatbelts, and $RF_{\text{withoutbelt}}$ : the fatality rate without seatbelts.

The number of fatalities recorded in 2007 was 744, then a reduction relative to seatbelt use rate was 2,057.

4.2 Effect of helmet use by motorcyclists

Figure 8 shows the rate of helmet use for motorcyclists involved in injurious accidents. That rate is high, and the increase in that rate has continued up to the present. The reduction of fatalities due to helmet use was evaluated. The helmet is used to protect the head or face of a rider. According to this fact, we calculated the fatality rate between the number of motorcyclist fatalities and the number of occupants injured on the head or the face. Table 7 shows the number of motorcyclist fatalities and the fatality rate of injured occupants with and without helmet use for each year from 1992 to 2007. We estimated the number of motorcyclist fatalities in 2007 without helmet using the fatality rates in Table 7.

Fatalities in 2007 = $I_{07} \cdot RU_{\text{helmet92}} \cdot RF_{\text{withhelmet}} + I_{07} \cdot (1 - RU_{\text{helmet92}}) \cdot RF_{\text{withouthelmet}}$

$$= 15,949 \times 0.884 \times 0.0369 + 15,949 \times (1 - 0.884) \times 0.0719 = 654$$  \hspace{1cm} (6)$$

where $I_{07}$ : the number of all occupants in 2007, $RU_{\text{helmet92}}$ : the helmet use rate in 1992, $RF_{\text{withhelmet}}$ : the fatality rate of occupants with helmet, and $RF_{\text{withouthelmet}}$ : the fatality rate of occupants without helmet.

As the number of fatalities recorded in 2007 was 494, it was evaluated that a reduction of 160 fatalities was achieved by the increase in helmet use.
Table 4  All injured occupants and fatalities with/without helmet whose major injured body regions were head or face in 1992, 2007

<table>
<thead>
<tr>
<th></th>
<th>92</th>
<th>07</th>
</tr>
</thead>
<tbody>
<tr>
<td>with helmet</td>
<td>19,196</td>
<td>15,413</td>
</tr>
<tr>
<td>without helmet</td>
<td>2,529</td>
<td>536</td>
</tr>
<tr>
<td>All injured occupants</td>
<td>21,725</td>
<td>15,949</td>
</tr>
<tr>
<td>Helmet use rate (%)</td>
<td>88.4</td>
<td>96.6</td>
</tr>
</tbody>
</table>

Table 5 All injured occupants and fatal occupants of motorcyclist who suffered the major injury on the head or the face with and without helmet (throughout 1992-2007)

<table>
<thead>
<tr>
<th></th>
<th>Fatality</th>
<th>All injured occupants</th>
<th>Fatality rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>with helmet</td>
<td>11,265</td>
<td>305,099</td>
<td>3.69</td>
</tr>
<tr>
<td>without helmet</td>
<td>1,891</td>
<td>26,312</td>
<td>7.19</td>
</tr>
</tbody>
</table>

5. EVALUATION OF ROAD INFRASTRUCTURE IMPROVEMENT

5.1 Effectiveness of road safety facilities
Road administrators throughout Japan have installed various road safety facilities to reduce traffic accidents. To measure the effectiveness of such facilities, we used the integrated traffic accident database for the years 1996 to 2005 maintained by the Japanese Ministry of Land, and Infrastructure, Transport and Tourism (MLIT). This database links great volumes of traffic accident data for national highways with a road geometry database of road alignments, roadside devices and facilities in Japan. The MLIT provides the national highway database regarding alignments, structures, facilities and so on, which name is Ministry of land, Infrastructure, transport and tourism Comprehensive Highway management system (called Michi Database).

The installation of traffic safety facilities by road administrators is expected to reduce the number of fatalities. This study evaluated the construction of the sidewalks, median strips and guard fences in terms of fatality-reduction. In this section, we compare the change in the number of fatalities with the cumulative length of the each road safety facility along national highways.

Figure 8(A) shows fatalities on non-intersection area per year and cumulative length of sidewalk installed from 1996 to 2005 for 774.4 km of national highways. Fatalities on non-intersection area numbered 49 in 1996, but only 35 in 2005 after installation of sidewalks along those 774.4 km of national highway. The fatality-reduction rate for this period was calculated to be about 30%. Figure 8(B) shows fatalities per year on non-intersection area and cumulative length of median strips installed from 1996 to 2005 for 397.8 km of national highways. Fatalities on non-intersection area along the 397.8 km without medians numbered 39 in 1996, but only 19 in 2005, after installation of medians. The fatality reduction rate was calculated as over 50%. Figure 8(C) shows the cumulative lengths of guard fences installed on 1987.2 km of national highway. Also, Figure 8(C) indicates changes in the number of fatalities on non-intersection area along those 1987.2 km from 1996 to 2005. The number of fatalities on non-intersection area declined from 147 in 1996 to 96 in 2005. The reduction rate was calculated as almost 30%. Fatalities decreased with increases in the cumulative length of each of the three facilities shown in Figure 8.
Figure 8 Cumulative lengths of three facilities, versus fatalities (1996 to 2005)

5.2 Effect of the 1st Nation-wide Blackspot Program in Japan
Accidents on arterial highways tend to concentrate at specified locations known as “blackspots.” It is effective to implement fatality-reduction measures at these blackspots. The MLIT and the NPA designated about 3,200 blackspots on arterial highways in 1996. The Road administrators throughout Japan cooperated with local police in implementing various fatality-reduction measures, such as intersection improvements and road lighting installation, to reduce traffic accidents at these 3,200 blackspots from 1996 to 2005.

The 1st Nationwide Blackspot Program monitored the number of accidents and the numbers of fatal accidents at each blackspot. Based on the monitoring results, we estimated the effects of implementing improvements on the fatality reduction. However, the monitoring survey measured the number of traffic accidents and number of fatal accidents only; it did not separate the number of fatalities from the number of fatal accidents. A converted rate of fatalities per the number of fatal accidents was estimated using the accident data occurred at arterial highways from 1990 to 1993 and 2002.

We evaluated the number of accidents at 2,127 blackspots where improvement works finished until 2001. We calculated the average annual number of accidents for “before improvement” using the accident record from 1990 to 1993. The average annual number of accidents for “after improvement” is calculated using the accident data from the next year when the improvement works had finished to 2002. Figure 9(A) indicates the number of traffic accidents per year before and after the improvements. Figure 9(B) indicates number of fatal accidents per year before and after each improvement at all of the 2,127 blackspots. Figure 9(C) shows the fatalities before vs. after the program using the converted rate. The 1st Nation-wide Blackspot Program was found to
have achieved an annual reduction of 1,269 traffic accidents and 464 fatalities (Figure 9(C)).

![Figure 9 Accident-reduction of the 1st Nationwide Blackspot Program](image)

5.3 Effectiveness of the 2nd Nationwide Blackspot Program

The 2nd Nationwide Blackspot Program in Japan went from 2003 to 2007, after the 1st Nationwide Blackspot Program finished in 2002. The MLIT and the NPA designated 3,956 blackspots on arterial highways in 2003. Road administrators throughout Japan cooperated with local police in implementing various fatality-reduction measures from 2003 to 2007. The second program has monitored the number of traffic accidents, and fatalities at each blackspot.

We evaluated the number of accidents at 2,216 blackspots where improvement works finished until 2005. The number of traffic accidents, fatal accidents and fatalities before and after each improvement at each blackspot were measured. The average annual number of traffic accidents, fatal accidents and fatalities for “before improvement” is calculated using the accident record from 1996 to 1999. The average number of traffic accidents, fatal accidents and fatalities per year for “after improvement” is calculated using the accident record from the next year when the improvements finished to 2006. Figure 10(A) indicates the number of traffic accidents per year before and after the program. Figure 10(B) indicates the number of fatal accidents per year before and after the program. Based on the accident records before and after the improvements, the 2nd Nationwide Blackspot Program reduced traffic accidents by 2,047 per year and fatalities by 84 per year (Figure 10(C)). These fatalities were estimated by the converted rate.

![Figure 10 Accident-reduction of the 2nd Nationwide Blackspot Program](image)

6. EFFECT OF CHANGES IN VEHICLE SPEED

This section evaluates the effect of reduction of a vehicle risk recognition speed on the number of fatalities. Recently, the reduction of the vehicle risk recognition speed is observed in almost all accidents. The vehicle risk recognition speed (hereinafter vehicle-speed) recorded in accident database refers to the speed when the driver noticed the conflict before the accident, rather than to the speed at impact. This reduction might have been occurred for the following reasons: a
lowering of the share of driving by younger drivers, an increase in the number of elderly drivers and an increased awareness of the importance of driving safety. Even though the vehicle-speed refers to the speed at recognition rather than at impact, lower vehicle-speeds tend to mean lower impact velocities. Reductions in impact speed tend to reduce the severity of occupant injury. In fact, the number of fatal accidents caused by speeding (mainly among younger drivers) decreased rapidly for the years 1992-2007.

![Graphs](image-url)

Figure 11 Cumulative percentages of the number of accidents in terms of vehicle speeds in 1992 and 2007.

In this section, we estimated the number of fatalities for 2007 based on the assumption that a distribution of the vehicle-speed in 2007 is the same as that of 1992. Figure 11 shows the difference in vehicle-speeds between 1992 and 2007 for five accident types. Cumulative percentages of all five accident types in 2007 were larger than those in 1992 over the whole vehicle-speed. The vehicle-speeds in 2007 are lower than those in 1992, and the distribution of the vehicle-speed contributes to the reduction of the number of fatalities. In order to understand influence of the vehicle-speed reduction accurately, we confined the following five accident types.

1) “Single-car accidents”: These are self-explanatory. The fatalities of persons*1 were analyzed.
2) “Single-2-wheeled-vehicle accidents”: These are self-explanatory. The fatalities of persons*1 of the 2-wheeled vehicle including motorcycles or mopeds were analyzed.
3) “Pedestrian-car accidents”: These are accidents in which a pedestrian*1 is hit by a passenger car or truck.
4) “Car-to-car accidents”*2: These are collisions between passenger cars or trucks. We exclude rear-end collisions, which account for almost half of car-to-car accidents but in which the injuries tend to be minor. Fatalities of persons*1 in the first vehicle and the second vehicle are analyzed.
5) “Car-to-2-wheeled-vehicle accidents”: These are collisions between passenger cars or trucks and motorcycles or mopeds*3. The injuries tend to occur to the persons*1 of the two-wheeled vehicle, so we analyzed only the fatalities of persons*1 of the 2-wheeled vehicle.

Note 1: Number of persons in this section includes all drivers and passengers of the car and the 2-wheeled-vehicle, and all pedestrians involving the accidents.

Note 2: There are at least two vehicles in a car-to-car accident. The “first car” is the primary vehicle that causes the accident; when two vehicles are equally at fault, the first car is the vehicle whose persons are less injured. The second car is the other vehicle.

Note 3: “Moped” means a motorized two-wheel vehicle with a displacement of less than 50 cc.

There are two different procedures to estimate the number of fatalities according to the accident types. Firstly, we explain a procedure to estimate the number of fatalities caused by accidents involving the single-car accidents, the single-2-wheeled accidents and the pedestrian-car accidents. In case of these three accident types, a concerned vehicle speed is only one, which is the vehicle-speed of the car or the 2-wheeled regardless of fault. In the accident database, the vehicle-speeds are recorded as categorical values. There are 14 speed-intervals including 10 speed-intervals of 10 km/h up to 100 km/h, thee speed-intervals of 20 km/h up to 160 km/h, and one speed-interval over 160 km/h.

The number of fatalities 'F' and persons 'I' involved in the accidents per each fourteen speed interval of the car or the 2-wheeled in years from 1992 to 2007 were estimated. Also, we took into account the seatbelt-wearing rate and helmet-wearing rate in the analysis. Factors such as seatbelt-wearing and helmet-wearing greatly affect the fatality rate. \( RFV1,with \) is defined as the fatality rate of persons in the y-th year which characterizes the V1-th speed interval of the car or the 2-wheeled and 'with' conditions. Symbol of 'with' means that the person wears the seatbelt or the helmet, and the 'without' means non-seatbelt or non-helmet. The estimation equation is shown here:

\[
RFV1,with,y = FV1,with,y / IV1,with,y \tag{7}
\]

where, \( FV1,with,y \) : the number of fatalities, and \( IV1,with,y \) : the number of all persons who were involved in the accidents.

Average fatality rates of \( RFV1,with,ave \) and \( RFV1,without,ave \) for years 1992-2007 were estimated using Eq.(8) and Eq.(9) respectively.

\[
RFV1,with,ave = \frac{\sum_{y} FV1,with,y}{\sum_{y} IV1,with,y} \tag{8}
\]

\[
RFV1,without,ave = \frac{\sum_{y} FV1,without,y}{\sum_{y} IV1,without,y} \tag{9}
\]

\( RNV1,with,92 \) and \( RNV1,without,92 \) are defined as the rate of persons involving the V1-th speed interval in 1992 to total persons with seatbelt over the whole of speed intervals in 1992.

\[
RNV1,with,92 = IV1,with,92 / Iwith,92 \tag{9}
\]

\[
RNV1,without,92 = IV1,without,92 / Iwithout,92 \tag{9}
\]

where \( IV1,with,92 \) and \( IV1,without,92 \) : the number of persons in 1992, and \( Iwith,92 \) and \( Iwithout,92 \) : total number of persons in 1992 over the whole of speed intervals.

Eq.(10) shows the number of fatalities with or without seatbelt/helmet in the V1-speed interval using the distribution of the speed-interval in 2007.

\[
FV1,with,07 = IV1,with,07 \times RFV1,with,ave \tag{10}
\]

\[
FV1,without,07 = IV1,without,07 \times RFV1,without,ave \tag{10}
\]

Total fatalities \( F'_{07} \) in 2007 is estimated by Eq.(10).

\[
F'_{07} = \sum_{V1} (FV1,with,07 + FV1,without,07) \tag{11}
\]

When the vehicle speed distribution in 2007 is the same as that in 1992, the number of persons in
2007 who are involved in accidents in the speed-interval $V_1$ is estimated by multiplying the rate of persons involving the $V_1$-th speed interval in 1992 and total number of persons in 2007.

\[ I_{V1,\text{with,07}}^n = I_{V1,\text{with,07}} \times RN_{V1,\text{with,02}} \]

where, $I_{V1,\text{with,07}}$ and $I_{V1,\text{without,07}}$: the number of persons in 2007, $I_{V1,\text{with,07}}$ and $I_{V1,\text{without,07}}$: total number of persons in 2007 over the whole of speed intervals.

Thus, total fatalities in 2007 using the vehicle-speed distribution in 1992 is estimated by Eq.(13).

\[ F_{07}^* = \sum_{V1} \left( F_{V1,\text{with,07}}^n + F_{V1,\text{without,07}}^n \right) \]

where, $F_{V1,\text{with,07}}^n = I_{V1,\text{with,07}}^n \times RF_{V1,\text{with,ave}}$, and $F_{V1,\text{without,07}}^n = I_{V1,\text{without,07}}^n \times RF_{V1,\text{without,ave}}$.

The reduction of fatalities due to changes in the vehicle-speed is calculated as $F_{07}^* - F_{07}$. Results per each three accident type are shown in Table 7.

Secondly, the procedure to estimate the reductions of fatalities in case of car-to-car or car-to-2-wheeled accidents is explained. There are at least two vehicles involved and usually there are difference between the vehicle speed distribution of the first vehicle and that of the second vehicle. Combinations of vehicle speeds about these two vehicles are considered in this procedure. Other estimation procedures are the same as those in the first procedure.

At the first step, the fatality rate is estimated on each speed-interval with or without seatbelt or helmet. The number of fatalities $F^*$ and persons $I^*$ involved in the accidents per each fourteen speed interval of the car or the 2-wheeled in years from 1992 to 2007 were estimated. The estimation equation of is total fatalities in years with or without seatbelt/helmet shown in Eq.(14), and total persons with seatbelt/helmet in years shown in Eq.(15).

\[ F_{\text{with,y}} = \sum_{V1} \sum_{V2} F_{V1,V2,\text{with,y}} \]

\[ F_{\text{without,y}} = \sum_{V1} \sum_{V2} F_{V1,V2,\text{without,y}} \]

where, $F_{V1,V2,\text{with,y}}$ and $F_{V1,V2,\text{without,y}}$: total number of fatalities including fatalities by the first party whose vehicle speed is in the $V1$ speed-interval fatalities by the second party whose vehicle speed is in $V2$ speed-interval.

\[ I_{\text{with,y}} = \sum_{V1} \sum_{V2} I_{V1,V2,\text{with,y}} \]

\[ I_{\text{without,y}} = \sum_{V1} \sum_{V2} I_{V1,V2,\text{without,y}} \]

where, $I_{V1,V2,\text{with,y}}$ and $I_{V1,V2,\text{without,y}}$: number of all persons with seatbelt including persons by the first party whose vehicle speed is in the $V1$ speed-interval and persons by the second party whose vehicle speed is in the $V2$ speed-interval.

The fatality rates shown in the symbol of $RF^*$ are estimated on each speed-interval throughout 15 years from 1992 to 2007 with or without seatbelt or helmet.

\[ RF_{V1,V2,\text{with,ave}} = \frac{\sum_y F_{V1,V2,\text{with,y}}}{\sum_y I_{V1,V2,\text{with,y}}} \]

\[ RF_{V1,V2,\text{without,ave}} = \frac{\sum_y F_{V1,V2,\text{without,y}}}{\sum_y I_{V1,V2,\text{without,y}}} \]
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$RNV_{V1V2,\text{with},92}$ and $RNV_{V1V2,\text{without},92}$ are defined as the rate of persons in 1992 with or without seatbelt/helmet estimated by Eq.(17).

$$\begin{align*}
RNV_{V1V2,\text{with},92} & = I_{V1V2,\text{with},92}/I_{\text{with},92} \\
RNV_{V1V2,\text{without},92} & = I_{V1V2,\text{without},92}/I_{\text{with},92}
\end{align*}$$  \hspace{1cm} (17)

where, $I_{V1V2,\text{with},92}$ and $I_{V1V2,\text{without},92}$: the number of persons in 1992 who vehicle-speed of the first vehicle is in the $V1$ speed-interval and vehicle-speed of the second vehicle is in the $V2$ speed-interval, and $I_{\text{with},92}$ and $I_{\text{without},92}$: total number of persons in 1992 over the whole of speed intervals.

Eq.(18) shows the number of fatalities in 2007 with or without seatbelt/helmet at the $V1$-speed interval for the first car and the $V2$-speed interval for the second car using the distribution of the vehicle-speed in 2007.

$$\begin{align*}
F'_{V1V2,\text{with},07} & = I_{V1V2,\text{with},07} \times RF_{V1V2,\text{with},\text{ave}} \\
F'_{V1V2,\text{without},07} & = I_{V1V2,\text{without},07} \times RF_{V1V2,\text{without},\text{ave}}
\end{align*}$$  \hspace{1cm} (18)

Total fatalities in 2007 is estimated as shown in Eq.(19):

$$F'_{07} = \sum_{V1} \sum_{V2} \left( F'_{V1V2,\text{with},07} + F'_{V1V2,\text{without},07} \right)$$  \hspace{1cm} (19)

When the vehicle speed distribution in 2007 is the same as that in 1992, the number of persons who are involved in accidents are estimated.

$$\begin{align*}
I''_{V1V2,\text{with},07} & = I_{\text{with},07} \times RNV_{V1V2,\text{with},92} \\
I''_{V1V2,\text{without},07} & = I_{\text{without},07} \times RNV_{V1V2,\text{without},92}
\end{align*}$$  \hspace{1cm} (20)

Total fatalities in 2007 using the vehicle speed distribution in 1992 are estimated as follows;

$$F''_{07} = \sum_{V1} \sum_{V2} \left( F''_{V1V2,\text{with},07} + F''_{V1V2,\text{without},07} \right)$$  \hspace{1cm} (21)

where, $F''_{V1V2,\text{with},07} = I''_{V1V2,\text{with},07} \times RF_{V1V2,\text{with},\text{ave}}$ and $F''_{V1V2,\text{without},07} = I''_{V1V2,\text{without},07} \times RF_{V1V2,\text{without},\text{ave}}$.

The reduction of fatalities due to changes in the vehicle-speed is evaluated as $F''_{07} - F'_{07}$. The results of evaluation are summarized in Table 7.

Table 7 Estimated fatalities in 2007 under assumption that the distribution of the vehicle recognition in 2007 is the same as those in 1992

<table>
<thead>
<tr>
<th></th>
<th>92</th>
<th>07</th>
<th>Estimated fatalities based on the vehicle speed of 1992</th>
<th>Reduction of fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fatalties</td>
<td>All occupants</td>
<td>Corrected fatalities</td>
<td>All occupants</td>
</tr>
<tr>
<td>1 Car-single (All occupants)</td>
<td>2,114</td>
<td>28,663</td>
<td>828</td>
<td>737</td>
</tr>
<tr>
<td>2 2-wheeled-single (All occupants)</td>
<td>731</td>
<td>12,718</td>
<td>285</td>
<td>361</td>
</tr>
<tr>
<td>3 Pedestrians hit by cars</td>
<td>2,739</td>
<td>69,660</td>
<td>1,763</td>
<td>1,440</td>
</tr>
<tr>
<td>4 Cat-to-car (All occupants)</td>
<td>2,176</td>
<td>346,570</td>
<td>948</td>
<td>946</td>
</tr>
<tr>
<td>5 Car-to-2-wheeled (All occupants of 2-wheeled)</td>
<td>1,412</td>
<td>137,562</td>
<td>657</td>
<td>710</td>
</tr>
<tr>
<td>Total</td>
<td>9,172</td>
<td>595,173</td>
<td>4,481</td>
<td>4,194</td>
</tr>
</tbody>
</table>

7. CONCLUSIONS

The study aims to evaluate the outcome of fatality-reduction measures based on the reduction of fatalities in Japan achieved by a comprehensive safety program that was launched around 1990.
As shown in Table 7, fatality-reduction measures covered in the study were effective in reducing fatalities. We determined the effectiveness of each fatality-reduction measure by comparing the number of fatalities that occurred with the means against the estimated number of fatalities that would have occurred without the measure. Safety training programs for the novice moped drivers and educational program for the elderly drivers achieved moderate reductions. The drivers’ license system of Japan has tightened its licensing producers to prevent accidents caused by novice drivers. This strict enforcement achieved large reductions. Increasing the severity of penalties for drink-driving implemented by the NPA achieved large reductions. The use of occupant protection devices like seatbelts and helmets achieved large reductions. The MLIT enhanced to have equipped various road safety facilities to reduce traffic accidents and fatalities every year. Increasing the installation of road safety facilities achieved steady reductions. Also the Nationwide Blackspots Program implemented by the MLIT and NPA achieved large reductions of traffic accidents and fatalities.

The comprehensive traffic safety program was launched around 1990. Japan achieved a 50% reduction in fatalities for 2007, compared with 1995. Japan reached at the low fatality rates which is below 6.0 fatalities per 100 000 inhabitants by 2006. Also, the Fundamental Traffic Safety Program proposed by the Cabinet Office in 2002, which calls for bringing annual fatalities to less than 5,500, is projected to achieve that goal by the end of 2012. To achieve this purpose, many agencies, private companies, and other organizations make traffic safety programs. It might be concluded that the nationwide comprehensive traffic safety program results in a large reduction in fatalities recent years. It should be noted that reducing number of fatalities in the study were affected by not only improvements of the target factor but also improvements of other factors. Also, fatalities were influenced by the social changes that occurred during the 15 years from 1992. In the future, additional in-depth analysis of data is required to identify trends in the number of fatalities and the causes of traffic accidents.

<table>
<thead>
<tr>
<th>Countermeasure</th>
<th>Evaluation Period</th>
<th>Program Period</th>
<th>Decreasing number of fatalities by countermeasure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moped Driver Training Course</td>
<td>1990-2007</td>
<td>1992</td>
<td>uncountable</td>
</tr>
<tr>
<td>Elderly Driver Educational Course</td>
<td>1996-2007</td>
<td>1998</td>
<td>uncountable</td>
</tr>
<tr>
<td>Enforcement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novice Driver Probationary Period</td>
<td>1986-2007</td>
<td>1990</td>
<td>uncountable</td>
</tr>
<tr>
<td>Occupant Protection Device</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seatbelt Use</td>
<td>1992-2007</td>
<td>1987 (for front seat) 2008 (for rear seat)</td>
<td>2,057</td>
</tr>
<tr>
<td>Helmet Use</td>
<td>1992-2007</td>
<td>1986 (for all occupant)</td>
<td>160</td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blackspot Program(1st)</td>
<td>1990-2002</td>
<td>1996-2002</td>
<td>464</td>
</tr>
<tr>
<td>Blackspot Program(2nd)</td>
<td>1996-2006</td>
<td>2003-2005</td>
<td>84</td>
</tr>
</tbody>
</table>

ACKNOWLEDGEMENTS
The authors wish to thank the Japan Society of Traffic Engineering for the technical assistance and encouragement of studies.

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