

# ANALYSIS OF ROAD ACCIDENTS IN 2002-2019 ON THE EXAMPLE OF POLAND

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## Abstract

The article presents a general description of the safety problem in Polish road transport in the years 2002-2019. The number of road accidents was analyzed in detail, taking into account the division into side, front and rear collisions and the dynamics of their changes. The article contains information on the dynamics of changes registered in passenger vehicles and trucks in Poland in the years 2000-2018. Moreover, the number of fatalities in road accidents in the years 2002-2019 was presented, taking into account the type of collision. The forecasts of changes in the number of road accidents and rear collisions presented in the article show the downward trend for the years 2020-2030 of frontal collisions. An inconspicuous rear collision by not braking a speeding vehicle carries a high risk of damage to the upper cervical spine. As a result of such a collision, even at a low speed of 20 km/h, they can cause irreversible health effects, which lead to permanent disability.

**Keywords:** road accidents; collisions; road safety; passenger vehicle

## 1. Introduction

Road accidents are considered to be one of the most important social problems of modern times. According to the World Health Organization (WHO), approximately 1.35 million people die in road accidents each year, while between 20 and 50 million people suffer serious injuries that have not resulted in death [23, 24, 41]. According to WHO statistics, as much as 93% of road fatalities around the world occur in low- and middle-income countries. Moreover, road traffic injuries are one of the top three causes of death among people aged 5 to 44 and a major cause of disability worldwide [2, 6, 42].

Road accidents cause serious problems for society, both in terms of treatment costs for accident victims as well as economic and property costs [36, 34, 40]. Understanding the various factors influencing the occurrence and frequency of accidents is of particular concern to many scientists around the world [2, 34, 36]. Undoubtedly, the driver's behavior and his reactions related to the occurrence of various types of road hazards is a particularly important factor influencing the prediction of road accidents [44]. The analysis of the

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types of accidents and their classification was carried out in the works [10, 35, 39]. In [13], particular attention was paid to the influence of roadside illuminated advertisements on driver's behavior. Moreover, in the work [29], the author pointed out that a significant share in road accidents has the aspect of limiting the driver's visibility through the lights of an oncoming vehicle. On the other hand, in [5, 8, 22] attention was paid to the driver's reaction time in particular road situations, which shows that the driver's reaction time is one of the most important parameters characterizing the driver. The average driver's reaction time to a dangerous situation is about 1s. The reaction time is part of the time needed to bring the vehicle to a halt in an emergency before an obstacle appears. Thus, the vehicle stopping time can be divided into the perception time, the driver reaction time, the time needed to activate the auto-brake system and the braking time [22, 44]. In [17, 31, 43], the authors drew attention to the impact of the impact velocity when the vehicle collides with an obstacle. These works show that the risk of serious injuries increases as the speed of impact increases. The International Road Safety Data and Analysis Group (IRTAD) in a publication [12] highlighted the impact of speed limits (enforced by road regulations) on improving road safety in nine countries. This work shows that speeding is one of the main problems of vehicle accidents in all motorized countries. The International Group for Data and Analysis on Road Safety (IRTAD), based on the example of Norway, estimated that if all drivers were driving below the speed limit, the number of people killed in road accidents would decrease by almost 20% [12, 30].

According to the Police statistics, the most common causes of road accidents include [16, 19, 37]:

- failure to respect the right of way of the vehicle,
- maladjustment of speed to the prevailing road conditions,
- failure to give way to pedestrians at a pedestrian crossing,
- failure to maintain a safe distance between vehicles,
- inappropriate behavior of a pedestrian,
- and incorrect vehicle overtaking.

In the case of dangerous behavior of a pedestrian, the most common offenses leading to a road accident include [4, 19, 37]:

- intrusion under the wheels of the vehicle,
- and crossing the road in a prohibited place.

According to WHO, collisions may be predictable and avoidable [27, 38]. This approach is based on the Swedish vision of "Zero" [27, 38]. This strategy has a long-term vision of no deaths and no serious injuries in the transport system. It is possible to achieve by introducing a safe road accident prevention system. And in the event of a collision, this strategy ensures the force of the impact so that the impact is insufficient to cause serious injury [9, 25]. Scientists from WHO believe that road accidents can only be prevented by effective government actions in terms of improving road safety, but in a holistic way [23]. Undoubtedly, this type of commitment requires efficient activities of many sectors, such as: transport, police, health care, education and activities related to the safety of roads, vehicles and road users [1, 15, 16].

Effective interventions include designing safer infrastructure and integrating road safety into land-use and transport planning, improving vehicle safety, improving post-accident care for road accident victims, establishing and enforcing legislation on key hazards, and raising public awareness [15, 20, 38].

## 2. Development of the automotive industry in Poland

Currently, about 38 million people live in Poland, who have a total length of the public road network of 420,000 km. There are over 19.3 thousand km of national roads and 16.9 thousand km of highways. The number of registered motor vehicles in 2018 was over 23,429,000 passenger vehicles and 3,338,000 trucks [18, 19]. There is also a noticeable yearly increase in registered new vehicles. In 2018, over 141 thousand new passenger vehicles and 16.8 thousand trucks were registered. The dynamics of changes that took place in Poland in the years 1999–2018 regarding the number of registered motor vehicles (passenger vehicles and trucks) are shown in Figures 1 and 2 [19, 20]. Figure 1 presents the overall list, while Figure 2 presents a list of registered new passenger vehicles and trucks in Poland.

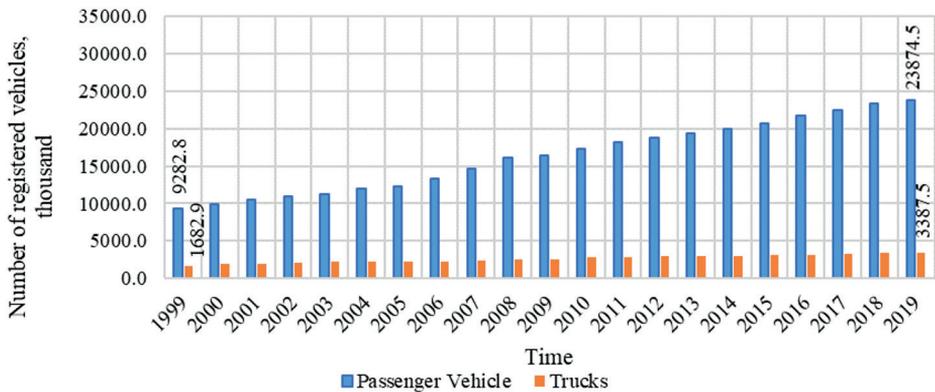


Fig. 1. The number of registered motor vehicles in Poland and the dynamics of changes in 1999–2018 [28]

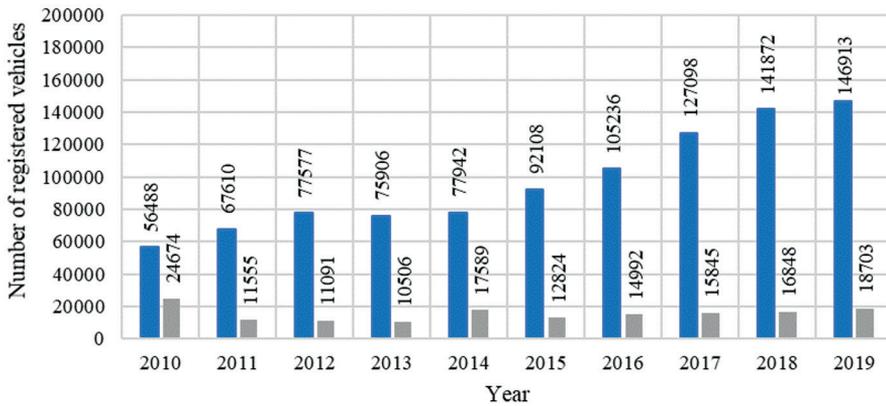


Fig. 2. The number of registered new motor vehicles in Poland and the dynamics of changes in 2010-2019 [28]

When analyzing registered motor vehicles in Poland in the years 1999-2018 (Figure 1 and 2), an upward trend should be noted. In the analyzed time horizon, the number of registered motor vehicles increased by an average of 744.5 thousand passenger vehicles and 106.3 thousand trucks each year. In the case of registered only new motor vehicles, in the period from 2010 to 2019, there is a visible annual increase in passenger vehicles by an average of 10,000. On the other hand, there is no visible upward trend in the case of new trucks [18, 20, 28].

### 3. Road accidents in Poland

Road accidents have a complex, multi-stage cause-effect structure, which has been at the forefront of national problems for years [4, 11, 18]. The persistent high number of road accidents is not only an analysis of the current situation, but also a warning for road users and entities responsible for road safety. Annual police reports and inspections carried out by the Supreme Audit Office alert that the road traffic hazard in Poland is too high. Poland is included in the European Union countries with a large number of road casualties. In 2019, the rate was 77 deaths per million inhabitants [27]. The European Union average is 51 deaths per million inhabitants [3].

Compared to 2018, in 2019 the number of accidents on Polish roads decreased by 4.4% and the number of people injured in road accidents by 5%. Unfortunately, the number of people killed in road accidents also increased by 1.6%. From 2001 to 2019, as many as 795220 road accidents took place in Poland, resulting in 81,778 deaths (Figure 3) [18, 20, 28]. In recent years, there has been a noticeable decrease in the number of accidents and fatalities on Polish roads. In the analyzed period, the number of road accidents decreased by 43.7% and the number of fatalities in road accidents by 47.5% [20].

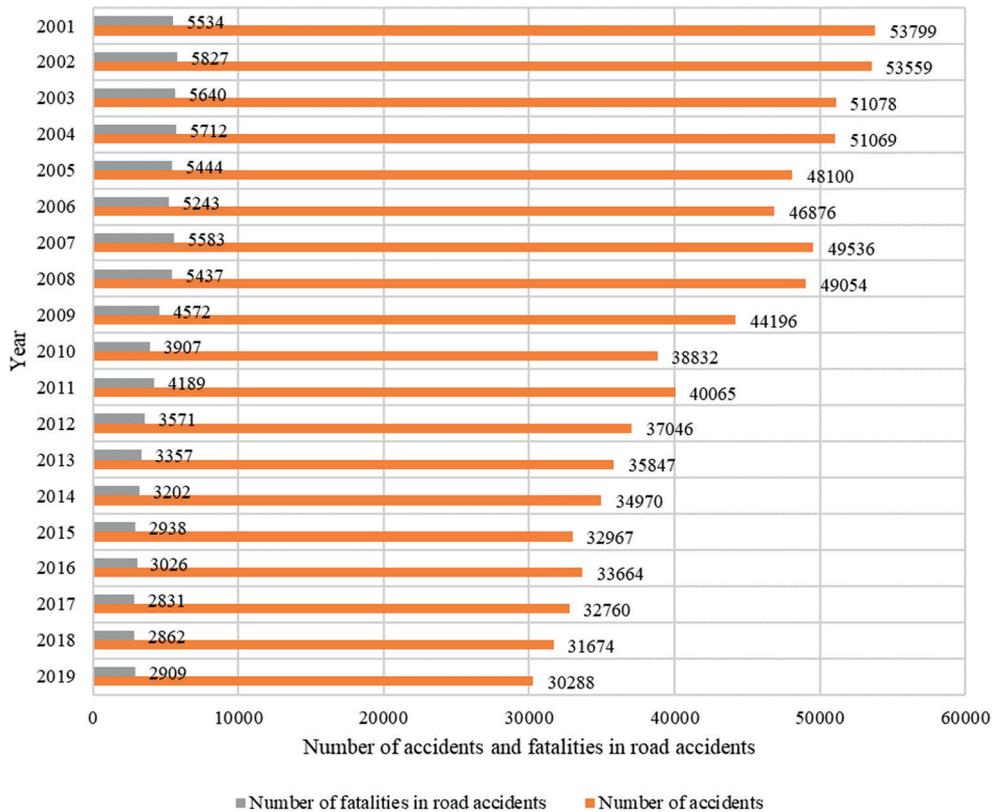


Fig. 3. The number of road accidents and the number of fatalities in Poland in 2001-2019 [28]

The number of side accidents on Polish roads is undoubtedly the most common form of road accidents, on average every year from 2002 to 2019 there are 10 thousand. On the other hand, the number of side and rear collisions in the analyzed period of time remains on average at the level of 4.5 thousand accidents. When analyzing road accidents in terms of the type of collision (Figure 4), it should be noted that from 2002 to 2019, people died as a result of a collision [28]:

- side - 12,570 people,
- frontal - 14,174 people,
- rear - 4558 people.

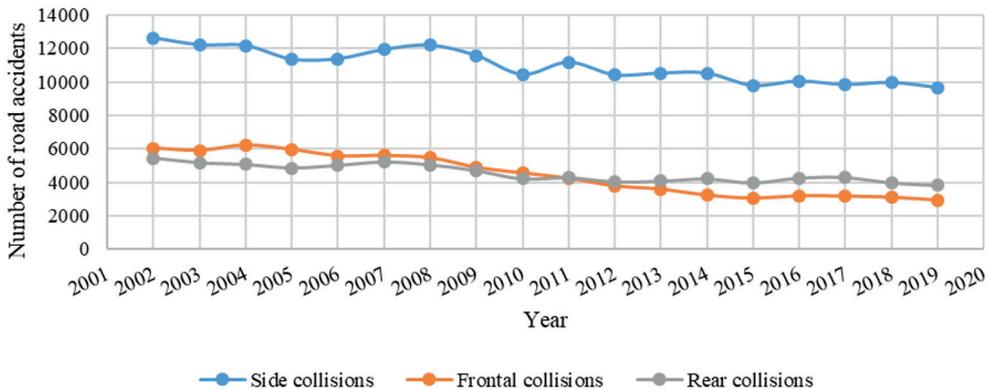


Fig. 4. Number of road accidents taking into account the division into side, front and rear collisions in the years 2002 – 2019 [28]

The most visible is the downward trend in the number of frontal accidents, which in 2019 was lower by 51% compared to 2002. On the other hand, the number of side accidents in the same period decreased by only 23%. Rear collisions decreased by 30% from 2002 to 2019, but only by 9% for the period 2010 to 2019. This means that the number of rear collisions has the smallest downward trend [20, 28].

In the years 2011-2019, the fact that there are more rear collisions than frontal collisions is noticeable (Figure 4). On average, rear collisions account for approximately 13% of all road accidents. Compared to the total number of such events, they are relatively rarely fatal, accounting for 7.5% of all fatal accidents [18, 20, 28]. On the other hand, many participants in such accidents are injured. In the event of a rear-end collision, the passengers may face cervical spine injury. Rear collisions most often occur when the correct distance from the vehicle driving in the same direction is not kept. Most of these types of collisions occur in the city and are associated with the inattention of drivers following the hit vehicle. However, sometimes serious and severe collisions occur because the rear of the vehicle has virtually no controlled crumple zone. The most dangerous rear collisions for human health occur when a stationary vehicle is hit, e.g. waiting for the traffic light to change at an intersection. In such a road incident, the cervical vertebrae of people riding in the vehicle hit the most. Figure 5 shows the number of fatalities in road accidents in Poland, broken down into side, front and rear collisions in 2002-2019.

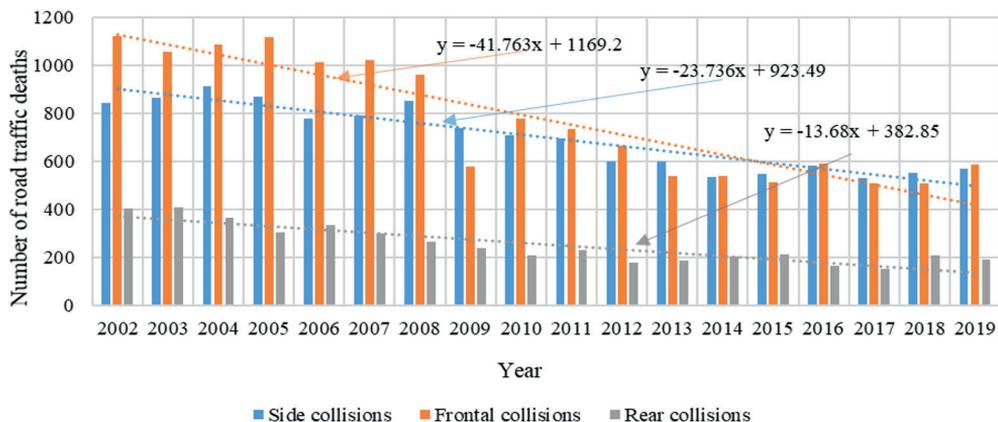


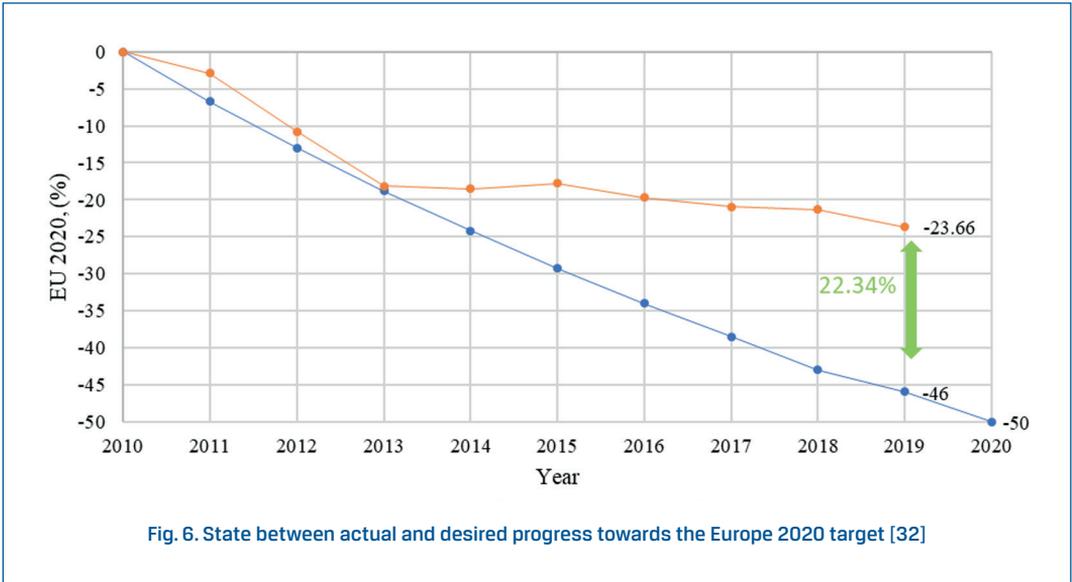
Fig. 5. Number of fatalities in road accidents in Poland, broken down into the side, front and rear collisions in 2002–2019 [28]

The rear-impact vehicle accelerates sharply forward. As the vehicle seat moves forward, the passenger's head often bounces. This is because a few drivers (and not all passengers) travel or sit with their heads against the headrest. After the head's initial forward bounce, it may also sharply backward when the vehicle stops. This unnatural "accelerated" movement of the neck - in both directions - can damage the cervical spine [14, 26]. Therefore, rear collisions in modern times are very problematic and carry a high risk of serious injuries, most often with a simultaneous low impact speed.

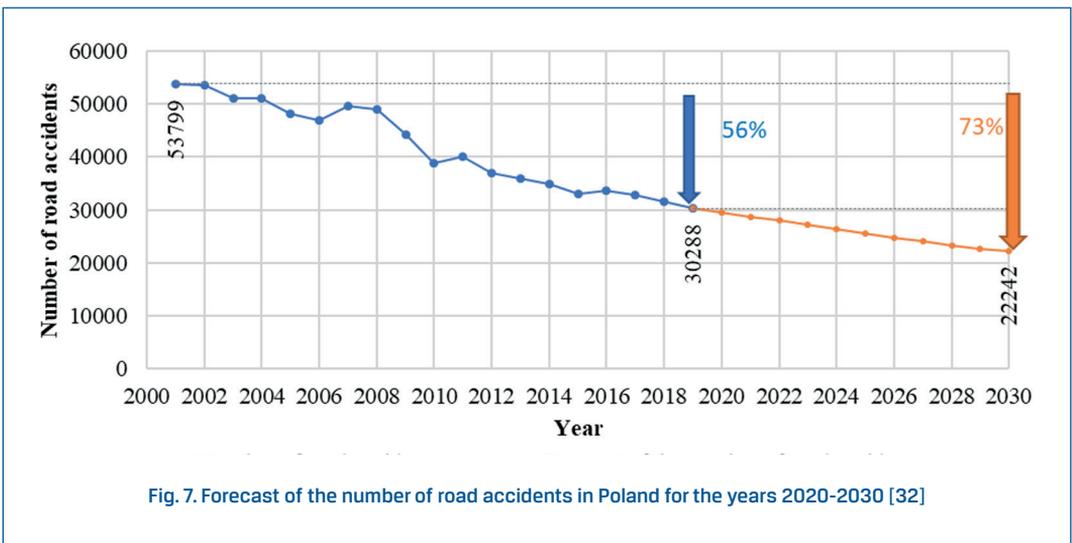
#### 4. Forecast of road accidents for the years 2020-2030

Strong and well-targeted efforts are now required at all levels and in all sectors of the European Union to increase road safety. The initial plan to increase road safety in the European Union assumed a 50% reduction in road accidents by 2020 [7, 21]. The progress of the plan implementation presented below shows that the assumptions of the policy of increasing road safety in the European Union significantly differ from the assumed plan. Over the course of 10 years, the number of accidents was reduced by 23.66% [7, 21, 32]. For the next decade, as part of the road safety policy, i.e. for the years 2021-2030, the European Union has set itself a new goal. Actions are planned to reduce the number of fatalities in road accidents and the number of serious injuries by 50% by 2030 [5, 8, 32]. The Stockholm Declaration of February 2020 provides the basis for further global political commitments for the next decade. It is estimated that for every person killed in a road accident, there are another five who suffer serious injuries that cause a permanent change in the way of life (there were around 120,000 in 2019). The estimated external costs of road accidents amount to approx. EUR 280 billion, i.e. approx. 2% of the EU GDP [15, 20, 38]. The Strategic Road Safety Action Plan presented by the Commission and the 2021-2030 policy also sets out ambitious road safety plans for 2050, even aiming to eliminate road fatalities

("zero vision") [7, 28, 32]. Figure 6 shows the difference between the assumed and physical state of the number of vehicle accidents in the European Union.



The available data on road accidents and the number of registered motor vehicles in our country may be the basis for forecasting the number of road accidents for the coming years. Road accident forecasts for 2020-2030 show a significant decrease in the number of road accidents from 27.6 thousand in 2020 to 13.4 thousand in 2030 [32, 33]. This forecast shows an annual decrease by an average of 7% of road accidents each year (Figure 7).



In the case of rear collisions, the forecasts for the years 2020-2030 include an annual decrease of 3% (Figure 8). Rear collisions, according to forecast data, will not fall below 3,000 a year over 10 years. In 2030, according to the forecast, the number of rear collisions will amount to 3001 incidents.

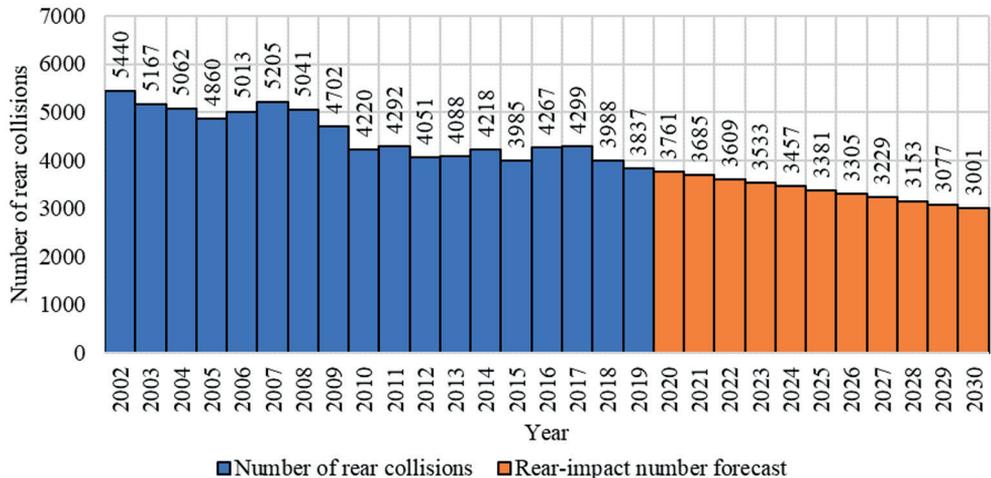
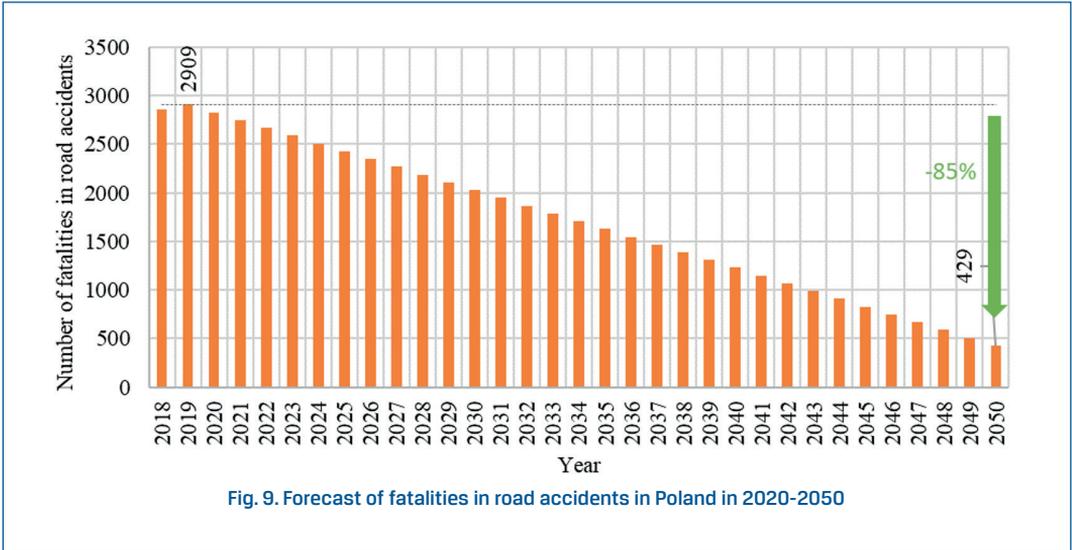


Fig. 8. A forecast of the number of rear collisions in Poland in the years 2020-2030

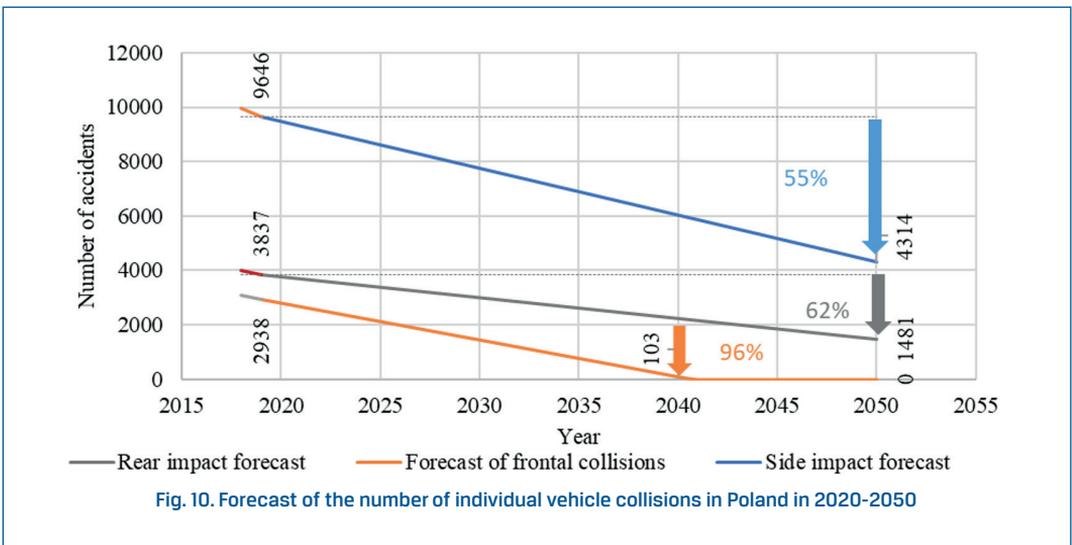
The persistence of more rear than front collisions in 2010-2019 is the result of the development of road infrastructure. The expansion of highways and expressways completely excludes frontal or side collisions, as all vehicles move in one direction. Therefore, rear collisions are in most cases the fault of the driver in the rear. In the event of a collision in built-up areas, they may be the result of inattention, e.g. due to the use of a mobile phone while driving. Haste is also often to blame - among others when the driver accelerates, hoping to be able to pass the intersection before the traffic light turns red, and the vehicle in front of him will stop. However, the most difficult thing to avoid rear collisions is on a highway or highway, where sudden braking of one vehicle can result in a collision.

The European Union, through its zero vision campaigns, aims to reduce the number of people killed in road accidents to zero by 2050. The annual statistics of the European Union record all fatalities directly in road accidents and those who died within 30 days of the road accident due to the blemished wounds. In 2019, there were 51 deaths in road accidents per million inhabitants in the European Union. On the other hand, in Poland, in 2019 this number was 71 killed. According to statistical data from 2002 to 2019 regarding fatalities, a forecast of fatalities in road accidents in the years 2020-2050 was prepared. This forecast shows an annual downward trend of 3%. Compared to 2019, the number of people killed in road accidents in Poland in 2050 will decrease by 85%. According to this forecast, the goal of reducing the number of fatalities in road accidents to 0 may not be achieved in Poland. According to the forecast, in 2050 there will be 11 deaths per million inhabitants in Poland.

Figure 9 presents the forecast of fatalities in road accidents in Poland in 2020-2050.



According to the forecasted data in Poland, by 2050 the number of all road accidents will decrease by 64% compared to 2019. The number of frontal collisions in Poland, according to the data forecasted in 2040 will be 103 cases. Figure 10 shows the forecast of individual collisions in 2020-2050. It can be seen that by 2041 the frontal collisions will be reduced to 0. In the case of side collisions, this number will drop by 55% by 2050 compared to 2019. There is also a noticeable decline in the number of rear collisions in 2020-2050 by 62% compared to 2019.



## 5. Summary

The aim of this article was to present the general characteristics of the road transport safety problem in the years 2002-2019, with particular emphasis on the side, front and rear collision data and the dynamics of their changes, which occur on the example of Poland. The analysis shows that increasing the safety of road users and reducing the number of accidents and people killed in road accidents is possible thanks to the government's policy in terms of road safety in a holistic aspect. Therefore, the European Union authorities approved a plan to extend the mandatory equipment list for new passenger vehicles. From 2022, intelligent speed limiters and lane assistant are to be included as standard equipment in a passenger vehicle. These changes are introduced under the so-called Vision Zero, in which the European Union has committed to reducing the number of road fatalities from 25,000 (2019) to 12,000 in 2030. And the next step in the Vision Zero strategy is to completely eliminate fatalities as a result of a road accident by the year 2050.

In Poland, the number of road accidents in the years 2002-2019 decreased by over 40%, this result shows a large downward trend, but compared to other European Union countries, we look unfavorable. In the infamous European Union statistics in terms of the number of people killed in road accidents per 1 million inhabitants, in 2018 Poland was in the 5th position with 76 people killed in road accidents per million inhabitants. Only more people killed on the roads are in Romania (95 per million inhabitants), Bulgaria (86 per million inhabitants), Croatia (77 per million inhabitants) and Latvia (76 per million inhabitants). In 2019, the number of people killed in road accidents per 1 million inhabitants in Poland increased to 77 people. More deaths per million inhabitants were recorded only in Bulgaria and Romania. In these countries, in 2019, 89 and 96 people per million died as a result of road accidents, respectively. The EU average is 51 road accident deaths per million. It follows that in the so-called In dangerous countries (in terms of fatal accidents), such as Bulgaria, Romania or Poland, almost 50% more people die on the roads than in other Member States of the European Union.

Undoubtedly, the increase in the number of registered passenger vehicles in Poland to almost 25 million over the years 2000-2018 affects both the intensity of Polish travel, which results in a greater probability of a road accident. The development of road infrastructure by expanding the network of motorways and expressways contributes to the reduction of the number of road accidents in terms of side and frontal collisions. Moving vehicles in one direction only increase the likelihood of rear-end collisions. Therefore, in the years 2010-2019, a very small downward trend in the number of these accidents is noticeable, remaining on average at the level of 3%. Moving in traffic jams, stopping in front of a traffic light, not adjusting the safe distance from the vehicle, or being distracted by the driver by a mobile phone or illuminated advertising, all contribute to the occurrence of rear collisions. In the years 2002-2019, 4,558 people were killed and 106,936 injured due to rear collisions on Polish roads. An inconspicuous rear collision by not braking a speeding vehicle carries a high risk of damage to the upper cervical spine. As a result of this type of collision, even at low speeds of 20 km/h, they may cause irreversible health effects, leading to disability. So, when you are parked, you should train yourself to press your head against the headrest. This will be the first simple step to increasing security.

The forecasts for 2020-2030 made on the basis of the collected statistical data on road accidents in the years 2002-2019 show a further downward trend in the number of all road accidents. On average, each year on the example of Polish roads, according to statistical forecasts, this number will decrease by 7%. In 2030, there may be only 13,400 road accidents in Poland. In the case of rear collision forecasts, there is a smaller downward trend, amounting to approximately 3% each year, which shows that in 2030 approximately 3,000 rear collisions can be expected.

## 6. References

- [1] Abdel-Aty M., Pande A., Lee C., Gayah V., Dos Santos C.: Crash Risk Assessment Using Intelligent Transportation Systems Data and Real-Time Intervention Strategies to Improve Safety on Freeways. *Journal of Intelligent Transportation Systems*. 2007, 11(3), 107-120, DOI: 10.1080/15472450701410395.
- [2] Cervical spine injury following a traffic accident: <https://nazdrowie.pl/artykul/fizjoterapia/uraz-kregoslupaszynego-wypadku-komunikacyjnym/> (in access 01.09.2020).
- [3] Choudhary P., Velaga N.R.: Modelling driver distraction effects due to mobile phone use on reaction time. *Transportation Research Part C: Emerging Technologies*. 2017, 77, 351-365, DOI: 10.1016/j.trc.2017.02.007.
- [4] Ditcharoen A., Chhour B., Traikunwaranon T., Aphivongpanya N., Maneerat K., Ammarapala V.: Road traffic accidents severity factors: A review paper," 2018 5th International Conference on Business and Industrial Research (ICBIR), Bangkok, 2018, 339-343, DOI: 10.1109/ICBIR.2018.8391218.
- [5] Europa pobila kolejny rekord. Chodzi o liczbę ofiar śmiertelnych wypadków (Europe has broken another record. It is about the number of fatalities in accidents): <https://www.wyborcikierowcow.pl/europa-pobila-kolejny-rekord-chodzi-o-liczbe-ofiar-smiertelnych-wypadkow/> (in access 01.09.2020).
- [6] Frej D., Grabski P.: The impact of the unbalanced rear wheel on the vibrating comfort of the child seat. *Transportation Research Procedia*. 2019, 40, 678-685, DOI: 10.1016/j.trpro.2019.07.096.
- [7] Ge J.I., Orosz G.: Optimal Control of Connected Vehicle Systems With Communication Delay and Driver Reaction Time. *IEEE Transactions on Intelligent Transportation Systems*. 2017, 18(8), 2056-2070, DOI: 10.1109/TITS.2016.2633164.
- [8] Global Plan for the Decade of Action for Road Safety 2011-2020, UN Road Safety Collaboration (2011), [http://www.who.int/roadsafety/decade\\_of\\_action/plan/en/](http://www.who.int/roadsafety/decade_of_action/plan/en/) (in access 01.09.2020).
- [9] Global Status Report On Road Safety 2019, World Health Organization 2018, in <https://www.itf-oecd.org/sites/default/files/docs/irtad-road-safety-annual-report-2019.pdf> .
- [10] Jaśkiewicz M., Stańczyk T.L.: The analysis of multi-section concept for an active air headrest. *Diagnostyka*. 2010, 3(55), 45-49.
- [11] Jaśkiewicz M.: Analysis of the operation of the head restraints at zero longitudinal velocity in relation to the head. *Autobusy, Technika, Eksploatacja, Systemy Transportowe*. 2011, 5, 175-180.
- [12] Joung E.J.: Application of safety management process for the safety analysis of level crossing. 2005 International Conference on Electrical Machines and Systems, Nanjing. 2005, 3, 2493-2497, DOI: 10.1109/ICEMS.2005.203024.
- [13] Jurecki R.S.: Road accidents in Poland, effects and causes. *Zeszyty Naukowe Politechniki Świętokrzyskiej. Mechanika*. 2002, 76, 223-231.
- [14] Jurecki R., Jaśkiewicz M.: Safety on the roads of the Świętokrzyskie voivodship in 2007-2011 compared to other regions of Poland. *Zeszyty Naukowe WSEI seria Transport i Informatyka*. 2012, 2(1), 27-40.
- [15] Khashbat J., Tsevegjav T., Myagmarjav J., Bazarraghaa I., Erdenetuya A., Munkhzul N.: Determining the driver's reaction time in the stationary and real-life environments (Comparative Study). 2012 7th International Forum on Strategic Technology (IFOST), Tomsk. 2012, 1-3, DOI: 10.1109/IFOST.2012.6357735.
- [16] Klingender M., Ramakers R., Henning K.: In-depth safety impact study on longer and/or heavier commercial vehicles in Europe. 2009 2nd International Conference on Power Electronics and Intelligent Transportation System (PEITS), Shenzhen. 2009, 368-373, DOI: 10.1109/PEITS.2009.5406992.

- [17] Lu J., Wang J. Road surface condition detection based on road surface temperature and solar radiation. 2010 International Conference on Computer, Mechatronics, Control and Electronic Engineering, Changchun. 2010, 4-7, DOI: 10.1109/CMCE.2010.5610255.
- [18] Łukasik Z., Kuśmińska-Fijałkowska A., Kołodziejczyk P.: Analysis of the safety condition on Polish roads. *Autobusy: technika, eksploatacja, systemy transportowe*. 2016, 17(10), 78-84.
- [19] Matuszak Z., Nowak A., Żabińska I., Martínez de Osés FX.: Road safety on the example of the city of Bytom. *The Archives of Automotive Engineering – Archiwum Motoryzacji*. 2019, 83(1), 43-57, DOI:10.14669/AM.VOL83.ART3.
- [20] Mobility and transport, Road Safety: [https://ec.europa.eu/transport/road\\_safety/topics/vehicles\\_en](https://ec.europa.eu/transport/road_safety/topics/vehicles_en) (in access 01.09.2020).
- [21] Moravčík E., Jaśkiewicz M.: Boosting car safety in the EU. 2018 XI International Science-Technical Conference Automotive Safety, Casta. 2018, 1-5, DOI: 10.1109/AUTOSAFE.2018.8373307.
- [22] National Road Safety Improvement Program for 2005-2007-2013 - GAMBIT 2005), Warszawa (2005), [https://www.obserwatoriumbrd.pl/pl/dzialania\\_na\\_rzecz\\_brd/programy\\_poprawy\\_brd/historia\\_programow\\_bezpieczenstwa\\_ruchu\\_drogowego\\_w\\_polsce](https://www.obserwatoriumbrd.pl/pl/dzialania_na_rzecz_brd/programy_poprawy_brd/historia_programow_bezpieczenstwa_ruchu_drogowego_w_polsce) (in access 01.09.2020).
- [23] Prochowski L., Jemioł L., Gidlewski M.: Analysis of the local accident risk in individual regions of the country. *The Archives of Automotive Engineering – Archiwum Motoryzacji*. 2017, 77(3), 133-147, DOI:1014669/AM.VOL77.ART9.
- [24] Prochowski L., Gidlewski M., Dąbrowski F.: Analysis of changes in the accident hazard for the elderly in road traffic compared to demographic changes and possibilities of supporting the elderly mobility. 2018 XI International Science-Technical Conference Automotive Safety, Casta. 2018, 1-8, DOI: 10.1109/AUTOSAFE.2018.8373297.
- [25] Prochowski L., Ziubiński M., Gidlewski M.: Experimental and analytic determining of changes in motor cars' positions in relation to each other during a crash test carried out to the FMVSS 214 procedure. 2018 XI International Science-Technical Conference Automotive Safety, Casta. 2018, 1-5, DOI: 10.1109/AUTOSAFE.2018.8373302.
- [26] Rezagholipour K., Massoudian N., Eshghi M.: Modeling and reducing overtaking accidents on two-lane curved road. 2016 2nd International Conference of Signal Processing and Intelligent Systems (ICSPIS), Tehran. 2016, 1-5, DOI: 10.1109/ICSPIS.2016.7869904.
- [27] Road safety: Europe's roads are getting safer but progress remains too slow: [https://ec.europa.eu/transport/media/news/2020-06-11-road-safety-statistics-2019\\_en](https://ec.europa.eu/transport/media/news/2020-06-11-road-safety-statistics-2019_en) (in access 01.09.2020).
- [28] Road accidents - annual reports: <https://statystyka.policja.pl/st/ruch-drogowy/76562.Wypadki-drogowe-raporty-roczne.html> (in access 01.09.2020).
- [29] Road mortality statistics in the EU (infographic) <https://www.europarl.europa.eu/news/pl/headlines/society/20190410ST036615/statystyki-smiertelnosci-na-drogach-w-ue-infografika> (in access 01.09.2020).
- [30] Save Lives, A road safety technical package: <https://apps.who.int/iris/bitstream/handle/10665/255199/9789241511704%E2%80%9393eng.pdf?sequence=1&isAllowed=y>, (in access 01.09.2020).
- [31] Sendek-Matysiak E.: Influence of roadside illuminated advertisements on drivers' behavior. *The Archives of Automotive Engineering – Archiwum Motoryzacji*. 2017, 77(3), 149-162, DOI: 10.14669/AM.VOL77.ART10.
- [32] Speed and Crash Risk: <https://www.itf-oecd.org/sites/default/files/docs/speed-crash-risk.pdf> (in access 01.09.2020).
- [33] Stańczyk T.L., Jaśkiewicz M., Jurecki R.S., Pieniążek W., Karendal M., Wolak S.: Tests of drivers' reactions to a vehicle leaving the right, carried out on a car track. *Zeszyty Naukowe Instytutu Pojazdów*. 2010, 1(77), 307-319.
- [34] Stark L., Obst S., Schoenawa S., Düring M.: Towards Vision Zero: Addressing White Spots by Accident Data based ADAS Design and Evaluation. 2019 IEEE International Conference on Vehicular Electronics and Safety (ICVES), Cairo, Egypt. 2019, 1-6, DOI: 10.1109/ICVES.2019.8906409.
- [35] Suzuki H., Ishikura T., Marumo Y.: Mitigation of rear-end collision risk based on intent inference of preceding car's deceleration behaviour. 2017 2nd IEEE International Conference on Intelligent Transportation Engineering (ICITE), Singapore. 2017, 194-197, DOI: 10.1109/ICITE.2017.8056907.
- [36] Theofilatos A, Yannis G., Kopelias P., Papadimitriou F.: Predicting Road Accidents: A Rare-events Modeling Approach, *Transportation Research Procedia*, Volume 14, 2016, 3399-3405, DOI: 10.1016/j.trpro.2016.05.293.

- [37] Törnros J., Bolling A.: Mobile phone use-effects of conversation on mental workload and driving speed in rural and urban environments. *Transportation Research Part F: Traffic Psychology and Behaviour*. 2006, 9(4), 298–306, DOI: 10.1016/j.trf.2006.01.008.
- [38] Vrabel J., Rievaj V., Synák F., Babic D.: Examination of the vehicle light intensity in terms of road traffic safety: a case study. *The Archives of Automotive Engineering – Archiwum Motoryzacji*. 2018, 81(3), 137–146, DOI:10.14669/AM.VOL81.ART10.
- [39] Vrabel J., Sarkan B., Vashisth A.: Changing the driver's reaction time depending on the amount of alcohol consumed by the driver - a case study. *The Archives of Automotive Engineering – Archiwum Motoryzacji*. 2020, 87(1), 47–56, DOI: 10.14669/AM.VOL87.ART4.
- [40] Wang Ch., Zhang W., Chen Q., Liu J., Feng Z., Wang K., et al.: Lane-change behavior in low illumination: Research based on a questionnaire investigation. *Journal of Transportation Safety & Security*. 2020, 1–22, DOI: 10.1080/19439962.2020.1744050.
- [41] Zhang Z., Asakawa Y., Imamura T., Miyake T.: Experiment Design for Measuring Driver Reaction Time in Driving Situation. 2013 IEEE International Conference on Systems, Man, and Cybernetics, Manchester. 2013, 3699–3703, DOI: 10.1109/SMC.2013.630.
- [42] Zuska A., Więckowski D., Frej D.: A comparative study of vehicle absorbers. 2018 XI International Science-Technical Conference Automotive Safety, Casta. 2018, 1–6, DOI: 10.1109/AUTOSAFE.2018.8373350.
- [43] Żuchowski A.: Analysis of the impact of the car impact velocity against an obstacle on the loads on dummies on the front and rear seats. *The Archives of Automotive Engineering – Archiwum Motoryzacji*. 2018, 81(3), 159–176, DOI:10.14669/AM.VOL80.ART12.
- [44] Żukowska J., Górską-Pawliczuk A.: Safety Assessment of the Regional Warmia and Mazury Road Network Using Time-Series Analysis. 2017 Baltic Geodetic Congress (BGC Geomatics), Gdansk. 2017, 297–300, DOI: 10.1109/BGC.Geomatics.2017.25.