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# Cost-Benefit Analysis of Automatic Emergency Braking System Installation from Thailand Vehicle Market

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**Abstract**

The automatic emergency braking (AEB) is one of the advanced active vehicle safety features which is the most promising safety technology in recent years for reducing accidents. This study analyzes the impact of AEB system installation in vehicle market using Cost-benefit analysis from Thailand. The benefit gain mainly bases on number of lives saved under rear-end collision accident. The cost is calculated from number of AEB unit installed in new vehicle each year. Sensitivity analysis is applied by varying effectiveness of AEB system. The results suggest that AEB is not cost-effective even in optimistic scenario under prescribed circumstance. Other benefit gain from AEB in aspect of accident prevention should be further investigated.

**Keywords:** Cost-benefit analysis, Automatic emergency braking (AEB), Thailand vehicle market

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## Introduction

World Health Organization (WHO) has reported that the number of road traffic deaths has reached 1.35 million a year. Up to 90% of this number is dominated by low- and middle-income countries and this number is still increasing every year (WHO, 2018). Thailand is categorized in the middle-income country group and has the highest traffic fatality rate among ASEAN and among the worst in the global level. Powered two-wheelers are the main proportion of the number of road fatalities following by pickup trucks and passenger cars respectively (Ministry of Public Health, 2021). In order to cope this problem, Thailand has to put many efforts into different strategies. One of the strategies is to improve vehicle safety standards (WHO, 2020) which can be achieved by using of the vehicle safety technologies.

The automatic emergency braking (AEB) system is one of the vehicle active safety technologies designed to prevent and mitigate rear-end and pedestrian collision accidents. The system constantly detects the objects ahead of the vehicle by using sensor which can be varied from cameras, radar, or combination of these sensors. It applies the brake automatically if the object ahead is approaching to the vehicle and the driver does not respond to the situation. Many studies reported the effectiveness of AEB system which can reduce the rear-end collision accidents by 25-50% (Cicchino, 2017) (Jeong & Oh, 2013) (Fildes et al., 2015) (Isaksson-Hellman & Lindman, 2016). However, cost of the system is very high (Sitthiracha & Koetniyom, 2021). Before issuing any policy, authorities or policy makers need information on feasibility of both technical and economic aspects. Then cost-benefit analysis (CBA), which is one of the useful economic analysis tools, can provide insight of the situation helping those governors.

There are few studies using CBA to analyze cost effectiveness of the vehicle safety technologies. Mohd Jawi, Ariffin, Ahmad, Abu Kassim, Mohamed & Voon (2014) demonstrated impact of electronic stability control and seat belt reminder systems through CBA and focuses only on Malaysia. European Commission Directorate General Energy and Transport (EC) (2006) used CBA to assess the cost effectiveness of 21 vehicle safety technologies across European region. Edwards, Nathanson, & Wisch (2014) estimated possible benefits of AEB system installation in vehicles sold in Europe and then used benefit-cost ratio (BCR) to determine range of the system costs for the break-even point. The parameters and scenarios, that were used by these studies for CBA, are summarized in Table 1.

**Table 1** Summary of parameters and scenario using for CBA

| Items | Mohd Jawi, Ariffin, Ahmad, Abu Kassim, Mohamed & Voon (2014) | EC (2006) | Edwards, Nathanson, & Wisch (2014) |
|---|---|---|---|
| **Benefit** | - Number of vehicles on road<br>- Number of road crashes (casualties & damage only)<br>- Technology effectiveness<br>- Crash costs (casualties & damage only) | - Baseline casualties<br>- Technology effectiveness<br>- Vehicle market forecasting<br>- Transport distance growth<br>- Effect of Improvements of vehicles and roads<br>- Casualty costs | - Injury risk curves<br>- Impact speed distribution<br>- Impact location<br>- Crash scenarios<br>- Driver braking behavior<br>- AEB performance<br>- Monetary casualty values<br>- Baseline casualties for Great Britain and Germany<br>- EU27 casualties |
| **Cost** | - System | - Installation | - System (as output) |
| **Scenario** | - 100% fitment on current vehicles with fixed number of the vehicles on road | - Do nothing<br>- Retrofit all current vehicles<br>- New vehicle penetration | - Nominal crash scene<br>- Optimistic crash scene<br>- Pessimistic crash scene |
| **CBA** | - BCR<br>- Discount rate | - BCR<br>- Discount rate | - BCR (as input) |

This study demonstrates how to evaluate the impact of AEB system installation in Thailand vehicle market using CBA. The framework for CBA is presented. Possible benefits and costs are determined through parameters and assumptions. The scenario covers from year 2021 through 2030.

## Methods

The main principle of CBA is comparison of total benefits and total costs of an interested issue which can be anything that investment is related (Layard, 1994). There is not only one way to determine benefits over costs as shown in Table 1. It depends on some assumptions and available data/information. In this study, the framework for CBA is shown in Figure 1.

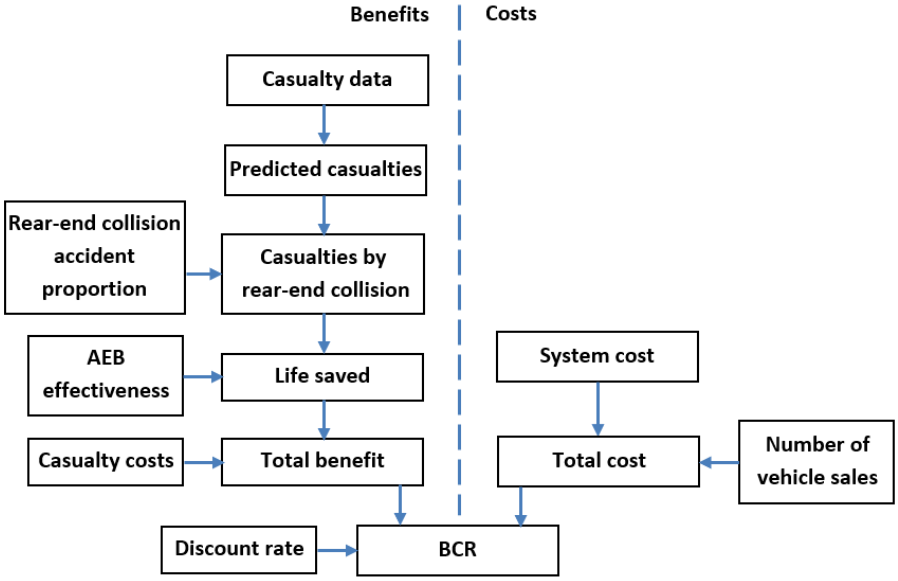



**Figure 1 CBA framework**

## Casualty data and predicted casualties

The numbers of road traffic deaths and injuries by four-wheel vehicles in Thailand between 2015 and 2019 are shown in Figure 2 and 3 respectively. These data are compiled from the Injury Data Collaboration Center (Ministry of Public Health, 2021). The data are selected from top-three ranks of the four-wheel vehicle group only which are pickup truck, passenger car/taxi and van. The pickup truck is the major contribution to the number of deaths and injuries when comparing to the other two. Trends of both death and injury are increasing every year. However, the injury database has not yet distinguished into serious and minor injuries. The proportion of the serious and minor injuries are obtained from Juntarasup (2018) by 13.4% and 86.6% respectively for the pickup truck and 25% and 75% for passenger car.

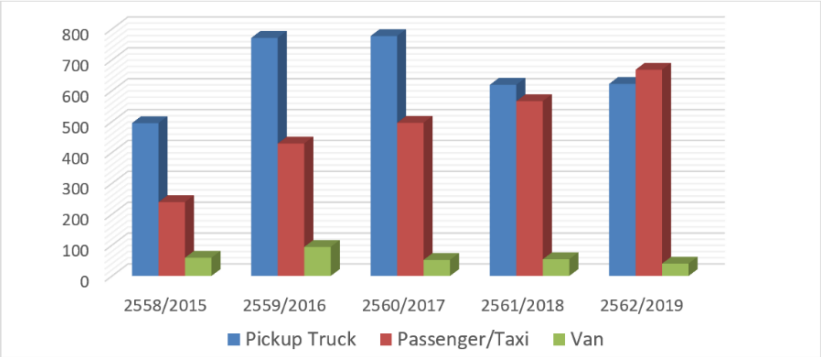



**Figure 2** Number of road traffic deaths by four-wheel vehicles (Ministry of Public Health, 2021)

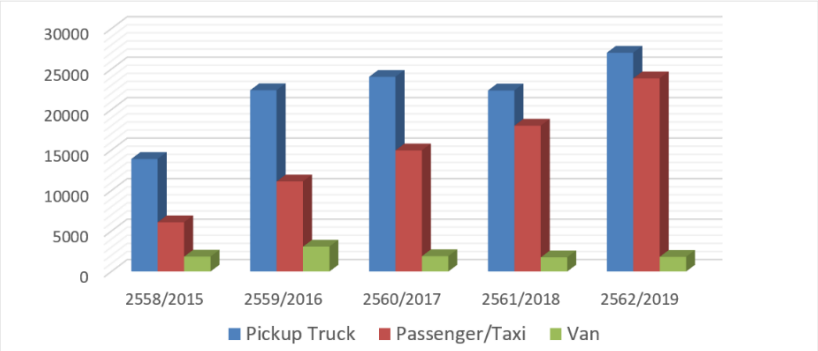



**Figure 3** Number of road traffic injuries by four-wheel vehicles (Ministry of Public Health, 2021)

There are many methods to forecast the road traffic casualties. Jomnonkwao, Uttra, & Ratanavaraha (2020) has attempted to forecast the road traffic death by using different techniques, e.g., Time-series analysis, curve estimation, regression analysis, and path analysis. Many input data are used to develop the models including death rate per 100,000 population, national gross domestic product, number of registered vehicles, and energy consumption in transportation sector. However, all models could not predict properly after 10 years. These results might imply that more factors influencing the road traffic death were not considered. Since there is not any model to forecast the road traffic casualties perfectly, the linear regression of previous data is used instead under following assumptions.

- Rate of change in number of deaths and injuries is constant due to constant vehicle sale volume.
- Deaths and injuries contributed by the van are neglected due to small number when comparing to other vehicle types.
- There is not any change in the vehicle safety equipment fitment of all vehicles sold in the Thailand market throughout the period under consideration.
- Pandemic decease and lockdowns due to Royal Thai Government's orders, which affect movement of goods and people since 2020, are neglected.

**Rear-end collision accident proportion**

AEB system is very effective in reducing a certain type of accident, i.e., the rear-end collision. The rear-end collision data related to the number of road traffic deaths and injuries are obtained from the Transport Accident Management System (TRAMS) (Ministry of Transport, 2021). According to TRAMS, the rear-end collisions account for the number of road traffic deaths and injuries in average around 17.6% and 16.8% respectively. Thus, forecasting of the number of road traffic deaths and injuries by the rear-end collision case is based on these percentages and the baseline data from Figure 2 and 3.

**AEB effectiveness**

In this study, it is assumed that basic AEB system is installed in all new vehicles starting from 2021. The percentage of lives saved bases on the effectiveness of AEB ranges from 25-50% as mentioned in the introduction. This can be used as sensitivity analysis by setting different effectiveness in different scenarios, e.g., pessimistic, nominal, and optimistic scenarios. The effectiveness is set at 25%, 38% (Fildes et al., 2015), and 50% for pessimistic, nominal, and optimistic cases respectively.

**Number of lives saved, casualty costs, and benefit gain**

The number of lives saved can be determined by following equations.

$$N_{\text{lives saved}} = \eta_{AEB} \times \%\text{rear-end} \times (N_{\text{death},Y} - N_{\text{death},2020}) \quad (1)$$

$$N_{\text{injuries saved}} = \eta_{AEB} \times \%\text{rear-end} \times \%\text{minor/serious injury} \times (N_{\text{death},Y} - N_{\text{death},2020}) \quad (2)$$

Where $\eta_{AEB}$ = AEB effectiveness for rear-end collision;
%rear-end = proportion of rear-end collision casualties;
%minor/serious injury = proportion of serious or minor injuries; and
Y = [2021, 2022, 2023, …, 2030].

The benefit gain of the road traffic casualties can be simply determined by multiplying the numbers of lives and injuries saved with the corresponding economic costs which are categorized into three groups: death, serious injury and minor injury. The cost of death and serious injury are 10 and 3 million baht/person in 2016 respectively (Thailand Development Research Institute,), while the cost of minor injury is 0.06 million baht/person in 2016 with inflation rate adjustment (Ministry of Transport, 2008). These values are necessary to be converted into true values corresponding each year by using inflation rate. The inflation rates obtained from Bank of Thailand are averaged and fixed at 0.6565% (Bank of Thailand, 2021).

**Number of vehicle sales, system costs, and investment cost**

The investment cost can be also simply determined by multiplying the number of vehicle sales in each year and AEB unit cost. The assumption is made on installation of AEB system in all new vehicle from 2021 through 2030 as a mandatory from Thai Government. Expected vehicle sale each year bases on the average of vehicle sales from 2012 to 2018 (Department of Land Transport, 2021) at about one million unit/year which are shown in Figure 4. The cost assumptions are made on the basic AEB system using single sensors which costs around 180 GBP (Thatcham Research, 2021) and is also adjusted by the inflation rate.

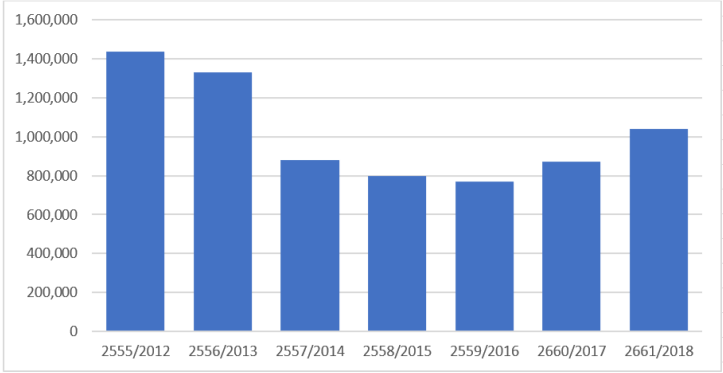



**Figure 4** Number of vehicle sales in Thailand from 2012 – 2018 [19]

## Benefit-cost ratio calculation

BCR can be calculated by Equation 3. Present values of total benefit and total cost can be calculated by Equation 4. Discount rate uses Social Rate of Time Preference (SRTP) which is based on what rate attract individuals to save their money rather than to consume them (University of Arizona, 2021). This concept corresponds to an assumption that there is not any subsidy or investment from the government. However, Thai government bond interest rate can be used instead of SRTP in practical (Royal Irrigation Department, 2012). Thai government 10-year bond interest rate is 1.873% (World Government Bonds, 2021).

$$\text{BCR} = \frac{Present\ value\ of\ total\ benefit}{Present\ value\ of\ total\ cost} \quad (3)$$

$$\text{Present value} = \text{Future value} \div (1 + \text{Discount rate})^{\text{No. of period}} \quad (4)$$

The criterion for deciding the cost effective is BCR > 1. If BCR is less than 1, that considered issue is not cost-effective (EC, 2006).

## Results and discussion

### Prediction of the road traffic casualties

Forecasted number of the road traffic casualties are shown in Figure 5 and 6. The number of road traffic deaths and injuries tends to be increased every year. When comparing to the historical data from 2015 to 2019 using the linear regression method, percentage errors are -16% and +22% for pickup truck and -11% and +17% for passenger car. After applying the proportion of the rear-end collision, the number of road traffic casualties by the rear-end collisions is forecasted as shown in Figure 7 and 8. The historical traffic accident data is crucial for identifying the specific accident and its casualties as shown in Figure 1. Thailand Development Research Institute (2020) has expressed a concern on the current Thailand traffic accident database which is not unified and is still far to be useful enough to identify the effective measures for the road safety problem. Different organizations involve the information collection with different purposes. It can be seen from the information used in this study have to be obtained from various sources. If the database is improved, the better prediction can be expected.

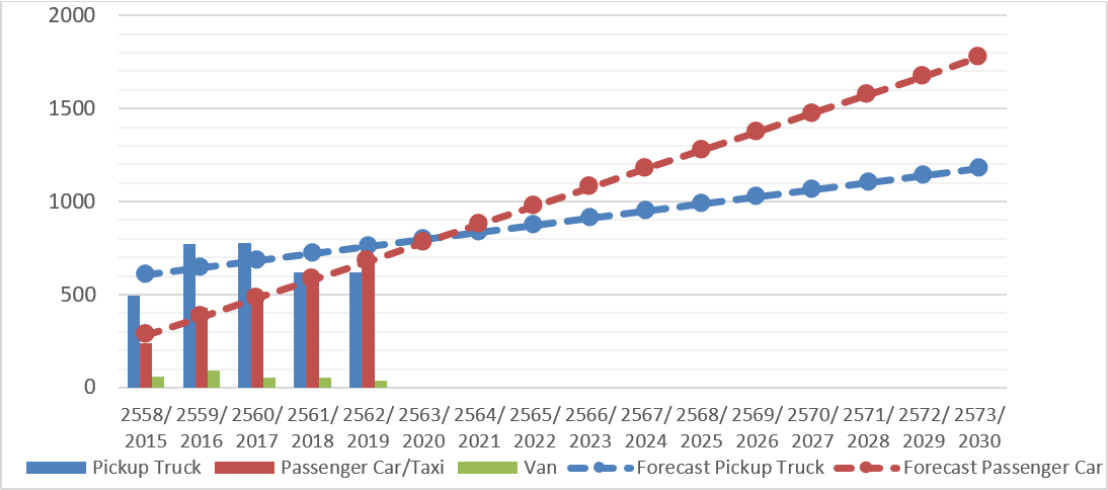



**Figure 5** Forecasted number of road traffic deaths by four-wheel vehicles

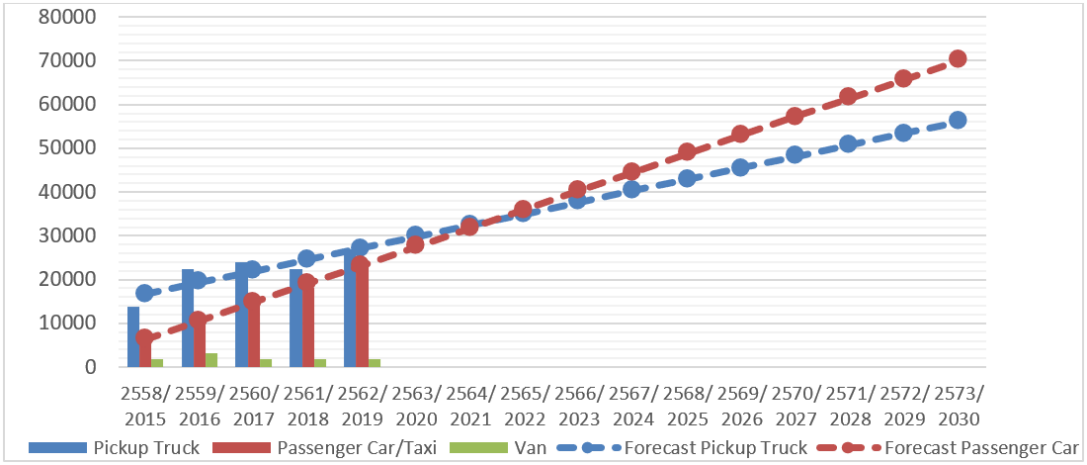



**Figure 6** Forecasted number of road traffic injuries by four-wheel vehicles

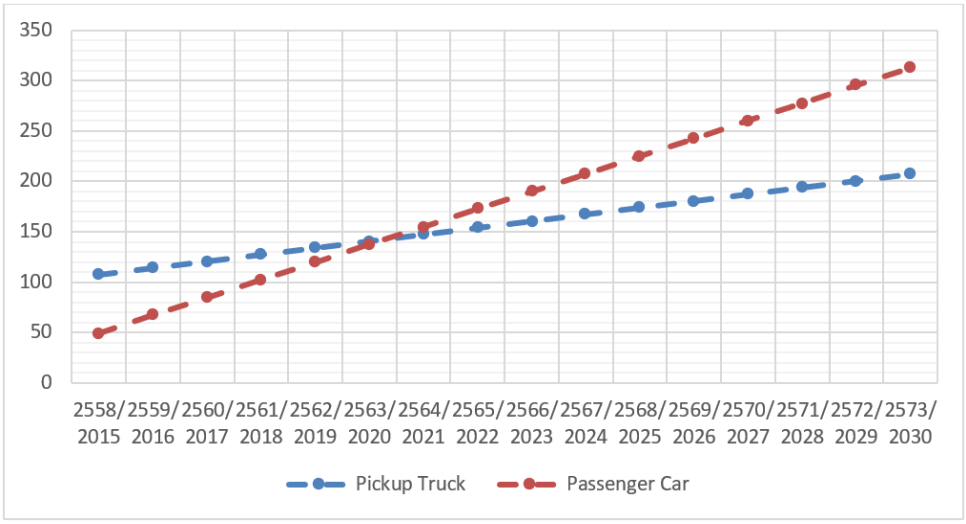



**Figure 7** Forecasted number of road traffic deaths by rear-end collisions

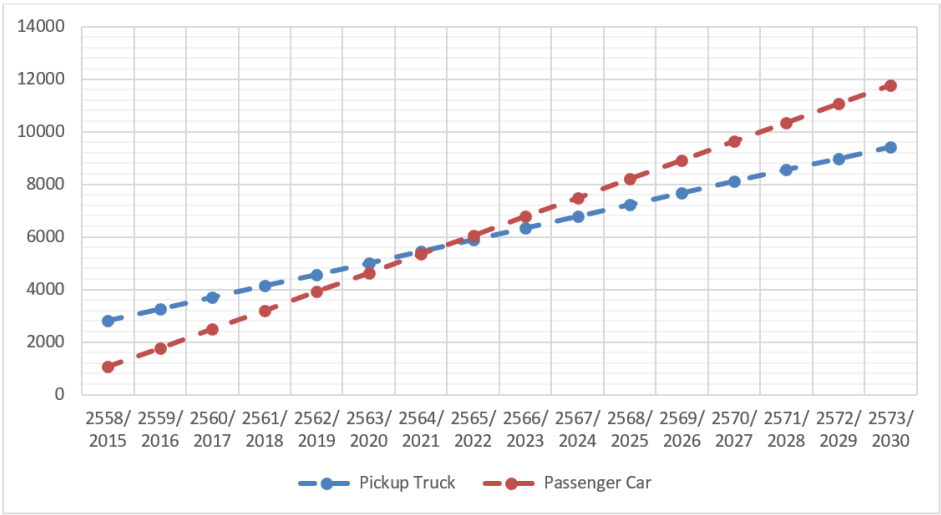



**Figure 8** Forecasted number of road traffic injuries by rear-end collisions

**AEB Cost-effectiveness**

Detailed calculations of the benefits and costs in different scenarios including the final BCR are shown in Table 2 and 3. The results of BCR in all cases are less than 1 which suggest that the AEB installation is not cost-effective under an assumed circumstance even the best AEB effectiveness under the optimistic scenario. This may come from two main reasons: the number of road traffic casualties by the four-wheel vehicles in Thailand and the economic cost of road traffic casualties for Thai people. The number of road traffic casualties in the Western, European and many high-income countries comes mainly from the four-wheel vehicles, while it is only 20% in Thailand. The economic cost of road traffic deaths and injuries is also very different between the Western countries and Thailand. The accident costs of a fatality, a serious injury and a minor injury in European Union year 2006 are 1,018,200 € (~40 million baht), 143,100 € (~5.6 million baht) and 23,100 € (~0.9 million baht) respectively (EC, 2006), while they are only 10, 3, and 0.06 million baht respectively in Thailand year 2016.

**Table 2** Benefit and cost calculations in different scenarios

| | Years | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **2564/ 2021** | **2565/ 2022** | **2566/ 2023** | **2567/ 2024** | **2568/ 2025** | **2569/ 2026** | **2570/ 2027** | **2571/ 2028** | **2572/ 2029** | **2573/ 2030** |
| **Nominal scenario** | | | | | | | | | | |
| - Lives saved [person] | 9 | 18 | 27 | 37 | 46 | 55 | 65 | 73 | 83 | 92 |
| - Injuries saved [person] | 439 | 878 | 1,317 | 1,756 | 2,195 | 2,634 | 3,072 | 3,512 | 3,951 | 4,389 |
| Benefit [MTHB] | 394 | 794 | 1,199 | 1,619 | 2,035 | 2,456 | 2,893 | 3,315 | 3,763 | 4,205 |
| Present value [MTHB] | 387 | 765 | 1,134 | 1,504 | 1,855 | 2,198 | 2,541 | 2,858 | 3,184 | 3,494 |
| **Total benefit [MTHB]** | | | | | **19,920** | | | | | |
| **Pessimistic scenario** | | | | | | | | | | |
| - Lives saved [person] | 6 | 12 | 18 | 25 | 30 | 36 | 43 | 48 | 55 | 61 |
| - Injuries saved [person] | 289 | 578 | 867 | 1,155 | 1,444 | 1,733 | 2,022 | 2,310 | 2,600 | 2,888 |
| Benefit [MTHB] | 261 | 524 | 792 | 1,073 | 1,337 | 1,614 | 1,907 | 2,180 | 2,481 | 2,772 |
| Present value [MTHB] | 256 | 505 | 749 | 996 | 1,218 | 1,444 | 1,674 | 1,880 | 2,099 | 2,303 |
| **Total benefit [MTHB]** | | | | | **13,123** | | | | | |
| **Optimistic scenario** | | | | | | | | | | |
| - Lives saved [person] | 12 | 25 | 36 | 48 | 61 | 73 | 84 | 97 | 109 | 121 |
| - Injuries saved [person] | 578 | 1,155 | 1,733 | 2,310 | 2,888 | 3,465 | 4,043 | 4,621 | 5,198 | 5,776 |
| Benefit [MTHB] | 520 | 1,058 | 1,582 | 2,123 | 2,683 | 3,238 | 3,790 | 4,371 | 4,949 | 5,534 |
| Present value [MTHB] | 511 | 1,020 | 1,497 | 1,972 | 2,445 | 2,897 | 3,329 | 3,769 | 4,188 | 4,597 |
| **Total benefit [MTHB]** | | | | | **26,225** | | | | | |
| **AEB cost [MTHB]** | 8,100 | 8,153 | 8,206 | 8,260 | 8,314 | 8,369 | 8,424 | 8,479 | 8,535 | 8,591 |
| Present value [MTHB] | 7,951 | 7,856 | 7,762 | 7,670 | 7,578 | 7,488 | 7,398 | 7,310 | 7,223 | 7,136 |
| **Total cost [MTHB]** | | | | | **75,371** | | | | | |

**Table 3** BCR according to different scenarios

| | **Pessimistic** | **Nominal** | **Optimistic** |
|---|---|---|---|
| **BCR** | 0.17 | 0.26 | 0.34 |

This study focuses mainly on benefit gain from saved casualties. There might be other benefits that still are not taken into account, for example, property damage cost and accident scene management overheads. BCR results may be improved if these factors are included.

## Conclusion

This study demonstrates how to analyze the cost-effectiveness of AEB installation in Thailand vehicle market using CBA for policy decision making aimed for casualty reduction from the road traffic accident. The results suggests that AEB is not cost-effective (BCR < 1). Thorough accident database is necessary for accurate prediction. It is suggested that further research should explore other benefits of AEB in aspect of accident prevention such as reductions of property damage and accident scene management overheads.

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