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THE USE OF THE R2 COEFFICIENT OF DETERMINATION TO DETERMINE THE IMPACT OF SELECTED PARAMETERS ON THE NUMBER OF FATALITIES IN ROAD ACCIDENTS IN POLAND COMPARED TO SELECTED EUROPEAN COUNTRIES IN 2010-2020

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Abstract – The article presents statistical data on the state of road transport safety in Poland against the background of selected European countries in the years 2010-2020. The article presents the characteristics of the change in the length of motorways along with the percentage rate of increase in the length of motorways in selected European countries. Statistical data on the number of registered motor vehicles in Poland against the background of selected European countries in the analyzed period are presented. The main purpose of the article is to use the coefficient of determination R2 to determine the impact of the number of registered motor vehicles and the length of motorways on the number of fatalities in road accidents in selected European countries. The authors chose the coefficient of determination R2 as an indicator of how reducing the overall number of road accidents and increasing the length of motorways will affect the number of fatalities. The coefficient of determination is used to determine what percentage of one variable affects the variability of the other variable. The determined high value of the determination index R2 (close to 1) indicates a large impact of the analyzed variable on the number of fatalities in road accidents. The high result of the determination coefficient R2 for Poland in terms of the analyzed variables confirms that a further reduction in the number of fatalities in road accidents is possible thanks to the expansion of motorways and the reduction of the number of motor vehicles.

Key words – motor vehicles, road accidents, road safety

JEL Classification – I18, J11, L90, Y90

INTRODUCTION

The World Health Organization (WHO) reports that every year as many as 1.35 million people die in road accidents around the world [1-3]. Half of the fatalities were pedestrians, cyclists and motorcyclists. On average, road accidents cost each country about 3% of its gross domestic product, while at the same time causing large economic losses for both families and the country as a whole [4-6]. These losses result from the cost of treating road accident victims, the lost productivity of fatalities and those who are permanently unable to work [7-11]. It should be noted that 93% of road fatalities worldwide occur in low- and middle-income countries, and road accidents are the most common cause of death for people aged 5 to 29 [12-15]. According to statistics from the World Health Organization, as many as 73% of all fatalities are young men under 25 years of age [16-18]. This means that men from an early age are three times more likely to die in a road accident than young women [19-20]. Although not every car accident ends in death or serious injury, it should be emphasized that as a result of globalization and technological progress, the number of cars around the world is increasing, making road accidents more common [21-25].

The approach to increasing road safety is primarily aimed at ensuring a safe transport system for all road users. The foundation of the system of increasing road safety is the elimination of fatal accidents and the reduction of serious injuries as a result of the creation of safe roads and roadsides, and the determination of a safe travel speed along with the design of safe vehicles [26-29].

The number of road fatalities in Europe fell by 36% between 2010 and 2020, making Europe's roads considered the safest in the world [30-31].

22800 people died on the roads of the European Union in 2019, while in 2020 this number decreased by 4000 people [32-34]. Among the countries of the European Union, Sweden has the lowest number of road fatalities (18 deaths per million inhabitants), while Romania has the highest number of road fatalities (85 deaths per million inhabitants). The European Union's mortality rate in 2020 was 42 deaths per million inhabitants, a figure almost 5 times lower than the global average, which in 2020 was 180 road fatalities per million inhabitants [34-35].

1. ROAD INFRASTRUCTURE

The motorway is by definition a route that is to serve us to move quickly over long distances. Motorway roads are important elements in the road network of every country, as they are a great convenience both in terms of logistics and business, as well as tourism. The country in the European Union that leads the rankings of motorway lengths is Spain, because the total length of Spanish motorways is over 17,000 kilometers. In second place is Germany with the result of over 15,000 kilometers of motorways. In third place is France with a motorway length of over 11,000 kilometers Figure 1 shows the characteristics of the length of the motorway of European countries in 2010 and 2020. Comparing the length of motorways in Spain, Germany and France over the last decade, it should be noted that a noticeable percentage increase occurred only in Spain. Spain increased the length of motorways from 14262 km to 17228 km between 2010 and 2020. In the case of Germany and France, the length of motorways in the period considered from 2010 to 2020 changed slightly. In the case of Germany, there was an increase in the motorway network by 3% and in the case of France by 2%.

Figure 2 shows the characteristics of the percentage changes in the length of the motorway of European countries. Comparing the state of motorways from 2020 to 2010, Romania recorded the largest increase of 177%. In Romania, in 2010, the total length of motorways was 332 km, and in 2020 the total length of motorways was 920. The second European country in terms of the largest motorway growth in the years 2010-2020 is Poland. Poland doubled the length of motorways in the period considered. In 2010, there were 857 km of motorways in Poland, while in 2020 there were 1712 km. In third place is Bulgaria with an increase of 84% motorway. It should be noted that despite the doubling of the length of motorways in Poland in the years 2010-2020, the length of motorways in Poland is still much smaller than in France, Spain or Germany.

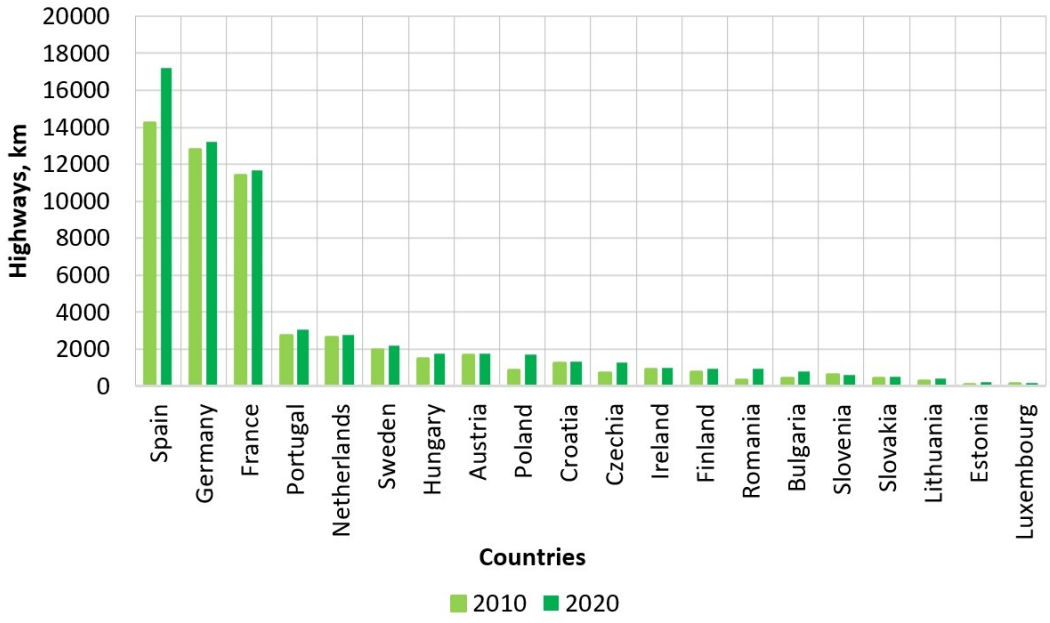

Fig. 1. Motorway length characteristics of European countries in 2010 and 2020

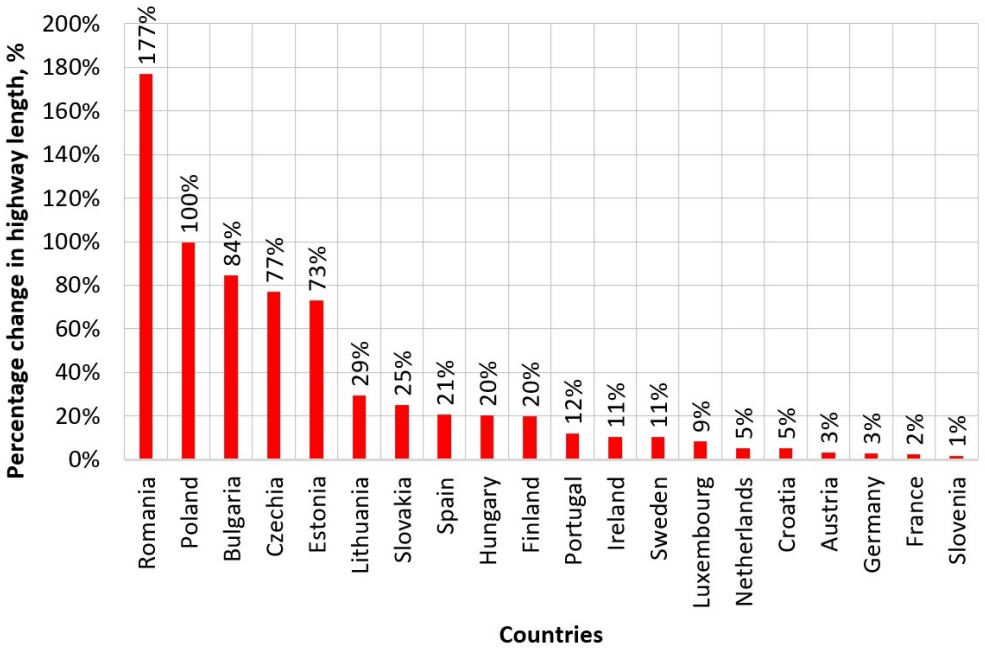

Fig. 2. Characteristics of percentage changes in the length of motorways in European countries in 2020 compared to 2010

2. NUMBER OF REGISTERED VEHICLES

The number of registered vehicles in European countries is increasing every year. The largest number of motor vehicles in 2020 were registered in Germany (53651934 units) and Italy (44980390 units). Figure 3 shows the characteristics of the change in the number of registered vehicles in European countries in 2010 and 2020. Figure 4 shows the percentage change of registered vehicles in European countries in 2020 compared to 2010. Analysing statistical data on the number of registered motor vehicles in European Countries, it should be noted that the most vehicles are registered in such countries as: Germany, Italy, France, Spain, Poland and Turkey. In total, more than 220 million motor vehicles are registered in these countries.

In the period considered from 2010 to 2020, the largest increase in motor vehicles occurred in Romania and amounted to 68%. During this period, the number of motor vehicles in Romania increased from 5058500 to 8518166 units. In Germany, the number of motor vehicles increased by 16 % during the period considered and in Italy by 8 %. In Poland, the number of motor vehicles in the years 2010-2020 increased by 44%. In Poland, in 2010, the number of registered motor vehicles was 20458100 units, while in 2020 it was 29466460 units. On the basis of statistical data, it should be noted that the decrease in the number of registered motor vehicles in the period 2010-2020 occurred only in Greece and Lithuania.

3. NUMBER OF FATALITIES IN ROAD ACCIDENTS

Road accidents happen for a variety of reasons. The drivers are often distracted at the wheel. In other cases, drivers may become fatigued after spending many hours behind the wheel, resulting in the errors that could have been avoided. Sometimes accidents happen for a variety of reasons, from poor visibility to unsafe road structures, or due to other drivers who are not careful. While the causes of accidents can vary, the consequences can be the same, from damage to the vehicle and property to fatalities [30-35].

About three-quarters (73%) of all road fatalities occur in young men under the age of 25, who are almost 3 times more likely to die in a road accident than young women. In addition to the pain and suffering caused by the tragedy of death or permanent disability, these accidents cause a severe economic loss to the community, due to medical costs and loss of the victim's services. It should be noted that accidents cause enormous suffering and countless disabilities, which are the main cause of death at all ages, entail huge costs for society and occur in all countries of the world [30-35].

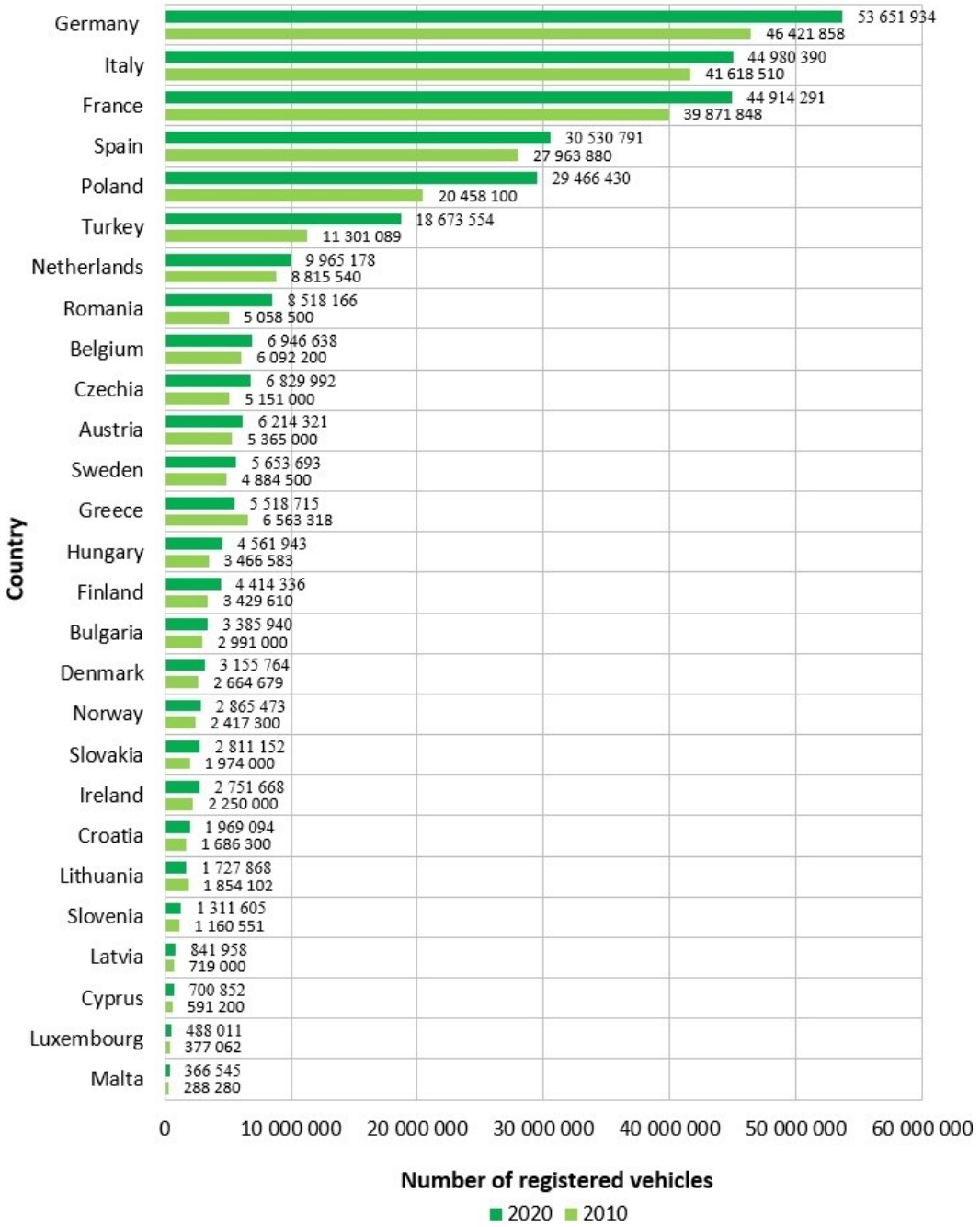

Fig. 3. Characteristics of the number of registered vehicles in European countries in 2010 and 2020

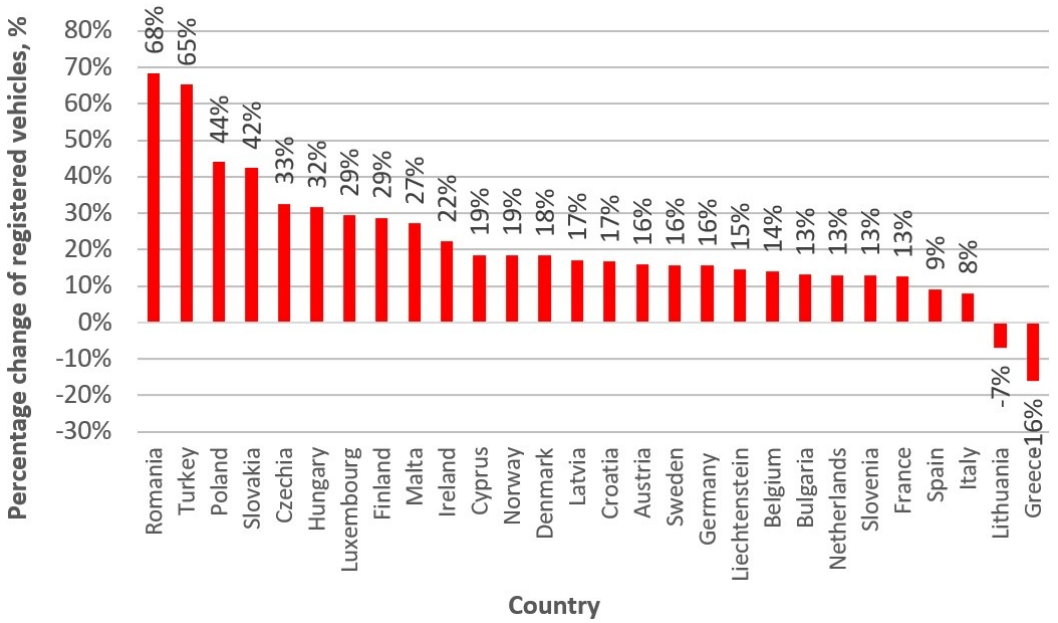

Fig. 4. Percentage of changes in registered vehicles in European countries in 2020 compared to 2010

Road accidents are preventable. Governments need to act to tackle road safety issues as a whole. This requires the involvement of multiple sectors such as transport, police, health, education and road, vehicle and road user safety [30-35]. Figure 5 shows the map of fatalities in road accidents in 2010 and Figure 6 for 2020.

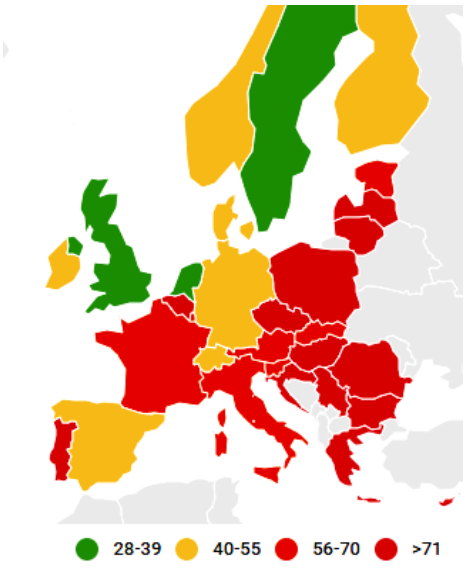

Fig. 5. Map of road fatalities in 2010 [263]

Fig. 6. Map of road fatalities in 2020 [263]

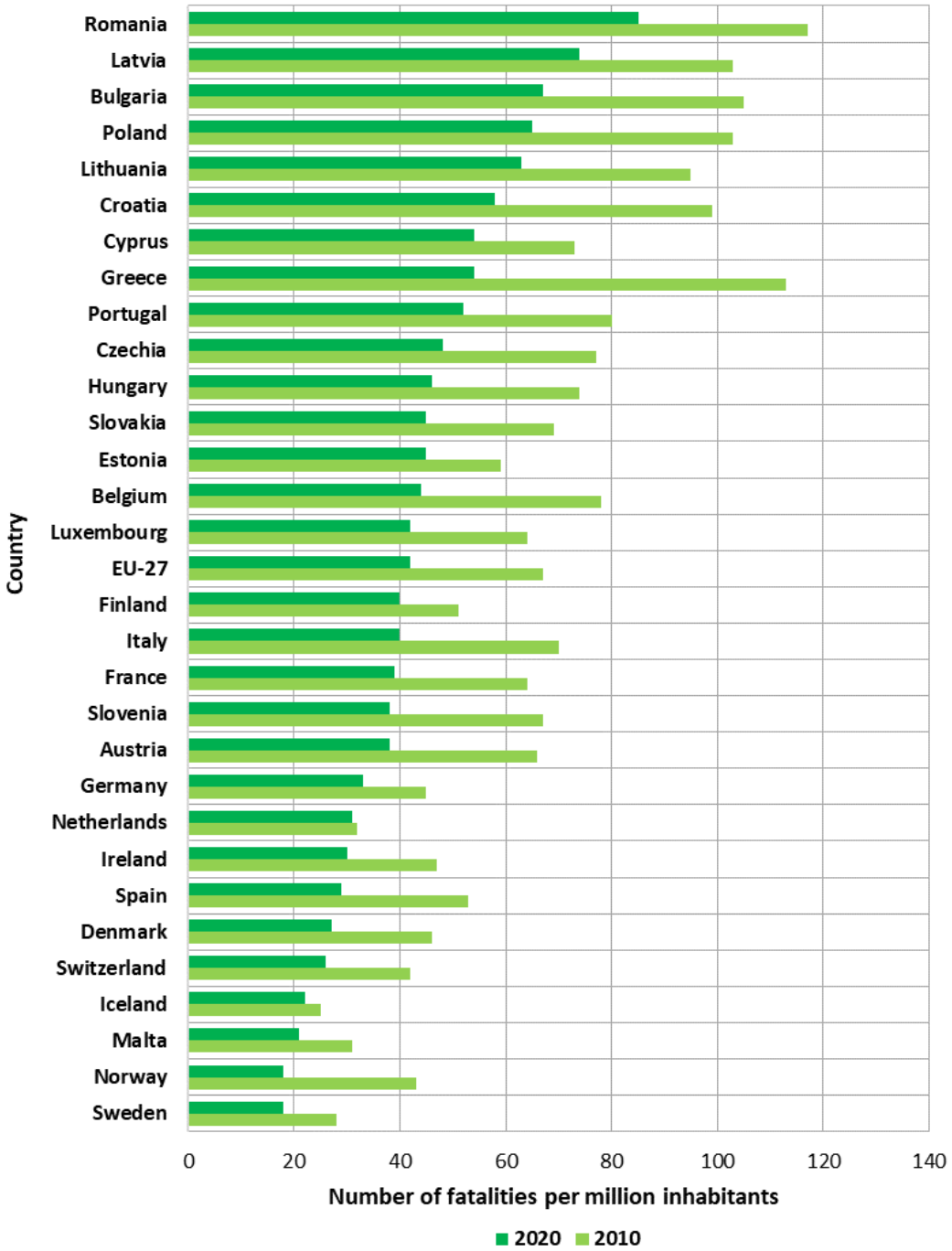

Fig. 7. Characteristics of the number of road fatalities per million inhabitants in selected European countries

In 2009, the World Commission for Road Safety proposed a series of measures to improve road safety in 2011-2020. The plan assumed the improvement of road safety management, the safety of motor vehicles, road infrastructure and shaping the behavior of road users along with road rescue and accident care. The most important assumption of the project was to reduce the number of road fatalities per million inhabitants by 50% by 2020 compared to 2010. This goal was not achieved in the allotted time [30-35]. The European Commission for Road Safety has committed to achieving the target reduction in road fatalities by 2030.

The total number of road fatalities in the EU decreased by 37% between 2010 and 2020. Unfortunately, the death toll has not improved significantly in all EU Member States and other European non-EU countries over the last decade. It should be noted that in 2020 the lowest number of fatalities in road accidents occurred in Sweden (18 fatalities per million inhabitants), while the highest occurred in Romania (85 fatalities per million inhabitants). The European Union's mortality rate in 2020 was 42 deaths per million inhabitants. It should be noted that according to the WHO, this is almost 5 times smaller than the global average, which in 2020 amounted to 180 road fatalities per million inhabitants. Figure 7 shows the characteristics of the number of road fatalities per million inhabitants in selected European countries.

In the longer term, the number of fatalities on European roads fell by 36% between 2010 and 2020, below the EU target of 50%. Only Greece (54%) exceeded the target, followed by Croatia (44%), Spain (44%), Portugal (43%), Italy (42%) and Slovenia (42%). In total, nine Member States recorded decreases of 40% or more. The safest roads remain in Sweden (18/million), in contrast to Romania (85/million) where the indicator in 2020 was the highest among all EU Member States. In 2020, 18,844 people lost their lives in road traffic in the EU, 10,847 fewer than in 2010, representing a 37% decrease [30-35]. There were 56 305 fewer deaths on EU roads in the target period than would have been if the deaths had remained at the same level as in 2010. It is estimated that the monetary value of the human losses avoided by preventing road fatalities for society, is approximately EUR 156 billion [30-35]. In the 2010-2020 target period, the largest annual decrease in the number of road fatalities in the EU was achieved in 2020: 3,919 deaths were avoided in the EU in 2020 compared to 2019, an unprecedented decrease of 17% in just one year. In comparison, road fatalities in the EU fell by just 3% in 2018-2019 and only by 6% in 2013-2019 [30-35].

In the period analyzed from 2010 to 2020, countries such as Greece and Norway achieved a 50% reduction in the number of road fatalities. A decrease of more than 40% was achieved by countries such as Belgium, Bulgaria, Spain, Croatia, Italy, Lithuania, Portugal and Slovakia. In Poland, in the analyzed period of time, there was a decrease of 37%. The percentage change in the number of road fatalities per million inhabitants in selected European countries in 2010 and 2020 is shown in Figure 8.

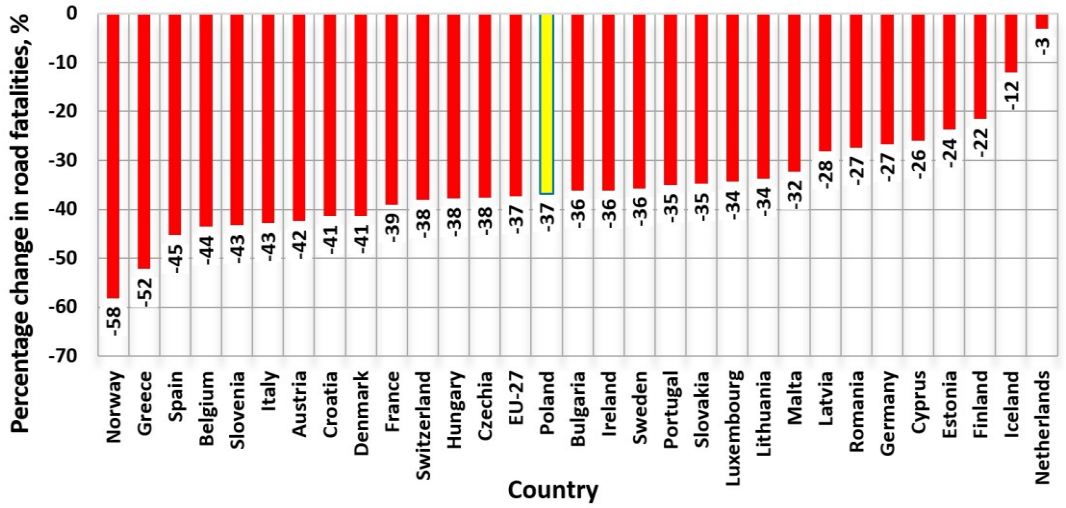

Fig. 8. Percentage change in the number of road fatalities per million inhabitants i in selected European countries in 2010 and 2020

The annual change in the number of fatalities in accidents on EU roads is shown in Figure 9. The largest annual decrease occurred in 2013 and amounted to 8.6% compared to 2012. In 2015, there was a 0.9% increase in the number of fatalities on EU roads compared to 2014. The annual downward trend in the number of fatalities in the Member States of the European Union varies widely. In Germany, in 2011, 2014, 2015 and 2018 there was an increase in the number of fatalities compared to the previous year (Figure 10). In France, the annual increase in road fatalities occurred in 2014, 2015 and 2016 (Figure 11). In Spain, on the other hand, the annual increase in the number of road fatalities was recorded from 2014 to 2017 (Figure 12). Figure 13 shows the annual change in the number of road fatalities in Poland. Based on statistical data, it should be noted that in 2015 there was an increase in fatalities by as much as 22.9% compared to 2014. The annual increase in the number of road fatalities in Poland also occurred in 2011, 2018 and 2019.

4. STATISTICAL ANALYSIS

In this work, the R2 coefficient of determination was used, which determines the impact of changing one variable in relation to another. The coefficient of determination R2 was determined using formula 1 [36].

$$R^2 = 1 - \frac{\sum_{i=1}^{n}\left(y_i - \hat{\ }\right)}{\sum_{i=1}^{n}\left(\dot{y}_i - y_i\right)^2} \quad (1)$$

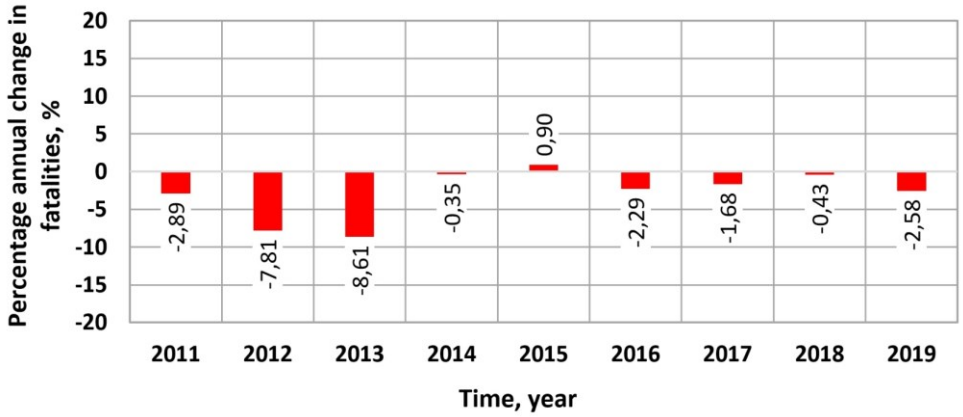

Fig. 9. Annual change in the number of fatalities in accidents on EU roads

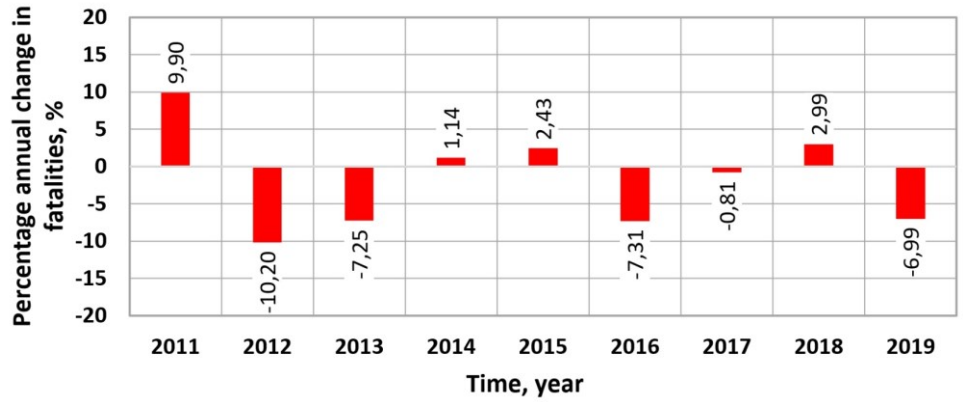

Fig. 10. Annual change in the number of fatalities in road accidents in Germany

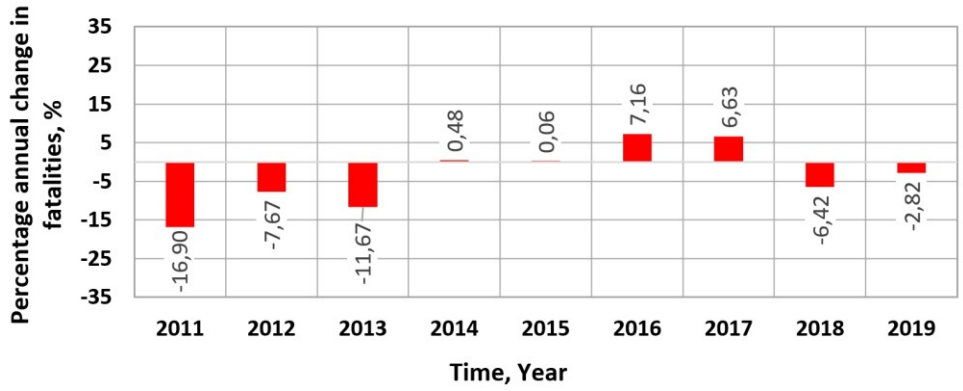

Fig. 11. Annual change in the number of fatalities in accidents on France's roads

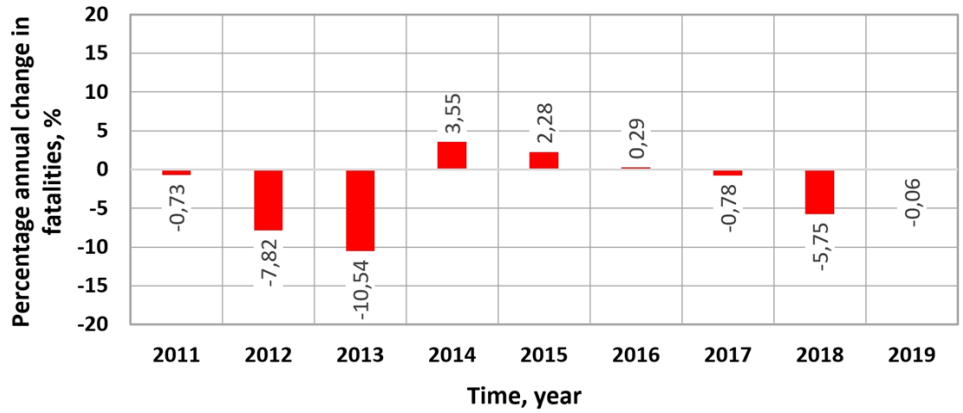

Fig. 12. Annual change in the number of fatalities in accidents on Spain's roads

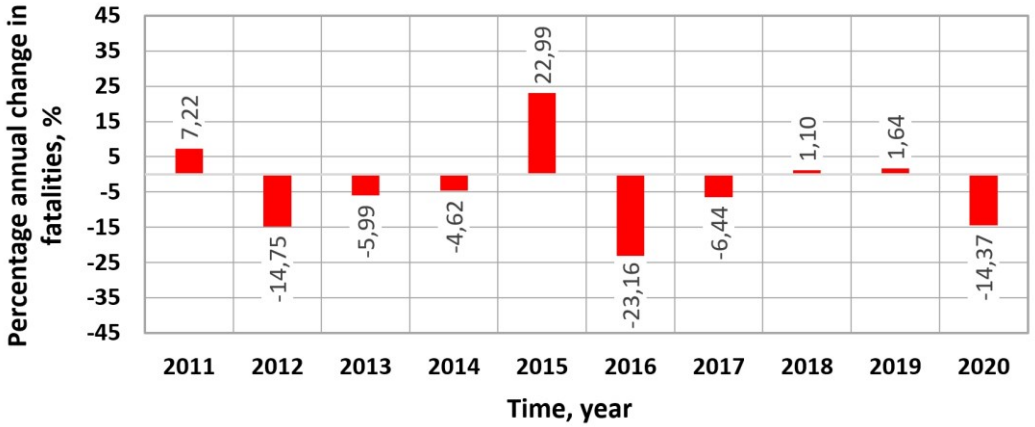

Fig. 13. Annual change in the number of road fatalities in Poland

By determining the R2 coefficient, which is a measure of the quality of the model's fit. The authors want to check which of the above factors (number of registered motor vehicles, length of motorways) most influences the decrease in the number of fatalities in selected European countries [36]. However, attention should be paid to the relationship between the number of road fatalities and the number of registered motor vehicles and the length of motorways. The coefficient of determination R2 for the data on the number of fatalities in terms of the number of registered motor vehicles in selected European countries is presented in Table 1. The results of the coefficient of determination R2 for Finland (R2=0.9608), Malta (R2=0.9149), Polish (R2=0.8599), Belgium (R2=0.7807), and Slovakia (R2=0.7765), indicate that the number of road fatalities is related to the number of registered motor vehicles. So in order to reduce the number of fatalities in road accidents in these countries, the total number of registered motor vehicles should be reduced. The lowest values of the R2 determination index are found for Estonia, Lithuania, Ireland and the Czech Republic. For these countries, the value of the determination index R2 did not exceed 0.1. In these countries, the number of road fatalities is not linked to the total number of registered motor vehicles.

Table 1. Determination coefficient R2 for data on the number of fatalities in terms of the number of registered motor vehicles in selected European countries

Country	R2	Country	R2
Finland	0.9608	Croatia	0.495
Malta	0.9149	Spain	0.450
Poland	0.8599	Slovenia	0.400
Belgium	0.7807	Italy	0.343
Slovakia	0.7765	Netherlands	0.324
Germany	0.7013	Romania	0.265
Greece	0.6942	France	0.231
Hungary	0.6915	Bulgaria	0.222
Portugal	0.6770	Austria	0.176
Latvia	0.6621	Estonia	0.029
Denmark	0.5291	Lithuania	0.019
Luxembourg	0.5231	Ireland	0.011
Sweden	0.5102	Czechia	0.001

Table 2. Determination coefficient R2 for data on the number of fatalities in road accidents in terms of length of motorways in selected European countries

Country	R2	Country	R2
Spain	0.8561	Italy	0.5263
Czechia	0.7175	Hungary	0.5263
Croatia	0.7090	Netherlands	0.4797
Germany	0.6921	France	0.4779
Slovakia	0.6714	Ireland	0.4068
Portugal	0.6457	Sweden	0.2824
Romania	0.6409	Denmark	0.2304
Poland	0.6334	Luxembourg	0.1802
Austria	0.6234	Bulgaria	0.1763
Finland	0.5628	Slovenia	0.0741
Estonia	0.5410	Lithuania	0.0032

The coefficient of determination R2 for data on the number of road fatalities in terms of length of motorways in selected European countries is presented in Table 2. The results of the coefficient of determination R2 for Spain (R2=0.8561), the Czech Republic (R2=0.7175), Croatia (R2=0.7090), indicate that the number of fatalities in road accidents is related to the length of motorways. Therefore, in order to reduce the number of road fatalities in these countries, the length of motorways should be increased. The results of the coefficient of determination R2 for Polish (R2=0.6334) indicate a moderate relationship between the number of fatalities in road accidents and the length of motorways.

However, it should be noted that this result further proves that a further increase in the length of motorways will contribute to a reduction in the number of fatalities in road accidents. The lowest values of the R2 determination index are for Slovenia and Lithuania. For these countries, the value of the R2 determination index did not exceed 0.1. In these countries, the number of road fatalities is not linked to the length of motorways.

CONCLUSIONS

The European Union's policy is aimed at improving road safety. A number of changes introduced by the Member States of the European Union are aimed at reducing the number of road fatalities. The introduced changes are aimed at improving the safety of motor vehicles, which is why new vehicles are equipped with a series of passive systems contributing to increased safety, in addition, road infrastructure is being developed, thanks to which collision-free roads (motorways, expressways) are created, in which all participants move in one direction.

Analysing the impact of the number of road accidents on the number of fatalities, it has been confirmed that in some EU countries, the only way to reduce the number of fatalities is to reduce the overall number of road accidents. Such countries include, for example, France, Greece and Italy. At the same time, these Member States have very good road infrastructure.

Perhaps the only effective means of reducing the number of road fatalities is the education of road users. Deterring drivers from breaking traffic rules with higher financial penalties and introducing new passive and active safety systems for vehicles can contribute to increasing road safety in the European Union.

The analysis of the impact of the number of registered vehicles and the length of motorways on the total number of fatalities in road accidents, using the determination coefficient R2, shows a large range of discrepancies between the results, this is due to the fact that European countries differ in terms of road safety. For some countries European countries, the change of the analyzed parameter will significantly affect the change in the number of fatalities, and for the others, the change of the analyzed parameter will not be significant.

An important problem concerning the level of safety in road traffic is the lack of unambiguous parameters that affect the level of safety. Determining the parameters and their extent to which they affect the number of road accidents or the number of fatalities in road accidents in a given country is an important element of the road safety improvement policy. Only by knowing the cause of the current level of road safety, it is possible to develop policy programs that increase the level of safety in given European Union Member States and European countries.

WYKORZYSTANIE WSPÓŁCZYNNIKA DETERMINACJI R2 DO OKREŚLENIA WPŁYWU WYBRANYCH PARAMETRÓW NA LICZBĘ OFIAR ŚMIERTELNYCH W WYPADKACH DROGOWYCH W POLSCE NA TLE WYBRANYCH KRAJÓW EUROPEJSKICH W LATACH 2010-2020

W artykule przedstawiono dane statystyczne dotyczące stanu bezpieczeństwa transportu drogowego w Polsce na tle wybranych krajów europejskich w latach 2010-2020. W artykule przedstawiono charakterystykę zmiany długości autostrad wraz z procentowym tempem przyrostu długości autostrad w wybranych krajach europejskich. Przedstawiono dane statystyczne dotyczące liczby zarejestrowanych pojazdów samochodowych w Polsce na tle wybranych krajów europejskich w analizowanym okresie. Głównym celem artykułu jest wykorzystanie współczynnika determinacji R2 do określenia wpływu liczby zarejestrowanych pojazdów samochodowych oraz długości autostrad na liczbę ofiar śmiertelnych w wypadkach drogowych w wybranych krajach Europy. Autorzy wybrali współczynnik determinacji R2 jako wskaźnik tego, jak zmniejszenie ogólnej liczby wypadków drogowych i zwiększenie długości autostrad wpłynie na liczbę ofiar śmiertelnych. Współczynnik determinacji służy do określenia, jaki procent jednej zmiennej wpływa na zmienność drugiej zmiennej. Wyznaczona wysoka wartość wskaźnika determinacji R2 (bliska 1) wskazuje na duży wpływ analizowanej zmiennej na liczbę ofiar śmiertelnych wypadków drogowych. Wysoki wynik współczynnika determinacji R2 dla Polski w zakresie analizowanych zmiennych potwierdza, że dalsze zmniejszenie liczby ofiar śmiertelnych wypadków drogowych jest możliwe dzięki rozbudowie autostrad i zmniejszeniu liczby pojazdów mechanicznych.

Słowa kluczowe: pojazdy mechaniczne, wypadki drogowe, bezpieczeństwo ruchu drogowego

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