# THE EFFECTIVENESS OF SEAT BELT REMINDER(SBR)S BY ANALYZING THE RESULT OF THE PILOT PROJECT OF AN INTERURBAN BUS WITH SBR

**Jinseop Park**
**Seung Hoon Lee**
**Joon-Ho Jun**
Korea Automobile Testing & Research Institute (KATRI)
Republic of Korea

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## ABSTRACT

It is a widely accepted fact that seat belts have been saving numerous lives in traffic crashes. However, if the effectual means are not used, discussing the effects is meaningless. This is why many countries make seat belt reminders (hereafter SBR) mandatory or introduce SBR assessment in their New Car Assessment Programs (hereafter NCAP). Although a SBR is a good solution for raising the seat belt wearing rate, the opinion on how many seat-belt non-users can be restrained by SBRs is arguable. This paper discussed the effect of SBR systems through the pilot project of an SBR-equipped interurban bus.

Korea Automobile Testing and Research Institute (hereafter KATRI) developed the customized SBR system for an interurban bus, which is actually being operated between two cities in Korea. The system consisted of a visual warning device, an occupancy detection sensor, and a buckle-up detection sensor (buckle-switch) on each passenger seat. There was a monitoring display system on the bus driver seat, so which seats are unfastened can be monitored and recorded. In order to figure out how many passengers wore seat belts, both the observational investigation and recorded data analysis were conducted. The results were compared with the one of buses without the SBR system.

According to the observed result, the wearing rate of seat belts in a bus without the SBR was 9.6% and the rate in a bus with SBR was 59.0%. To figure out how effective the SBR system is, the recorded log data was also analyzed. The overall average seat belt use rate of the SBR-installed bus was calculated to be approximately 55.82%.

There was a difference between both results of the observational investigation and log data analysis, but it is clear that the SBR system noticeably increased seat belt wearing rate. The SBR system applied to this pilot project did not include an audible warning. This means that the system reminded passengers of not wearing seat belts only by a warning light when they did not buckle up. Therefore, the effectiveness of SBR in this paper is only limited to the type of SBR with a visual warning.

SBR systems do influence the seat belt use rate. This paper showed that the SBR with occupant detection and visual warning could increase the rate by about 40 to 50%, compared to the case without the SBR. The current regulation does not require mandatory SBR for all seats and most NCAPs do not equally assess SBR in front and rear seats. Mandatory SBRs in the rear seats of M2 and M3 and the introduction of more advanced SBR assessment for NCAPs need to be studied and discussed.

## INTRODUCTION

It is a widely accepted fact that seat belts have been saving numerous lives in traffic crashes. According to the result comparison of crash tests conducted by Korea Automobile Testing and Research Institute, the possibility of serious injury of restrained occupants by seat belts is approximately 6 times higher than the unstrained [1]. However, if the effectual means are not used, discussing the effects would be meaningless.
Unfortunately, there are many countries struggling with the low seat belt wearing rate of occupants in vehicles. Korea is one of them. Especially, the wearing rate in rear seats of passenger cars is extremely low, compared to the one in front seats. On the other hand, northern or western European countries show comparatively high seat belt wearing rate in the rear seats, which is often almost similar to the rate in front seats. Figure 1 shows the seat belt wearing rate of each country in around 2013 [2].

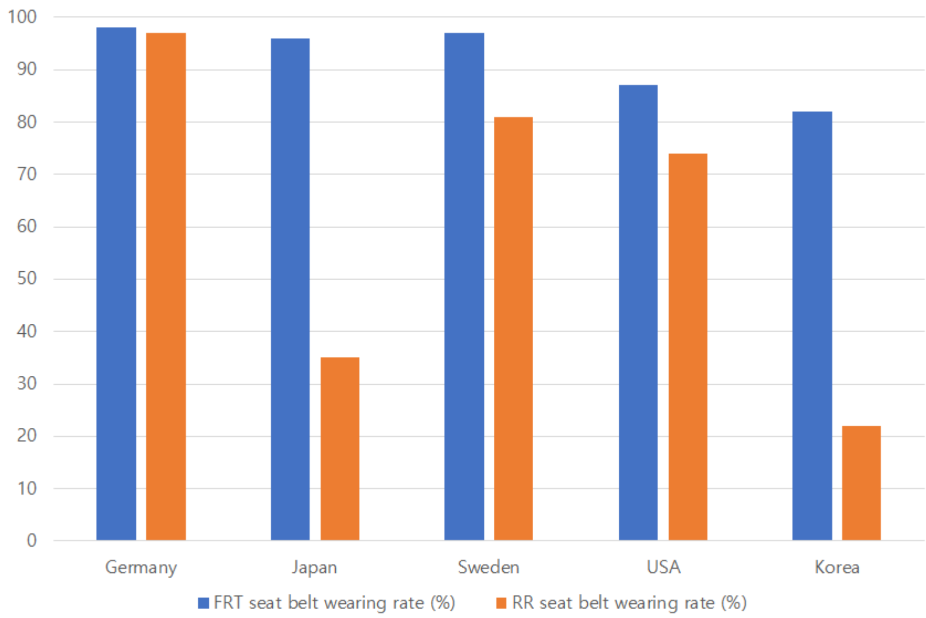



***Figure 1. Seat belt wearing rates of front and rear seats by countries (2015 IRTAD report).***

Because of this issue, Korean government has made nationwide efforts for the several years at the seat belt usage increase since 2010s. Continuous campaigns have been conducted and educational programs have been widely provided. On top of that, the Seat Belt Reminder (hereafter SBR) assessment has been introduced in Korean New Car Assessment Program (hereafter KNCAP) since 2013 [3]. Slight increases in the wearing rate appeared, but the rate has remained at about 40 to 60 % [4]. The seat belt usage rate of passengers in buses was nothing better than that, either.

Korea suggested the amendment of UN Regulation to mandate SBRs not only in a driver seat of M1 vehicles but also in other seats in 2014 and has been actively involved in the development of the amendment to UN Regulation 16 with European Commission and Japan. In 2016, the amendment extending the scope from M1 to other categories was finally approved with a few seat exemptions in UNECE WP.29 session [5].

Although there is no doubt a seat belt reminder is a good solution for raising this seat belt wearing rate, the opinion on how many seat-belt non-users can be restrained by it or how much effective it has been contributing to the seat belt use is various and arguable. Therefore, this paper studied the effects of SBRs in raising the seat belt usage rate through the monitoring process of an SBR-installed bus, which was actually being operated between two cities in Korea. Furthermore, how the more advanced SBR assessment can be introduced in KNCAP and regulations was discussed.

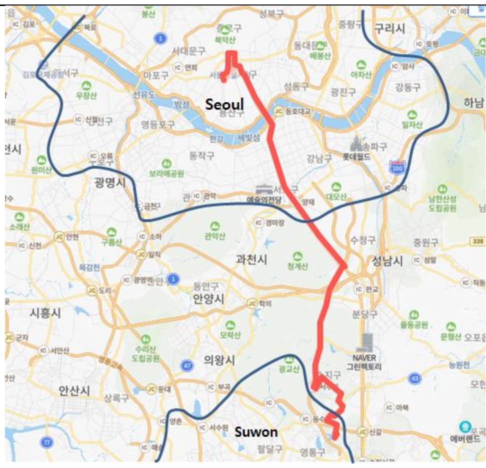
## METHODS

Korea Automobile Testing & Research Institute (hereafter KATRI) conducted a pilot project to study the effectiveness or influence of a SBR system on increasing a seat belt wearing rate. The project purpose was to compare the seat belt use rate of a bus with a SBR system to the rate of a bus without the SBR system. So, the effectiveness of SBRs in raising the seat belt wearing rates of passenger seating positions can be figured. Before the project, Korea Transportation Safety Authority (hereafter KOTSA), the mother organization of KATRI, has investigated the wearing rate of passengers in buses and reported that the interurban buses showed about 15% of seat belt wearing rate.

### Pilot project using an interurban bus with SBR

The customized SBR system was installed in an inter-urban bus, which is actually being operated between two cities, Seoul and Suwon in Korea. KD transit group operated the SBR bus. The information on the route or specification of the bus is as follows (See Table 1).

***Table 1. Information on pilot project of an interurban bus with SBR.***

| Bus Number | 5500-2 | | |
|---|---|---|---|
| Departure | Suwon | Destination (Turn-around) | Seoul |
| Overall route distance (km) | 40 | Route map | |
| Highway route distance (km) | 24 |   | |
| Number of stops | 25 | | |
| Passenger seating capacity (Number of persons) | 45 | | |
| Belt type | 2-point belt | | |
| Project term | July 11, 2015 ~ September 6, 2015 | | |

**Bus SBR system**

KATRI developed the SBR systems for the project with Controller Area Network (CAN) experts and installed the system to the interurban bus provided by the bus operator. All components including control circuits were newly designed, but the occupancy detection sensors and buckle-up detection sensors were used and modified from the parts of existing passenger cars. Each passenger seat had a visual warning indicator, an occupancy detection sensor, a buckle-up detection sensor (buckle-switch), a control unit. There was a monitoring display system and main controller on the bus driver seat, so which seats were not fastened was able to be monitored and recorded. The configuration is described in Figure 2.

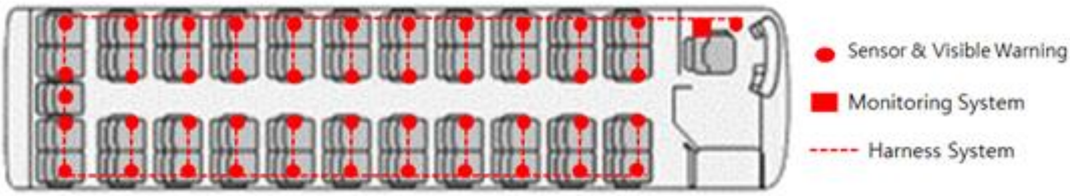



*Figure 2. Configuration of SBR system in the bus (top view).*

Basically, the system was designed to give a passenger a visual warning when the passenger did not wear the seat belt. Because KATRI was concerned that audible warnings could negatively affect the driver's safe driving and comfortable travel of many passengers, the simple reminding method was applied. In addition, the failure possibility of the SBR system with audible warning function was also considered.

In this system, when a passenger did not wear the seat belt after being seated, the visual warning light from the indicator on the back side of the seat in front of the passenger comes on with the symbol in table of UN regulation No.121, and the unrestrained seats appears on the monitoring display. This process is operated by controllers mounted beneath seat cushions and the program in the monitoring display system. How the system gives the warning and what are relevant parts in the system are shown in the Figure 3 below.

The program in the monitoring system also had a function to record data regarding occupancy and buckle status of each passenger seat. In every 5 seconds, it recorded the number of taken seats in the bus, the number of buckle-up seats in the buses, and the number of abnormal seats, etc. Here, the abnormal seats mean seats with worn seat belts when no one is seated, or seats with abnormal signals detected.

The monitoring system was made using a tablet and mobile application. Thus, the bus operator was able to easily download data and send those to the research team. Additionally, it was helpful for the research team to communicate with the application developer and bus operator because revising, updating, and upgrading the application program could be done easily.

| | |
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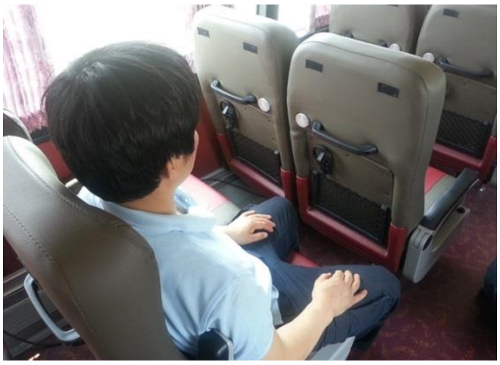
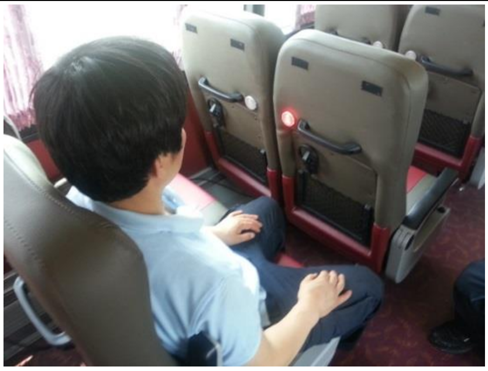
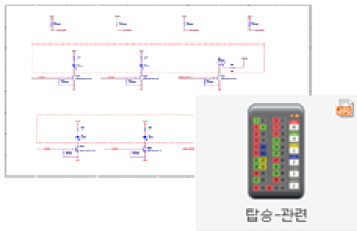
|  |  |
| Fastened (warning light off) | Un-fastened (warning light on) |
|  |   |
| Occupancy detection sensor and controller | Monitoring display system |

***Figure 3. Visual warning indicator and components of SBR system***

**Investigation into seat belt wearing rate**

**Observational investigation**

KOTSA carried out the investigation on the seat belt wearing rate of the public bus with the SBR system and buses not equipped with the SBR system. Here, the buses without the SBR system included not only the bus running on the same route but also interurban buses running on 6 other routes between Seoul and satellite cities. Investigators were on board and observed the wearing rate after the bus entered to the highway. After the observation, an interview regarding the effectiveness of the SBR system was conducted on the passengers wearing seat belts. To find out the pure SBR effect on the increase in seat belt use rate, bus drivers were asked not to encourage passengers to wear seat belts

**Data analysis of SBR system**

As it was mentioned earlier, the system was designed to record the number of taken seats in the bus, the number of buckle-up seats in the buses, and the number of abnormal seats every 5 seconds. The team analyzed the seat belt wearing rate everyday using two methods. For the first method, the wearing rate was calculated by the summation of the number of taken seats, the summation of the number of seats with seat belt fastened, and the summation of the number of abnormal seats. Equation (1) described how the rate was calculated. The second method is to average the seat belt wearing rates of all data sets for the day. At each data set, the wearing rate was calculated using the number of taken seats, the number of seats with seat belt fastened, and the number of abnormal seats. Equation (2) explained that in mathematical form. In both methods, for a more accurate and conservative calculation, the numbers of abnormal seats were subtracted from the number of restrained seats because it could be the case where seat belt was worn behind the back when the passenger was seated or the seat belt was fastened before the passenger took the seat.

$$seat\ belt\ wearing\ rate\ A = \frac{(\sum_{i=1}^{n} fs - \sum_{i=1}^{n} as)}{\sum_{i=1}^{n} os} \quad equation\ (1)$$

$$\text{seat belt wearing rate B} = \frac{\left(\sum_{i=1}^{n} \frac{fs - as}{os}\right)}{n} \quad \text{equation (2)}$$

where,
$os$: number of taken seats at data set (occupancy)
$fs$: number of seats with seat belts fastened at data set
$as$: number of abnormal seats at data set
$n$: number of data sets every 5 seconds during an analysis duration

## RESULTS

### Seat belt wearing rate from observational investigation

166 passengers of the buses with and without the SBR system on the project route were observed by KOTSA, and 526 passengers of interurban buses with 6 other routes were observed. The wearing rate of the bus with the SBR system was 59.0%. This was 49.4% higher than the rate of the bus without the SBR system. In case of 6 other interurban bus routes, only 15.2% of passengers used seat belt. Figure 4 summarizes the result.

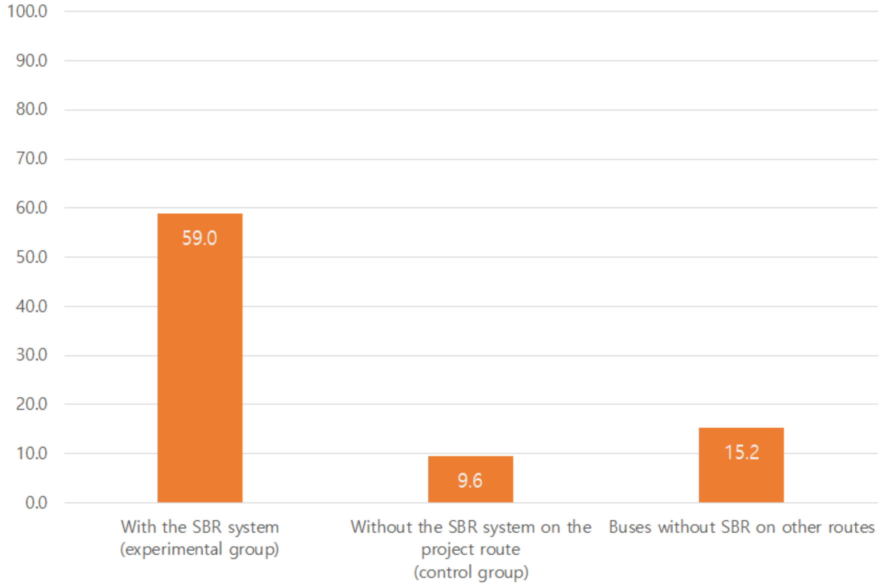



***Figure 4. Seat belt wearing rate (%) depending on applying the SBR system***

After the observation, investigators interviewed some passengers who buckled up in the bus. In the interview with 40 passengers, 19 passengers answered that the SBR system affected them to wear seat belts. This means 47.5% of passengers directly agreed on the effectiveness or influence of the SBR system with a visible warning on the increase in seat belt usage rate.

### Seat belt wearing rate from SBR system data analysis

There was 49-day data obtained from the system. Since some data were incorrectly saved or even not saved on certain days, those were excluded. Finally, the data for consecutive 40 days from July 27th to September 4th was selected and analyzed. As a result of analyzing all data sets of 40 days, the seat belt wearing rate A by equation (1) showed 55.82%, and the seat belt wearing rate B by equation (2) was 52.08%. The both results were slightly lower than the one by observational investigation, but about 42 to 46% higher than the wearing rate of buses without the SBR system. Therefore, whether the used method was by an observational investigation or by SBR data analysis, the project result clearly showed the SBR system is very effective for increasing the seat belt wearing rate. One thing noticeable was the difference between the result by equation (1) and equation (2). Because while equation (1) calculated the rate using the whole number of taken seats and seat-belt-fastened seats during a day, equation (2) averaged the every-5-second wearing rates of the day, if there were not many passengers in the bus and some passengers did not wear seat belts for a long time, then the individual rate values from the data sets with small number of passengers might have dominated the overall wearing rate calculated by equation (2). Due to this reason and a lot of data sets, the seat belt wearing rate from the data analysis result based on equation (1) was referenced for further discussion on this paper. Unlike the observational investigation, the data analysis method was able to analyze how long the SBR effect could last. The team looked at the change by computing the seat belt wearing rates on a weekly basis. Figure 5 displayed the trend of seat belt wear rate during the project term.

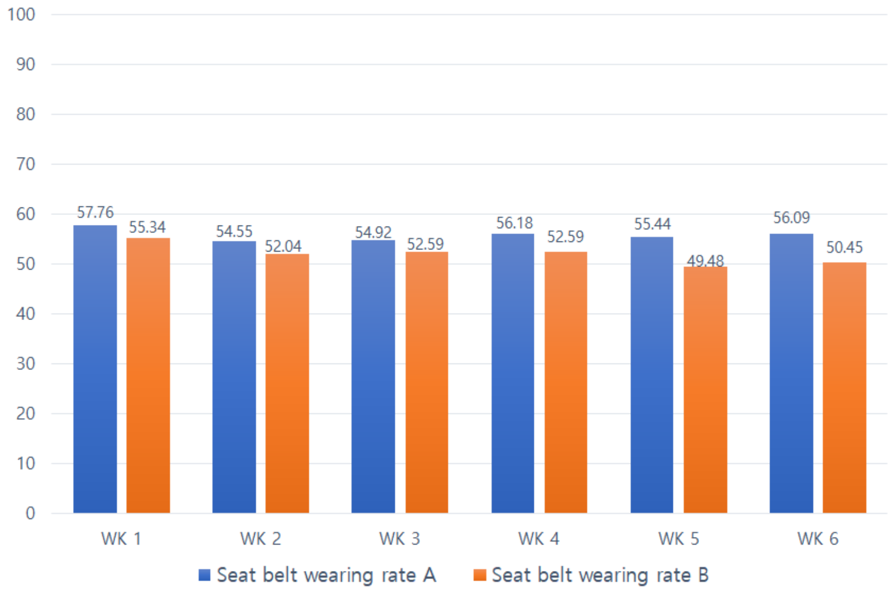



***Figure 5. Change of the seat belt use rate (%) of the SBR bus during the project period***

## DISCUSSION AND LIMITATIONS

### Literature reviews

There were several studies and papers on the effect of SBRs on seat belt wearing rate out there. According to an extensive study by Sweden, 85.8% belt wearing rate in driver seat positions without SBRs and 97.5% with Euro NCAP compliant SBRs were observed. The paper also reported about 80% of drivers not wearing seat belts without SBRs wore seat belts in vehicles equipped with an SBR with a light signal and a sound signal [6].

In order to figure out the effectiveness of Ford SBR system, Insurance Institute for Highway Safety (IIHS) and Ford motors made observations of driver belt use at 12 Ford owned dealers in 2001. The author estimated the overall use rate at 71% for drivers of vehicles without SBRs and 76% for drivers of vehicles with SBRs. The author concluded the difference of 5% points was statistically significant ($p<0.01$) [7].

In 2015, Mousel et al summarized results of a laboratory study conducted by Japan in relation to effect of SBRs on belt use of both driver and rear seat passengers. In this study, the initial belt wearing rate without a SBR warning was 38%. When both driver and rear seat passengers were presented with a visual warning, the usage rose to 72%. When an audiovisual warning was applied, the rate rose to 97% [8].

### Effectiveness of SBRs on increasing a seat belt wearing rate

Through this pilot project, it was confirmed that the effectiveness of the SBR with even only a visual warning on increasing seat belt wearing rate could be more than 40%. The wearing rate increased by approximately 50% according to the result from the observational investigation, and the rate increased by about 45% based on the result of SBR data analysis, compared to the rate in a bus without the SBR system. The result from the interview with 40 restrained passengers also stated that SBR visual warnings given directly to passengers could increase seat belt use rate by about 48%. The issue also has been discussed that the SBR effectiveness might be diminished as passengers adapt to the SBR system. Because this SBR system was installed in one particular bus and same people usually use the bus, some may be concerned about the reduction in the SBR effectiveness by familiarity resulting from prolonged exposure to the SBR. However, no strong correlation between the duration to use the SBR and the effectiveness of the SBR on the increase in seat belt usage rate was observed in the result of data analysis, which has been done through the procedures to compare the seat belt usage rate of each week.

**KNCAP and SBR**

KNCAP introduced the SBR assessment in 2013. The maximum 0.3 additional points had applied to KNCAP overall rating until 2016 as an incentive. In 2017, KNCAP included the SBR rating in the overall rating scheme with maximum 1 point. After UN regulation No.16 extended the SBR scope from M1 driver seat to other vehicle categories, the new SBR test protocol and rating scheme were included in KNCAP as an incentive again.
Indeed, the program was successful. The installation rate of SBRs in the test vehicle models has increased rapidly since 2013. For domestic vehicles in Korea, the SBR already became a standard device in both front and rear seats in 2019 before the implementation date of the mandatory regulation (See Figure 6).

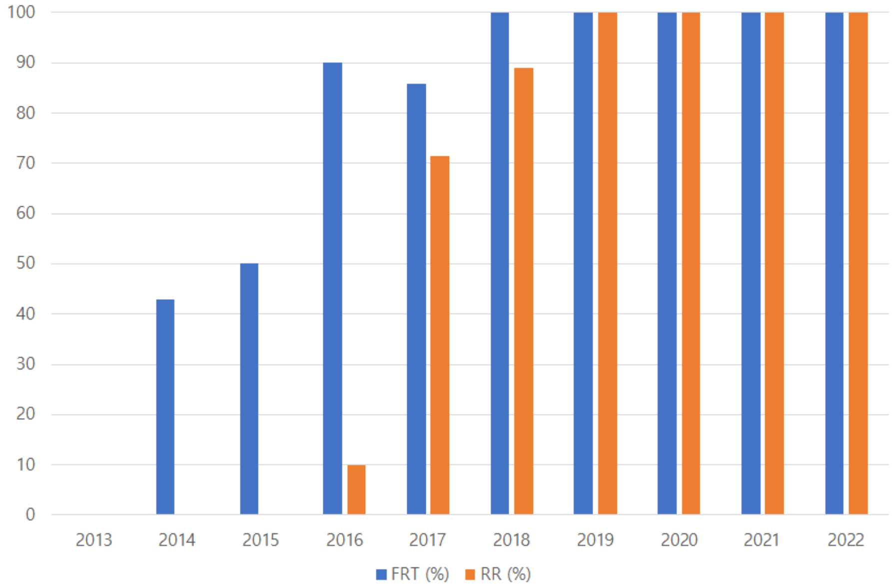



*Figure 6. Annual SBR installation rates of assessed passenger car models(≤ 10 passengers) in KNCAP*

Even though SBR systems have been installed in all seats of passenger cars as a standard, the seat belt wearing rate of rear passenger seats are still much lower than the rate of front passenger seats in Korea. As Figure 7 shows, the rate change of rear seats is standstill recently. This is why KNCAP needs to pay attention to and come up with idea to raise the seat belt wearing rate in rear seats to the level of the seat belt wearing rate in front seats.

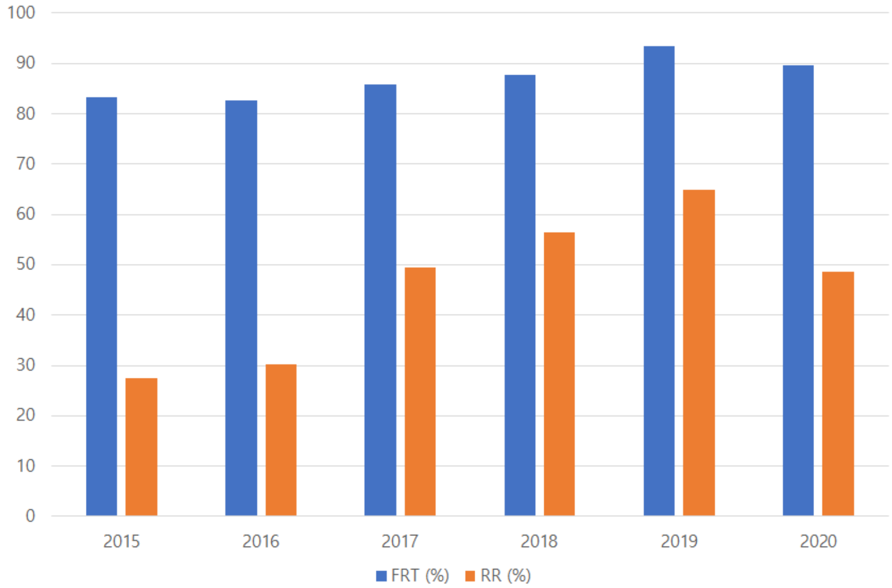



*Figure 7. Trend of seat belt wearing rates of FRT & RR seats*

This study gives some clues to it. The SBR system of this project directly warned each passenger with an occupancy detection sensor and a constant warning light unlike the current typical SBR system of passenger cars. First of all, the application scope of detection sensors should be reviewed. Currently, an additional score is given to a car applying occupancy detection sensors to rear seats in KNCAP. There are already many vehicle models with detection sensors in the rear seats. The technology is sufficiently available and mature in the market, and various occupancy detection sensing systems are under research and development. Therefore, including the assessment of a seating detection function as a standard in the program is highly recommended. This may also be an effective way to facilitate all passenger seats of various vehicle models to be equipped with appropriate SBRs. Secondly, KNCAP needs to encourage all cars to warn all passengers in cars when they are not retrained by seat belts, so they can recognize that they have to wear seat belts. Because the current protocol requires SBRs to remind only a driver of the unrestrained seating positions, there is an issue that the SBR effectiveness relies on the driver's second reminding and responsibility. The issue is soluble. Future cars will include various interior displays. It means many potential measures to remind all passengers of their restraint status will be available. On the other hand, the issue must be solved. The future cars will provide driverless ride environment in the age of autonomous vehicles sooner and later. Equal reminding is inevitable. This study obviously showed direct warnings to passengers worked. Almost half of passengers who fastened their seat belts in this project responded that they buckled up by the warning light in front of them. KNCAP should consider the introduction of new technologies and assessment protocols in relation to direct warnings to all passengers.

In line with this, there was research on different seat belt assurance systems, which are, so called, seat belt interlock (hereafter SBI). Two concepts, vehicles with speed limiter and with transmission interlock were suggested. Unlike SBR, SBI is a more active system to render passengers restrained with seat belts. [9]

Since KNCAP is about to establish the next KNCAP roadmap, KNCAP and stakeholders need to discuss and consider new measures to increase the seat belt wearing rate as the previous KNCAP protocol made contribution to the increase in the seat belt wearing rate. It is time to change and take a second leap forward in SBR assessment.

### Regulation and SBR

The current Korean Motor Vehicle Safety Standard (KMVSS) and UN regulation mandate SBRs for all vehicle categories, but have several exceptions, which exempt folding seats and passenger seats in the rear of buses. Excluding passenger seats in buses and coaches is debatable because applying SBRs to driver seating positions in those vehicles is mandatory. It is not fair that passengers in the same car are provided with different levels of safety performance. This study presented a solution to apply SBRs to passenger seats in buses and demonstrated its possibility. Discussion on mandating SBRs in all passenger seating positions is highly recommended with the follow-up benefit-cost analysis.

### Limitations

The SBR system developed and applied in this pilot project included only a visual warning, which was a constant light signal when the passenger did not wear a seat belt. Therefore, the effectiveness of the SBR system is limited to only a visual warning function, not a flashing optical warning function, an audible warning function or an audiovisual warning function in this study.

The research team found that seat belts on the bus were sometimes fastened without seated passengers while the bus was in service. This might have led to incorrect data analysis if passengers had been seated on the seats. In addition, hardcore seat belt non-users might have affected the overall wearing rate calculation depending on a situation as it was mentioned earlier.

## CONCLUSIONS

For decades, seat belts have played an important role in car safety. Even in the era of autonomous vehicles, they will remain effective for a considerable period of time. According to the survey conducted by KATRI, consumers still wanted to have injury mitigation systems in their autonomous vehicles and preferred seat belts the most among currently existing restraint devices [10]. Hence, SBR systems is also important. This paper demonstrated the SBR with only a visual warning to each passenger influenced the increase in the seat belt use rate by more than 40%.

To keep passengers in cars safer, manufacturers have to develop more advanced SBR technologies and try to introduce those for future vehicles. It could be the extension of passengers in cars who benefit from SBRs, direct warnings not only to a driver but also to individual passengers using new interior displays or indicators, or mild interlock function. In line with the new technologies, the government and society also need to improve the safety assessment system to raise the wearing rate of seat belts.

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