Traffic accident reduction potential and economic impact - automotive safety items

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ABSTRACT

Traffic accidents have become a public and financial issue for many countries. Its related cost could be reduced by the implementation of automotive safety technologies, such as ADAS (*Advanced Driver Assistant Systems*). Many of these systems were implemented in the past years, mainly in developed countries, and have positive effects in regards to the diminishment of traffic accidents. Brazil not only has registered a high accident rate, as well as delays on the adoption of measures that could diminish its rate. Thus, this work aims to comprehend the different traffic accidents in Brazil and correlate with the potential reduction rate according to each available technology in market that have known safety effects in other countries. Furthermore, the social-economic impact of the insertion of such technologies was estimated according to the actual traffic accidents costs statistics.

INTRODUCTION

Traffic Accidents [TA] are the eighth biggest cause of deaths in the world, leading the ranking for ages between 5 and 49 years [1]. Some estimates with costs show that TA in Brazil could correspond up to 4% of the national GDP, which is equivalent to the public expenditure of approximately 220 billion reais per year [2]. The social and economic impacts related to TA are worrisome and solutions that aim to mitigate the tragic consequences must be considered in the creation of public policies.

The decrease in TA cases and / or the mitigation of their severity is a reality in some developed countries, where measures have been implemented with scientifically proven effects, such as: application of appropriate speed limits, increased enforcement and compliance with legislation, improvements in infrastructure of roads, implementation of safety equipment, among others [3]. Brazil, in addition to registering a high rate of accidents per inhabitant, is far beyond the established goal by the United Nations [UN], in which between 2011 and 2021, a 50% reduction in the number of victims of TA should be expected [4].

The new incentive program for the automotive industry proposed by the Brazilian government, known as *Rota 2030*, defines energy efficiency targets for vehicles and also measures to reverse this scenario, such as the implementation of different vehicle safety items. Technologies such as the Electronic Stability Control [ESC], Forward Collision Warning [FCW], Autonomous Emergency Braking [AEB] and the Seat Belt Reminder [SBR] are part of the ADAS package and will be discussed in depth in this work. Of these, AEB is the one with the highest levels of effectiveness in reducing TA and severity mitigation and therefore will become mandatory in North America for light vehicles by 2023 according to the voluntary agreement between automakers, the agency "*National Highway Traffic Safety Administration*" [NHTSA], and the organization "*Insurance Institute for Highway Safety*" [IIHS] [5]. The potential for TA reduction with these technologies is subject of study by several authors such as [5], [6], [7], who have shown very significant results through analysis of accident data from other countries correlated with the characteristics and positive effects of this automotive safety equipment. No studies were found that correlate the implementation of these technologies and the assessment of their socioeconomic impacts in Brazil, which are considered of great importance to support the adoption of public policies.

The work is divided into the following sections: Objective, which summarizes the goal of the work; Methods, which comprises the methodologies used in the research; Results, which addresses the outcomes obtained and a discussion about the limitations of the proposed work, and finally the Conclusion, which includes reflections on the obtained results produced analyzes.

OBJECTIVE

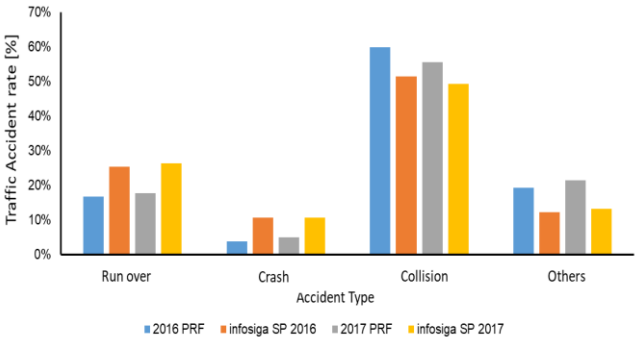
This work aims to provide an estimate of the potential economic impact with the adoption of various automotive safety technologies in Brazil. To this end, this work seeks to stratify TA in Brazil by type and correlate with the reduction potential of TA according to each safety technology mentioned, based on its known effects in other countries.

METHODS

TRAFFIC ACCIDENTS – The database of the *Polícia Rodoviária Federal* [PRF] [8] which contains only TA occurring on federal highways, is an important source for studies on the topic and became the main basis for the analysis of this work, due to its level of detail. The greatest difficulty of the work was to understand the precision, the feasibility and the quality of data that can make the analysis of TA relevant. An example of influence on the quality of data was the change in the registration methodology through the implementation in 2015 of the tool *Declaração eletrônica de acidente de trânsito* [DAT], which allows the registration directly through the internet of TA without injured or dead people. This reduced the number of TA recorded, and consequently made it difficult to analyze and compare data in years prior to the implementation of the tool [9].

Despite the reduced availability and differences in the methodology and categorization of TA at the municipal, state and federal levels, it is understood that the extrapolation of data is valid for comparing them. This hypothesis is supported by the evaluation of accident costs on state and federal highways, which are similar [10]. In order to understand the difference of quality of information, data from state and municipal roads in the state of São Paulo was used as a comparison, which was collected from the Infosiga system [11]. As an example, the comparison of the number of deaths on federal and state highways between the two databases for different years, as shown in Figure 1 below, indicates that both are comparable to each other considering its similarity on proportion and low percentage difference between types of accidents.

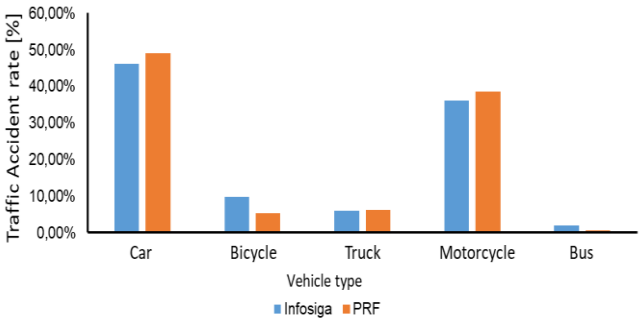
Figure 1. Database comparison of TA by cause.



Source: Author - based on [11] e [8]

Another analysis that supports the choice of the PRF database as main object of this work, is that TA with deaths on the road that have collision as a cause are also similar between Infosiga and PRF data in 2017, when analyzed from the perspective of types of involved vehicles, as shown in figure 2 below:

Figure 2. Database comparison of TA by vehicle type.



Source: Author - based on [11] e [8]

According to the Infosiga database, the percentage of TA with deaths in collisions on state and municipal highways is 56% and 44% respectively, which shows an approximate proportion and similarity of TA between different types of roads. As the safety technologies studied have an effect on all types of TA or only collisions as shown in table 3, it is satisfactory to use the PRF database, although it comprises only about 20% of traffic accident related deaths in the national territory.

AUTOMOTIVE SAFETY ITEMS – The Rota 2030 program aims to make the implementation of safety devices mandatory from 2021 for light vehicles and 2027 for heavy vehicles [12]. Table 1 lists various automotive safety items and the year of its mandatory implementation for light vehicles. Other items not listed have some effect in accident reduction, but due to the lack of detail of the available TA data, most of these items were not subject to be used for estimation of the potential reduction of TA in Brazil.

Table 1. Rota 2030 automotive safety items

Technology	Mandatory year
Electronic Stability Control [ESC]	2022
Seat Belt Reminder [SBR]	2021
Autonomous Emergency Braking [AEB]	-
Forward Collision Warning [FCW]	2023

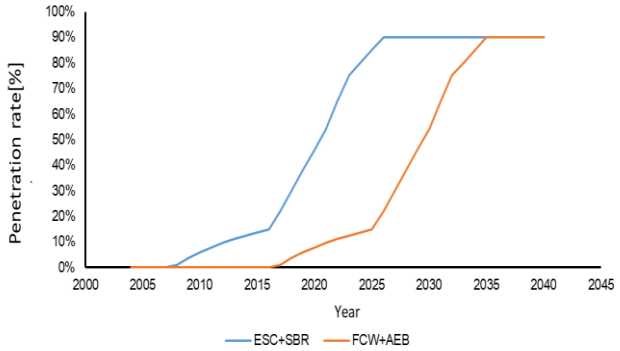
Source: [13]

Regarding the different security systems and devices that exist today, there was greater attention to those related in the Rota 2030 program, which are statistically more relevant for TA reduction and have broader bibliography of positive results scientifically proven by several methods that can be applied to the national scenario, which were: ESC, FCW, AEB and SBR. These systems belong to ADAS and are intended to reduce TA mainly due to causes related to human error [14]. Directly or indirectly, human errors are responsible for a large part of the TA, with 37% due to lack of attention to driving, 13% due to disobedience to traffic regulations, 8% to the speed of the vehicle

incompatible with that allowed on the road, 8% for drinking alcohol and 8% for not keeping safe distance, according to PRF data of 2019 [8]. To estimate the penetration of these automotive safety equipment, the current percentage of new vehicles for each system was linearly interpolated to the foreseen rate regulated in the Rota 2030 program [12]. All light vehicles sold in the country must have at least 65% of all items foreseen in the program and there are certain benefits in tax discounts all items are fully implemented by the automakers [12].

It was considered that the effectiveness of automotive safety technologies is similar for light and heavy vehicles. According to [15], as the share of the heavy vehicle fleet is only about 15% of the total fleet, the 5-year lag established in the Rota 2030 program for heavy vehicles in the calculation of penetration was not considered. The Figure 3 below shows the penetration for each technology:

Figure 3. Penetration rate predict for new vehicles.



Source: Author - based on [16] and [12]

Electronic Stability Control [ESC] - ESC is a braking system suitable for light and heavy vehicles that aims to stabilize the car and prevent skidding in different situations and conditions, resulting in an estimated 5% TA reduction [17].

In 2015, the system in Brazil would be available in 9% of the fleet and, in 2017, 22% of the new cars should come out of the assembly line with it installed [16] and [18]. As shown in figure 3, a linear projection of the technology penetration was considered according to the established in the Rota 2030 program [12].

Seat Belt Reminder [SBR] - The SBR is a system that uses visual and audible devices to warn the driver to fasten its seat belt [17]. Studies show that according to the effectiveness of the warning system, the use of seat belts can be increased by 7% [17]. This efficiency is correlated with the potential to reduce in 45-50% the TA with deaths and moderate to severe injuries with the use of the belt, as evidenced in [19] which results in a reduction potential of 3-4% of the number of TA considered. According to 2019 data of PRF evidenced in [8], 60% of the TAs caused by vehicles that could be suitable for such technology have no victims. Thus, a 1.5% reduction in all TA was considered as the effectiveness potential of the SBR.

Due to the lack of penetration statistics for such technology, the same penetration of cars with ESC was considered as shown in figure 3, as they have similar mandatory periods as shown in table 1.

Forward Collision Warning [FCW] and Autonomous Emergency Braking [AEB] - The FCW is a system of audible and visual devices that warns the driver of an imminent collision, whereas the AEB brakes to avoid the TA or reduce the impacts caused by it [17].

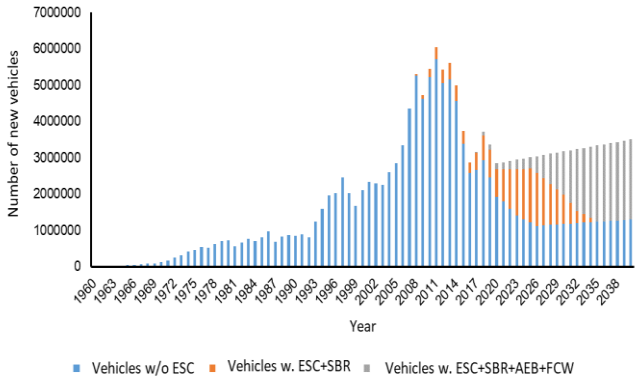
A study shows that the costs and benefits of the systems are fundamentally difficult to predict due to the unavailability of a database with sufficient information [20], making it almost impossible to predict the effectiveness of the AEB system for light vehicles. Despite the large number of studies in the literature, the measure of the effectiveness of technologies in relation to preventing an accident is highly uncertain, and can vary between 10 and 72% according to the method used [7]. Even for cases where the accident is not prevented, they can decrease the severity by approximately 30% [21]. Studies show that the emergency braking warning system (FCW) has significant TA reduction effects, and in 2023 will be a mandatory item for new produced vehicles. Despite this, it is considered a greater effectiveness of FCW in conjunction with AEB [6] For this reason, it was considered for this work a potential reduction of TA of both systems together according to the article published by [6], which considers a reduction in the rear collisions of 50%, which are the cause of approximately 25 % of TA in Brazil [8].

As shown in table 1, AEB is on the list of technologies under study and its mandatory year has not yet been defined, so the same ESC penetration curve with a 10-year delay was considered, as shown in figure 3. This period is very satisfactory, taking into account the current penetration of the AEB system in the Brazilian market, as seen in [14] for the year of 2017. It states that 1% of vehicles in Brazil are produced with the system, which is similar to the 2007 ESC penetration estimate, calculated by the current penetration and interpolated with the proposed mandatory year by the Rota 2030 program. Another reason for choosing the period is the difference of approximately 10 years in the mandatory strategy in Brazil compared to Europe, as seen in [22] where ESC is mandatory for new models since 2011.

Fleet Estimate - The ordinary least squares model of the Gretl 2020b program (The Gretl Team) [23], was used to obtain the projection of the Brazilian fleet from 2019 onwards based on the fleet data of vehicles registered in Brazil annually [15]. The proportion of 70% of the fleet with vehicles suitable to use the technologies covered in this work was considered. The penetration of technologies in the fleet was also taken into account according to figure

3. To simplify the share of effects for each technology and the penetration rate in the fleet, vehicles with AEB + FCW technologies were considered to have ESC + SBR. Figure 4 below illustrates the projection over the years of the Brazilian vehicle fleet.

Figure 4. Brazilian Fleet prevision according to new technologies.



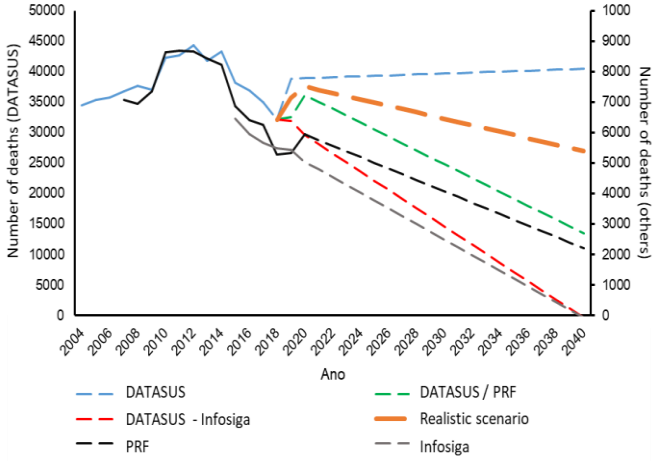
Source: Author - based on [15]

Number of Accidents and deaths estimate - For the forecast of the number of TA, a direct relation of the projection of the number of deaths by TA in the coming years was considered. It is important to highlight that each TA comprehends one individual that was involved in an accident.

The number of deaths curve is the result of the ordinary least squares model of the Gretl 2020b program ("The Gretl Team") [23], calculated from the PRF database out of the number of deaths by TA on federal highways; state and municipal authorities in the state of São Paulo from the Infosiga report; from all over the Brazilian territory using the Mortality Information System [SIM] from DATASUS. The projections of the number of deaths shown in figure 5 does not contemplate the implementation of the technologies that will be considered in the next items. Different projections were considered: the first taking into account the prediction of the number of deaths according to the DATASUS database only; the second using a correlation of DATASUS and PRF data; the third an average of the first and second scenarios; the last one according to the DATASUS and Infosiga database.

The realistic scenario (no. 3) used in the work was given by the average projection of the data from DATASUS with those from the PRF, as shown in figure 5. The solid line corresponds to the official data for each related database, whereas dashed its respective projection. The non-linearity of the figure 5 around 2018 is consequence of the transition from the real data to the trend line. Since the scenarios were calculated based on a linear regression of a determined period of the real data, the line tends to be rough on the transition of the two.

Figure 5. Number of deaths by traffic accidents.



Source: Author - based on [8]; [11]; [24]

The projection of the number of deaths in Brazil without the implementation of mandatory safety equipment follows an expectation of reduction, as seen in the years after 2014 for most databases. For the arbitrary choice of the projection of the realistic scenario, a qualitative and quantitative analysis was carried out according to the quality of the data history, whereby the correlated projection of DATASUS with Infosiga data is excluded because it does not present data prior to 2015 and, therefore, result in very optimistic projections (no fatal accidents around 2040), as seen in figure 5. On the other hand, the use of predictions of the accident projection according to DATASUS data combined with the positive expectation of an increase in the number of vehicles produced for the coming years shown in figure 4 result in pessimistic projections (no. 1) of an increase in the number of accidents, portraying a negative scenario that does not consider factors such as possible improvements in infrastructure, increased compliance with legislation, among others. The case scenario used (no. 3) estimates a reduction in TA in 2040 to approximately 27,000 deaths in Brazilian territory (compared to 32,113 deaths in 2018) and to 4,000 only on federal highways (compared to 5271 in 2018). Below a summary of the cases scenarios without the implementation of safety items:

1. DATASUS: Linear regression coefficient according to available 2004 – 2018 DATASUS database. Positive trend from 32113 in 2018 to 40445 deaths in 2040 (+26%)

2. DATASUS – PRF: Linear regression coefficient according to 2007 – 2019 PRF Database applied to DATASUS data of 2018 onwards. Negative trend from 32113 in 2018 to 13448 deaths in 2040 (-58%)

3. Realistic Scenario: Average of Scenario 1 and 2. Negative trend from 32113 in 2018 to 27000 deaths in 2040 (-16%)

Accident reduction potential - As previously discussed, it was considered that the technologies covered also serve heavy and light vehicles, except those in the "L" category corresponding to two or three-wheel vehicles, such as motorcycles, scooters, tricycles, among others. Table 3 indicates the summary of the potential of the percentage of TA reduction for the automobile safety equipment technologies considered in this work given by $PercTec_{red.}$

Table 3. Traffic accident reduction percentage for technology type

Technology	Accident type	% Accident reduction
SBR	All	1,5%
FCW + AEB	Rear-collision / All	50% / 11,3%
ESC	All	5%

Source: Author – based on [6]; [17] and [19]

As previously discussed, approximately 25% of all accidents are of the rear collision type. Since 50% reduction in TA for this type was considered by the implementation of FCW and AEB technology, a 11.3% reduction percentage of all TA was used to simplify the calculations.

Costs related to traffic accidents - The economic impact related to TA takes into account several factors and can be divided into several different categories such as: human cost, cost of material damage and general cost of TA [10].

To calculate the economic impact, it was necessary to update the costs of TA in Brazil to current and future values using monetary correction of the inflation indicator IPCA. IPCA was chosen for being considered the official inflation index in Brazil as seen in [25]. A factor related to the number of deaths in 2005 was also used, year when the main base analysis of the cost estimate of TA in Brazil was made [2006]. Similar metrics are used in [25] and [26]. The projection of the inflation index (IPCA) until 2030 was used according to [28] and was extrapolated until 2040 due to the lack of data on the subject for long periods.

Methodology - According to the categorization of a monograph according to procedures, objectives and problems seen in [27], this work is defined in a descriptive research scope for addressing the theme through data investigation and interpretation without interference from the author [29]. Such objective is evidenced by the analysis and interpretation of the data in a delimited way through models and formulas. The approach to the problem is given by the type of quantitative research for evaluating it through the collection and analysis of statistical data. Finally, the procedure is of a documentary research type, starting from the listed materials and remodeling them in order to extract new analyzes and interpretations [30].

To predict the potential for reducing TA and its expenditure, the factors mentioned above were considered. TA databases available in the literature were analyzed, which were then compared to make it possible to accurately estimate the difference in TA between federal, state and municipal highways. After defining the TA database used in the study, the different available technologies and their potential to reduce TA for each type of cause and vehicle were evaluated. Subsequently, projections for the number of TA and fleet were considered, in addition to the potential penetration of technologies and their implementation in the coming years. In order to estimate the cost reduction, expenses with TA were updated by the IPCA inflation index and correlated with the reduction in TA by the implementation of automotive safety devices.

RESULTS

Based on the number of deaths calculated for the realistic scenario, the number of TA on the federal highways was estimated according to this same scenario. The projection of the number of total TA in the Brazilian territory follows the direct correlation of the number of deaths to the TA of the federal highways according to this perspective adopted. Table 4 shows the calculation of the total TA over the next years.

To estimate the potential for TA reduction, a model for TA reduction factor per year was proposed as evidenced by eq. (1).

$$TA_{red\,i} = \left[\sum_{i}^{i-50} (PenTec_i * PercTA_i)\right] * PercTec_{red} * PercVeic \qquad (1)$$

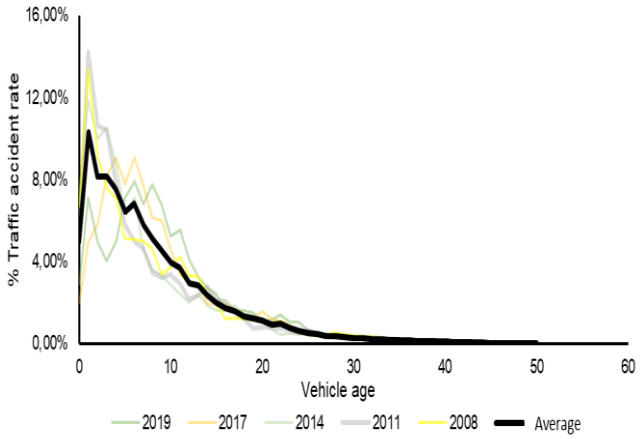
where, TA_{red}: is the TA reduction factor; i: is the year under study; $PenTec_i$: is the penetration of annual technology; $PercAT_i$: is the percentage of the fleet's accident of the year considered up to the previous 50 years; $PercTec_{red}$: it is the reduction of accidents by technology according to table 3; PercVeic: it is the percentage of vehicles involved in TA able to implement the safety equipment discussed in this work.

Initially, the proportion of 70% of vehicles capable of using the technologies covered by PercVeic would be used, as evidenced in the projection of the Brazilian fleet, but this figure does not represent the proportion of vehicles involved in accidents. According to [8], excluding light vehicles that are not able to implement the safety equipment in tables 1, such as motorcycles and scooters, about 76% of accidents in the year could be avoided or reduced by their severity if they had some kind of safety equipment installed. Therefore, for PercVeic a fixed value of 76% was considered according to the 2019 PRF data [8].

The number of TA occurring in a year is dependent on the age of the fleet for that year. A proportional trend over the years between the databases of each year is evident, from which the average was used to calculate the

reduction in the number of TA. Figure 7 shows this percentage of accidents according to the age of the vehicle for each reference year.

Figure 7. Traffic accident rate x vehicle age.



Source: [8]

A longer-term TA database would be needed to understand more deeply the relationship of increased TA for newer vehicles. Despite this, considering that newer vehicles are probably safer than older vehicles, it is understood that the higher percentage of TA for newer vehicles may be correlated with the number of annual vehicle production. Between 2017 and 2019 for example, there was a period of recession in the production of vehicles in Brazil, which is evidenced by the decrease in the percentage of TA for cars produced in these years. Between the years 2008 to 2014, when there was a greater production of vehicles, the opposite is revealed, that is, in this period the percentage of the number of TA is higher for newer vehicles. The arbitrary 50-year period used in formula 1 considers the low percentage of TA as shown in figure 7. In addition, the percentage of vehicles over 50 years old in the fleet is low, as shown in figure 4.

Table 4 shows the potential for reducing TA and deaths according to the result of TA_{red} calculated according to formula 1 over the next few years. For the calculation of the reduction in TA and deaths, the data for total TA projections, detailed in the other sections of this work was used. Table 4 also summarizes the penetration percentages of the technologies given by $PenTec_{red}$ over the years according to figure 3. Costs of accidents is referred to the study of economic impact done in 2014 [25], the same year was used for the calculations related to the reduction of TA and deaths. According to table 4, the mandatory safety equipment in vehicles produced in Brazil according to the Rota 2030 program, such as ESC, AEB, FCW and SBR could bring a reduction of approximately 1 million victims of TA and 32 thousand deaths among years 2014 and 2040.

Table 4. Potential reduction of accident and death rate

Year	Number of deaths – Realistic scenario	Number of TA - Realistic scenario	Number of reduced TA	Number of reduced deaths
2014	43232	1935048	3787	85
2016	36910	1247608	3692	109
2018	32113	1004038	4892	156
2020	37529	1142155	9921	326
2022	36471	1109949	15614	513
2024	35413	1077743	22498	739
2026	34354	1045537	29521	970
2028	33296	1013331	37577	1235
2030	32238	981126	46103	1515
2032	31180	948920	55232	1815
2034	30122	916714	64030	2104
2036	29063	884508	71469	2348
2038	28005	852302	76610	2517
2040	26947	820096	79684	2618
Total (2014-2040)			999455	32747

Source: Author

From the updated cost estimate for TA for federal highways in 2014 as seen in [25], the total cost from TA was calculated, with a direct proportion of federal highway accident costs correlated with the expected number TA in the realistic scenario. Table 5 summarizes the cost calculations involved with TA.

Table 5. Costs related to traffic accidents

Year	Total TA costs	Cost reduction of implementation
2014	R$67.325.674.571	R$131.759.738
2016	R$87.007.287.209	R$257.502.499
2018	R$98.142.730.813	R$478.215.126
2020	R$116.316.061.613	R$1.010.382.888
2022	R$124.600.556.785	R$1.752.810.911
2024	R$133.475.231.442	R$2.786.249.587
2026	R$142.982.004.801	R$4.037.129.424
2028	R$153.165.898.093	R$5.679.767.472
2030	R$164.075.139.185	R$7.709.948.804
2032	R$175.761.390.973	R$10.230.223.327
2034	R$188.279.996.046	R$13.150.949.491
2036	R$201.690.238.764	R$16.296.779.725
2038	R$216.055.626.020	R$19.420.395.952
2040	R$231.444.187.983	R$22.488.128.191
Total (2014-2040)		R$199.191.812.185

Source: Author – based on [25] and [28]

According to table 5, the implementation of mandatory safety equipment ESC, SBR, FCW and AEB can reduce the costs with TA by between 200 billion reais between the years 2014 and 2040.

The presented model takes into account several premises to predict the TA and its related costs reduction, which have fundamentally possible inaccuracies due to the number of involved variables which can affect the final result. Although calculated, one example is that the fleet estimate increase was not considered in the model, since the direct relationship between fleet increase and TA was not clear according to the database. Another example, TAs with motorcycles, scooters or similar were not considered, since the technologies discussed are not yet considered for implementation in this type of vehicles. It is worth remembering that the number of TAs with these vehicles has much higher gravity compared to the percentage of vehicles in the fleet [8]. Although these vehicles are not able to implement such technologies, it is possible that the results of this work may be much greater, as the number of TA caused by vehicles from this category could be reduced by those that have the safety equipment addressed.

CONCLUSION

The implementation of new technologies for automotive safety equipment, such as the Electronic Stability Control System, Forward Collision Warning, Autonomous Emergency Braking and Seat Belt Reminder, is evaluated as an efficient solution in reducing traffic accidents and its consequent expenses in Brazil, which was evidenced in the objective of the research when estimated by 2040 a reduction of about R$ 200 billion and 32 thousand deaths caused by traffic accidents. Public policies that seek to reduce the number of traffic accidents have been very successful in recent years. As an example, it can be highlighted the reduction in the number of deaths from 2012 with the implementation of Law No. 11,705 of 2008, known as the “Lei seca”, which is evidenced by the zero tolerance in the limits of alcohol intake by drivers. Another example is in 2014, with the implementation of items such as ABS and Airbag that were fundamental to mitigate the intensity of accidents. Therefore, it is evident that implementations of efficient measures such as the implementation of new technologies of automotive safety items can bring positive results in the social and economic scope in the short term. The delay in regulation and mandatory implementation of technologies that have reasonably low costs and high social benefits can be considered as a serious problem of simple solution in the national scenario given the complexity of the topic. In addition, these guidelines are in line with international practices that have already proven positive effects. Future projects related to this work may consider different TA databases for greater robustness and assertiveness in the quality of the results. Another suggestion would be to correlate the cost of implementing technologies with the potential for cost savings with TA to consider the cost-benefit of implementing each technology.

REFERENCES

[1] World Health Organization [WHO]. 2018. Top 10 causes of death. Available in: <https://www.who.int/gho/mortality_burden_disease/causes_death/top_10/en/>. Access in: 27 maio 2020

[2] Contador, C. R.; Oliveira, N. 2015. Estatísticas da dor da perda do futuro: novas estimativas. Texto de pesquisa. Funenseg, Rio de Janeiro, RJ, Brasil.

[3] World Health Organization [WHO]. 2014. Injuries and Violence: The Facts. Geneva. Available in: <http://apps.who.int/iris/bitstream/10665/44288/1/9789241599375_eng.pdf> Access in: 27 maio 2020

[4] Organização das Nações Unidas [ONU]. 2015. Transformando nosso mundo: A Agenda 2030 para o desenvolvimento Sustentável. Available in: <https://nacoesunidas.org/wp-content/uploads/2015/10/agenda2030-pt-br.pdf>. Access in: 27 maio 2020

[5] Friedman, K; Mattos, G; Paver, J. 2017. Potential Effects of Automatic Braking on Accident Fatalities and Serious Injuries. In: 25th International Technical Conference on the Enhanced Safety of Vehicles (ESV), 2017, Detroit, Michigan, Estados Unidos. Anais… Artigo número 17-0152

[6] Cicchino, J. B. 2017. Effectiveness of forward collision warning and autonomous emergency braking systems in reducing front-to-rear crash rates. p. 142-152. In: Accident Analysis & Prevention 99. Elsevier, Amsterdam, Netherlands.

[7] Doecke, S.D., Anderson, R.W.G., Mackenzie, J.R.R., Ponte, G. 2012. The potential of autonomous emergency braking systems to mitigate passenger vehicle crashes. Centre for Automotive Safety Research. In: Australasian Road Safety Research, Policing and Education Conference, 2012, Wellington, New Zealand.

[8] Polícia Rodoviária Federal [PRF]. 2020. Dados Abertos – Acidentes. Available in: <https://portal.prf.gov.br/dados-abertos-acidentes>. Access in: 27 maio 2020

[9] Ministério dos Transportes, Portos e aviação Civil [MTPA]. 2017. Anuário estatístico de segurança rodoviária. Brasilia, DF, Brasil.

[10] Instituto de pesquisa econômica aplicada [IPEA]; Departamento Nacional de Trânsito [DENATRAN]; Associação Nacional de transportes públicos [ANTP]. 2006. Impactos sociais e econômicos dos AT nas rodovias brasileiras. Relatório Executivo. Brasília, DF, Brasil.

[11] Governo do Estado de São Paulo [GESP]. 2020. Relatórios e Base de Dados. Available in:

<http://www.respeitoavida.sp.gov.br/relatorios/> Access in: 28 maio 2020

[12] Kutney, P. 2019. Indústria automotiva toma o rumo da Rota 2030. Automotive Business. Available in: <http://www.automotivebusiness.com.br/noticia/29055/industria-automotiva-toma-o-rumo-da-rota-2030> Access in: 27 maio 2020.

[13] Grande, P. C. 2019 Brasil prevê só 9 novos itens de segurança obrigatórios em carros até 2030. Available in: <https://quatrorodas.abril.com.br/noticias/brasil-preve-so-9-novos-itens-de-seguranca-obrigatorios-em-carros-ate-2030/> Access in: 27 maio 2020

[14] Santos, P. M.; Guinzani, D.; Lima, G. A.; Batagini, E. 2019. Influência de requisitos NCAP e do programa Rota 2030 na implementação de sistemas AEB para indústria automotiva brasileira. In: XXVII Simpósio Internacional de Engenharia Automotiva, 2019, São Paulo, SP, Brasil. p. 786-801.

[15] Departamento Nacional de Trânsito [Denatran]. 2019. Frota de Veículos – 2019. Available in: <https://infraestrutura.gov.br/component/content/article/115-portal-denatran/8559-frota-de-veiculos-2019.html> Access in: 27 maio 2020

[16] Guimarães, G. 2017. Controle de estabilidade já está em 22% dos automóveis nacionais. Available in: <https://www.autoindustria.com.br/2017/11/22/controle-de-estabilidade-ja-esta-em-22-dos-automoveis-nacionais/> Access in: 27 maio 2020

[17] European Comission [EC]. 2018. Advanced Driver Assistance Systems. Directorate General for Transport. Available in: https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/ersosynthesis2018-adas.pdf>

[18] Agência Transporta Brasil [ATB]. 2015. Até 2022, controle eletrônico de estabilidade será item de série em automóveis. Available in: <https://www.transportabrasil.com.br/2015/12/ate-2022-controle-eletronico-de-estabilidade-sera-item-de-serie-em-automoveis/> Access in: 27 maio 2020

[19] National Highway Traffic Safety Administration [NHTSA]. 2000. Fatality Reduction by Safety Belts for Front-Seat Occupants of Cars and Light Trucks. Relatório nº *DOT HS 809 199.* Washington, DC, USA.

[20] Grover, C.; Knight, I; Okoro, F et al. 2008. Automated emergency brake systems: technical requirements, costs and benefits. Published Report - PPR 227. TRL Limited, Wokingham, UK.

[21] Imlay, M. 2018. ADAS systems. Available in: <https://www.sema.org/sema-news/2018/07/adas-systems> Access in: 27 maio 2020

[22] Dekra, A. G. 2012. Road Safety Report 2012 – People and Technology. Stuttgart, Alemanha.

[23] Gretl. 2020. Gretl. Available in: <http://gretl.sourceforge.net/> Access in: 29 maio 2020

[24] DATASUS. 2020. Sistema de Informações sobre Mortalidade – SIM. Available in: <http://tabnet.datasus.gov.br/cgi/tabcgi.exe?sim/cnv/ext10uf.def> Access in: 02 Jun. 2020

[25] Instituto de pesquisa econômica aplicada [IPEA]. 2015. Estimativa dos Custos dos Acidentes de Trânsito no Brasil com Base na Atualização Simplificada das Pesquisas Anteriores do Ipea. Relatório de Pesquisa. Brasília, DF, Brasil.

[26] Bastos, J. T. 2015. Atualização do custo total dos acidentes de trânsito no Brasil. Observatório Nacional de Segurança Viária. Available in: <http://iris.onsv.org.br/iris-beta/downloads/Atualizacao_Custos_20150416-2.pdf> Access in: 27 maio 2020

[27] Beuren, I. M. et all. 2008. Como elaborar trabalhos monográficos em Contabilidade: teoria e prática. 3ed. Atlas, São Paulo, SP, Brasil.

[28] Instituição Fiscal Independente [IFI]. 2019. Relatório de acompanhamento fiscal. Available in: <https://www2.senado.leg.br/bdsf/bitstream/handle/id/564604/RAF34_NOV2019_Contexto_Macro.pdf > Access in: 27 maio 2020

[29] Andrade, M. M. 2002. Como preparar trabalhos para cursos de pós-graduação: noções práticas. 5ed. Atlas, São Paulo, SP, Brasil.

[30] Gil, A. C. 1999. Métodos e técnicas de pesquisa social. 5ed. Atlas, São Paulo, SP, Brasil.