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LEVELS OF ROAD SAFETY IN THE EUROPEAN UNION AND ITS SPATIAL DIVERSITY

Road safety is one of the most important global social issues. According to data from the United Nations, every year, around 1.2 million people worldwide die as a result of road accidents; that is, on average, one person dies every 30 seconds. Children and teenagers make up 40% of the fatalities. An additional 30–50 million people are injured as a result of these accidents; some of them become permanently disabled. The main types of accident risks are well documented; they concern a large range of factors, most often related to the behavior of drivers, especially in terms of speed. This article ranks the European Union countries in 2004 and 2018 by their levels of road safety. Four groups of countries are distinguished: very high, moderate, low, and very low levels of road safety.

KEYWORDS: road transport, road accident, sustainable development, safety, Hellwig's method.

1. INTRODUCTION

Transport is one of the main pillars of the modern economy, it also plays an important social function. An efficient transport system ensures the implementation of basic freedoms, including freedom of movement, freedom to work and study, or the free movement of goods and services. Besides the great opportunities, transport involves serious risks, for example: high risk of traffic accidents which generate huge economic, personal, and material costs. These costs are mostly related to the need to engage of: paramedic services, police, fire brigade, and other ones like helping the injured, treatment costs, rehabilitation and psychological help, temporary or permanent inability to generate GDP, costs of court proceedings or payment of compensation and social benefits (Dyr, Jaździk-Osmólska, Kozłowska, 2017).

Road transport is the greatest threat to safe mobility. It is the cause of almost all deaths related to the movement of persons and loads. Every day, there are many deaths and serious injuries on the roads. Human mistakes are the biggest source of risk in road traffic, they

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are most often committed by road users who ignore applicable road laws and use roads in an irresponsible way, posing a threat to themselves and others (www.ec.europa.eu).

The most important task of the road safety system is to protect the health and life of its participants. This importance is reflected in various aspects of transport policy aimed at ensuring sustainable mobility. Improving the quality of transport services, including personal safety, and reducing the number of accidents and health risks are priorities for the European Union (Biała Kięga, 2011) as transport is of great importance for social cohesion in a more environmentally friendly economy, education and innovation for Europe. Reducing the number of road user casualties is a key factor in improving the overall performance of the transport system and in meeting the needs and expectations of citizens and businesses. The European Commission is very active in promoting legislation, technical standards and awareness campaigns aimed at reducing road deaths. It took the "Vision Zero" approach and a safe system, aiming to eliminate fatalities and serious injuries. EU actions are complemented by national, regional and local actions.

The purpose of this study is to present the level of road safety in individual European Union countries in 2013–2018 and its spatial diversity. The year 2004 adopted as the base year results from the fact that this year saw the greatest enlargement of the European Union with the accession of ten countries, including Poland.

2. EUROPEAN AND NATIONAL CONDITIONS OF ROAD SAFETY

Activities related to ensuring road safety began in the 1980s, before the entry into force of the Treaty on European Union in 1993. Initially, these activities focused on harmonization of regulations in terms of working time of drivers carrying passengers and loads and standards for the construction of engines in operation vehicles, and then directly related to the safety of people in individual means of transport, related to e.g. the introduction obligation to fasten seat belts and safe transportation of children in vehicles. The then European Economic Community also undertook commitment to develop a joint traffic safety program road, covered by the active policy of the European Union (Allsop, 2010).

First action program for road safety was introduced in 1993, which was the basis for the creation of the joint the database of information on road accidents (Com(93)246 final). Moreover, it constituted a basis for discussing the topics of future activities that gave rise to develop another program for 1997–2001, this time relying mainly on: exchange of information on best practices in European information system, road safety and the application of measures preventing accidents, and in the event of their occurrence – mitigating the consequences.

In 2003, the European Commission published the third European Action Program for road safety for the period 2003–2010 (COM(93)246 final), assumed halving the fatalities of road accidents until the end of 2010. This document stresses the necessity of monitoring not only the number of road incidents, but also failure to respect regulations of road users, applicable regulations, and any behaviors that may be the cause of these events.

In 2010, the European Union renewed its commitment to improvement road safety, also targeting the reduction of mortality on roads by 50%, but this time by 2020 compared to 2010. In order to achieve this goal, activities were identified in the following areas: education and training of road users, enforcement of traffic regulations road, safer road infrastructure, safer vehicles, modern technologies, taking action in emergency situations and after injuries, protection of particularly vulnerable road users accidents

(COM(2010)389 final). The document also stated that "reducing the number of victims among road users is a key factor in overall improvement transport system parameters and meeting the needs and expectations citizens and businesses". The need to ensure safety in traffic road has become a key component of the unified creation plan European Transport Area - white paper from 2011. In this document 2050 was set as the deadline for moving closer to the 'zero fatalities' target. Seven goals were identified: improving user education and training roads, as well as monitoring the application of the traffic safety regulation road; improving the safety of road infrastructure and vehicles; popularization of the use of intelligent transport systems, including implementing the automatic emergency call system "eCall" in vehicles; improving the operation of rescue services and providing assistance to the injured; protection unprotected road users, such as pedestrians and cyclists (Biała Księga, 2011).

In 2018, the European Commission published a communication entitled Europe in motion (COM(2018)293 final). This announcement complements the enabling process people in the European Union to benefit from mobility (COM(2017)479 final). It was found that safety in the transport system must always constitute the highest priority. The Europe on the Move communication is characterized by a new one approach to road safety. First, it was underlined the need to change the thinking provided for in the "zero vision" not only among decision makers, but also among society as a whole, road accidents, unlike, for example, air crashes, they are often unnoticeable by public sphere. Second, a "secure system" should be implemented at the Union level, and the most important elements of this system should be ensuring safe vehicles and safe infrastructure and safety road users by enforcing compliance with regulations, e.g. control sobriety of drivers, vehicle speed control, seat belt control safety, as well as much better care after an accident. Third, we must face the dangers of distracting road users by mobile devices and the technical solutions that are currently available in a transitional phase and may only contribute in the future reducing the role of human mistakes.

In addition, this Communication extends "vision zero" to serious injuries. It was indicated that the approach based on the "safe system" death and serious injuries must not become "the unavoidable price for mobility". It was emphasized that accidents would still happen, albeit fatal and serious `injuries can largely be prevented by, inter alia, better construction vehicles, better infrastructure or lower speed standards. In conjunction with above, as part of this package, the European Commission adopted the conclusions legislative: the first to transform EU standards in the field vehicle safety components combining new prevention systems accidents with updated active and passive safety measures, the second aimed at improving the management of infrastructure safety road traffic so as to reduce both the number of accidents and their consequences. This approach is the basis for the definition of the Union's road safety framework European Union for the period 2021-2030 (SWD(2019)283 final).

3. DIAGNOSIS OF THE LEVEL OF ROAD SAFETY IN THE EUROPEAN UNION

Analyzing the effects of road accidents in 2004–2018 in the European Union, we can see a clear downward trend in both the number of victims fatal and serious injuries (see Fig. 1) and the average size of the victims fatalities per number of inhabitants, number of vehicles, and transport work performed (see Fig. 2).

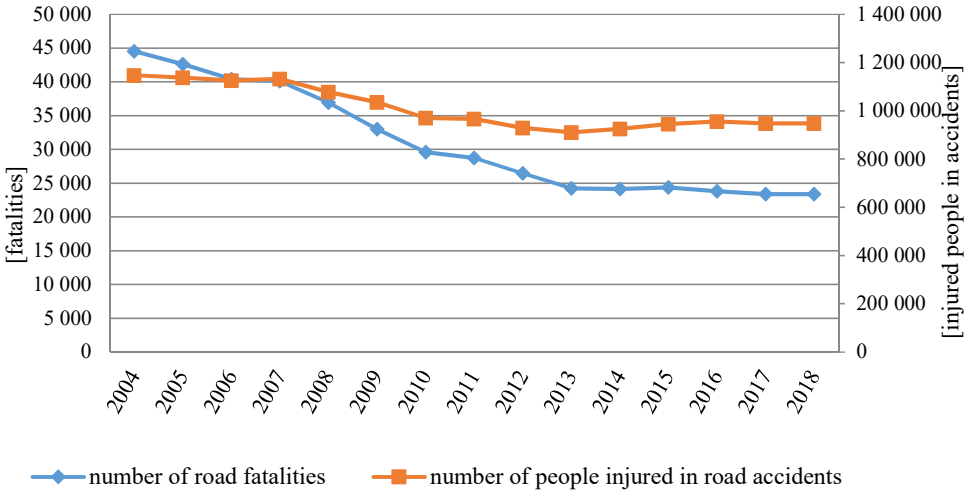

Fig. 1. Change in the number of fatalities and injuries as a result of road accidents in the EU in, years 2004–2018

Source: Own elaboration based on the Statistical pocketbook 2020 (https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2020_en [access: 06.01.2021]).

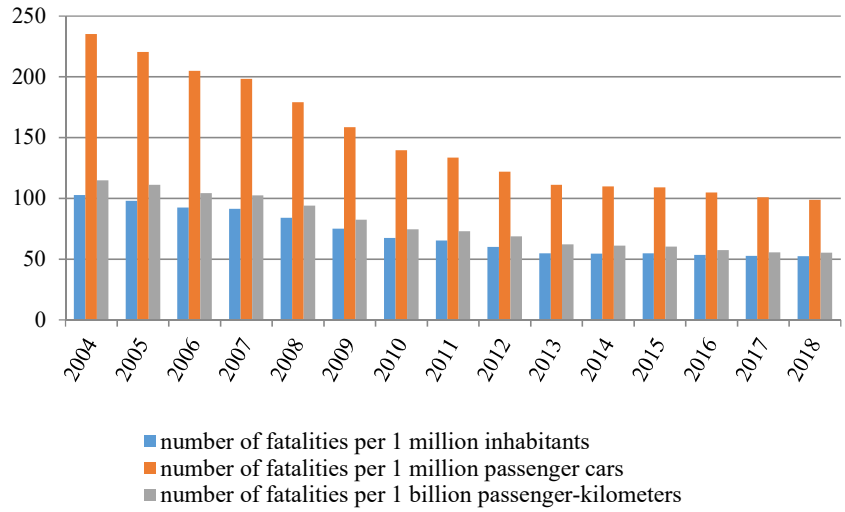

Fig. 2. Change in the number of road fatalities in the EU in relation to population, number of vehicles and mobility from 2004 to 2018.

Source: Own elaboration based on the Statistical pocketbook 2020 (https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2020_en [access: 06.01.2021]).

Fatalities in all EU member states in 2004, amounted to 44 530 people, representing 103 victims per 1 billion inhabitants, 235 victims for every million cars registered in the European Union, and 115 victims for every billion kilometers traveled by European Union

citizens. In 2018, despite the increase in the population, a larger one number of vehicles and carrying out more transport work, the death toll fell by 48% to 23,394 fatalities. This value is 52 casualties per 1 million inhabitants, 99 people killed in accidents per 1 billion passenger cars used, and 55 fatalities for each billion km performed by road passenger transport. In the analyzed period, there was also a significant decrease in people suffering from injuries in road accidents - from 1,147,470 people in 2004 to 948,511 people. This means that almost 200,000 people are less exposed to suffering and financial hardship, and in so many cases the economic costs are reduced.

Despite a significant improvement in road safety in the European Union, in some countries the mortality rate is still very high. In 2018, the greatest number of fatalities as a result of a road transport accident occurred in Italy (3 334 people), Germany (3 275 people), France (3 249 people) - so in countries with the largest population and additionally in Poland, where the number of people killed in road accidents amounted to 2,900. The risk of losing life on Polish roads is twice as high as the European average, and more than three times higher than in the leaders in road safety, for example in Sweden. In 2018, 2,177 people died in 27,556 accidents caused by drivers, and 348 people died in 2,119 accidents caused by pedestrians. Based on the data collected by the National Road Safety Council, it can be stated that out of 100 accidents in Poland, there are approximately: 9 fatalities, 35 seriously injured and 118 moderately and slightly injured. The high accident severity rate proves that it is still the basic factor of road accidents vehicle speeding (Raport, 2018).

The participation of the above-mentioned countries account for as much as 54.6% of the total number of road fatalities in the entire European Union. The number of fatalities on the European roads of the associated countries in comparison with the population, mobility and number of vehicles compared to the European Union average is presented in Fig. 3.

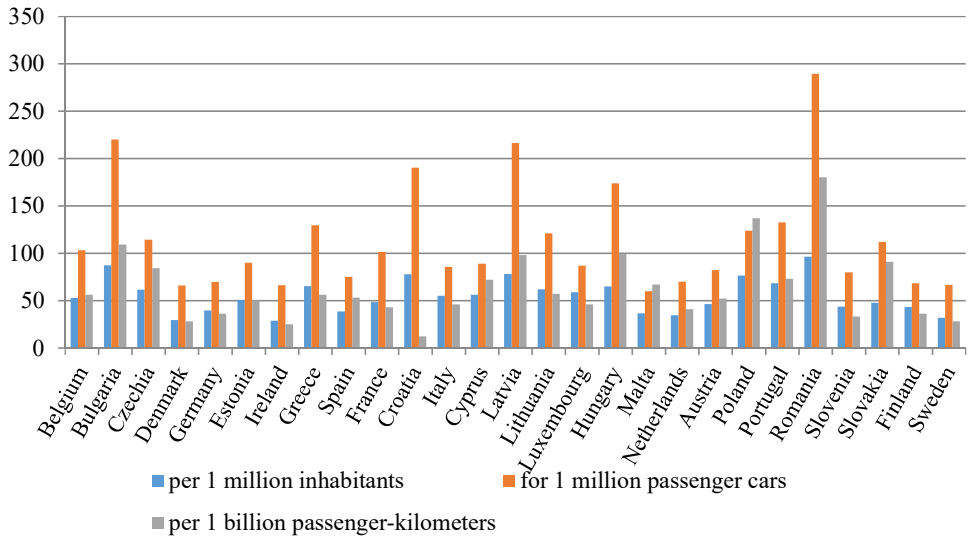

Fig. 3. Number of fatalities due to road accidents in EU countries in relation to population, number of vehicles and mobility in 2018.

Source: Own elaboration based on the Statistical pocketbook 2020 (https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2020_en [access: 06.01.2021]).

In the classification measured by the number of fatalities per year per 1 million inhabitants in 2018, the best results belong to the Scandinavian countries. In Denmark, this indicator was 29 people, and in Sweden 32 people. Poland, with a result of 76 victims per million inhabitants, was in the fifth place from the end, just behind Romania, Bulgaria, Lithuania, and Croatia (it is among the economically less developed countries). The situation of Poland is even worse in the ranking the number of fatalities per 1 billion passenger-kilometers, it is in the penultimate place with 137 people, with the European average being 63 people. Poland presents a bit better, though still far from the European average, according to the death toll rate per million passenger cars, which amounted to 124 people, with the European average amounting to 114 people. This result is mainly related to the rapid increase in the number of cars in recent years, often different in age from cars in other European Union countries (Jamroz, 2019). In 2018, the average age of cars in Poland was over 13 years, which means that it is in the 17th position out of 25 classified countries (www.acea.be).

4. SPATIAL DIFFERENTIATION OF THE LEVEL OF ROAD SAFETY IN EUROPEAN UNION

In the study of the spatial differentiation of the level of road transport safety in the European Union, a multidimensional comparative analysis was used to assess objects whose condition and behavior are simultaneously affected by many features and factors (Hellwig, 1981). This method allowed for a broad and objective view of the studied phenomenon.

The first stage of the study involved selecting a set of statistical features determining the level of road safety. The study used risk indicators monitored by the European Statistical Office, which express the ratio of the number of fatalities and injuries in a given area to the number of inhabitants of that area, to the number of cars, and the amount of transport work performed by individual means of transport, i.e.:

- X_1 – the number of fatalities from road accidents in relation to the population (number of fatalities per million people);
- X_2 – the number of fatalities from road accidents in relation to the number of vehicles (number of fatalities per number of vehicles);
- X_3 – the number of fatalities from road accidents in relation to passenger-kilometers (number of fatalities per billion passenger-kilometers);
- X_4 – the number of injuries in road accidents in relation to the population (number of injuries per million people);
- X_5 – the number of injuries in road accidents in relation to the number of vehicles (number of injuries per number of vehicles);
- X_6 – the number of injuries in road accidents in relation to passenger-kilometers (number of injuries per billion passenger-kilometers).

The next step was to build synthetic measures of road safety level. From the economic point of view, all the variables accepted for the analysis were considered destimulants.

The use of the Hellwig's method required the construction of an observation X matrix consisting of n rows (EU countries) and m columns (diagnostic features):

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \tag{1}$$

In order to obtain the comparability of variables, the observation matrix was transformed into a matrix of standardized variables according to the formula:

$$Z_{ij} = -\frac{x_{ij} - \bar{x}_j}{s_j} \tag{2}$$

Z_{ij} – standardizing the value of a variable in an EU country
j – variable number
i – EU country number
x_{ij} – the value of the variable in the EU country
$\bar{x}_j$ – arithmetic mean of the variable determined according to the formula

$$\bar{\mathrm{x}}_{\mathrm{j}} = n^{-1} \sum_{i=1}^{n} \mathrm{x}_{\mathrm{ij}} \tag{3}$$

s_j – standard deviation of the variable was determined according to the formula

$$S_j = \sqrt{n^{-1} \sum_{i=1}^{n} (x_{ij} - \bar{x}_j)^2} \tag{4}$$

In order to determine the diversity of the group of observations, and thus to check whether the given feature is statistically significant, the coefficient of variation was calculated according to the formula:

$$V_j = \frac{S_j}{\bar{x}_j} \tag{5}$$

V_j – coefficient of variation of the variable
S_j – standard deviation of the variable
$\bar{x}_j$ – arithmetic mean of the variable.

Based on the variables after standardization, a pattern was established, which is an "idealized" state with the best possible coordinates:

$$Z_{0j} = \max Z_{ij} \tag{5}$$

After transforming the variables, the reference method assuming the existence of a model object – a reference one – was used, in relation to which the taxonomic distances of the studied objects are determined using the Euclidean metric. The synthetic measure of the level of road safety in the European Union was calculated as a synthetic indicator of the taxonomic <distance> of a given country from the theoretical pattern. A distance is specified for each site (EU country) from the pattern (value of the synthetic measure, the so-called measure of development), according to the following formula:

$$M_i = 1 - \frac{d_{i0}}{d_0} \ (I = 1, 2, \ldots, n) \tag{7}$$

where:

$$d_{i0} = \sqrt{\sum_{j=1}^{m} (z_{ij} - z_{0j})^2} \; (i = 1, 2, \ldots, n; j = 1, 2, \ldots m) \tag{8}$$

where:

$$\begin{gathered} d_0 = \bar{d}_0 + 2S_0 \\ \bar{d}_0 = n^{-1} \sum_{i=1}^{n} d_{i0} \\ S_0 = \sqrt{n^{-1} \sum_{i=1}^{n} (d_{ij} - d_0)^2} \end{gathered} \tag{9}$$

M_i – synthetic meter
d_{i0} – Euclidean distance of each pattern to build
m – number of variables
n – number of countries
z_{ij} – standardized value of output features (variable for regions)
z_{0j} – normalized value of the pattern for the variable
z_{0j} – arithmetic mean of the taxometric distances
z_{0j} – standard deviations of the taxonomic distances.

In the final stage, a ranking of countries was made and grouped using the k means method, dividing the set into two subsets, i.e. according to objects larger and smaller than the mean, and in subsequent stages – according to intermediate means for each group. Such a division made it possible to distinguish the following groups:

- group I – very high level of road safety: when $z_i \geq \bar{Z}_{1l}$
- group II – moderate level of road safety: when $\bar{Z}_1 < z_i \leq \bar{Z}_{1l}$
- group III – low level of road safety: when $\bar{Z}_{2l} < z_i \leq \bar{Z}_l$
- group IV – very low level of road safety: when $z_i \leq \bar{Z}_{2l}$

where:

- $\bar{Z}_l$ – the average of the meter
- $\bar{Z}_l$, $\bar{Z}_{2l}$ – intermediate means of the meter values

On the basis of the obtained research results, it was determined which of the European Union Member States is characterized by the highest and the lowest level of safety in transport. The values of synthetic measures, in turn, provided the basis for assessing this differentiation in the studied area and for developing a ranking of countries in terms of the

development of the factor in question. The level of safety differentiation in transport and its changes in the years 2004–2018 are presented in Fig. 4 and Fig. 5.

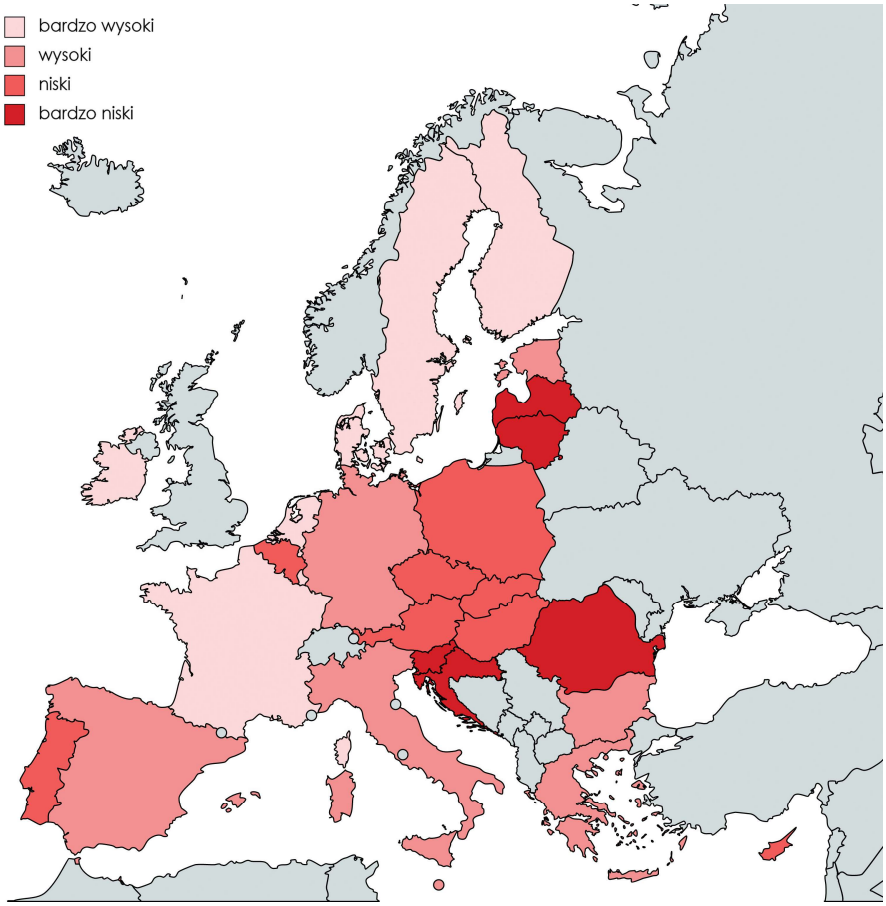

Fig. 4. Spatial differentiation in the level of safety in EU transport in 2004

Source: own study.

A very high level of sustainable transport development in terms of transport safety in 2004 was characteristic of the Netherlands, Finland and Denmark, followed by Sweden, France, Ireland and Luxembourg. In 2018, Estonia and Cyprus joined this group, while Luxembourg fell in the ranking from the group with a very high level of transport safety to the group with a high level. The countries with a very low level of safety in transport, both in 2004 and 2018, were: Romania, Croatia and Lithuania. Moreover, in 2004, Slovenia and Latvia belonged to this group, which in 2018 changed the group from "very low" to "low" and "high", respectively. Portugal and Austria, on the other hand, fell from the low-safety group to the very low group. In both analyzed years, Poland was in the group with a low level of road transport safety.

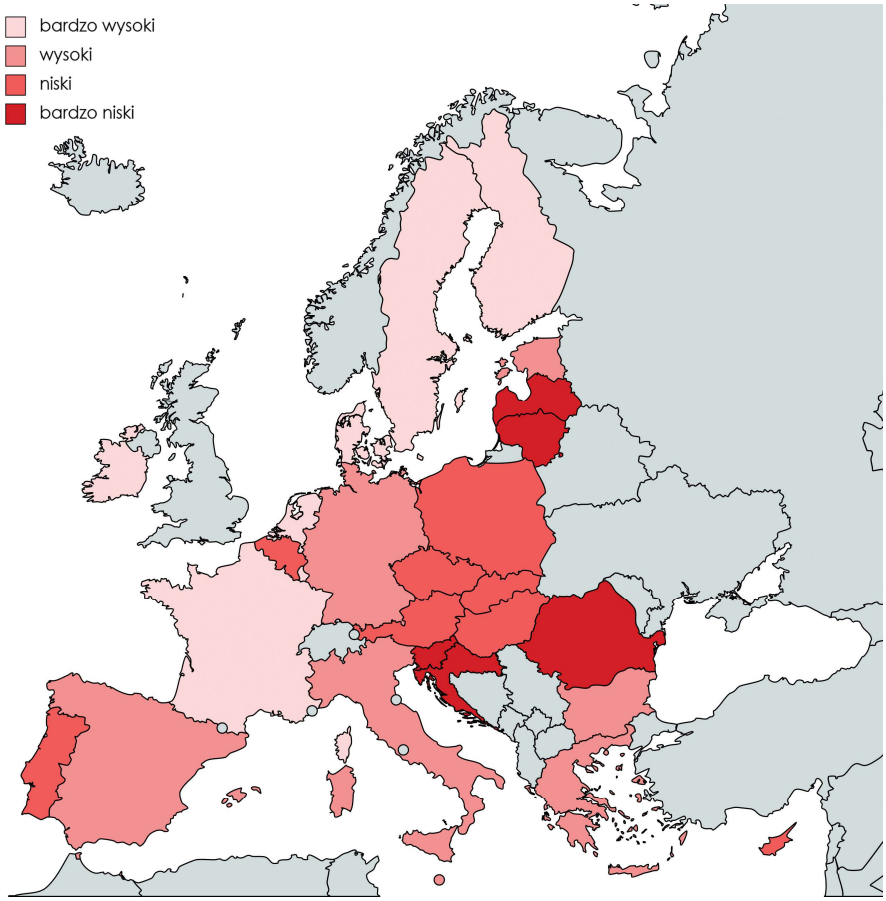

Fig. 5. Spatial differentiation in the level of safety in EU transport in 2018

Source: own study.

Based on the spatial distribution, a level ranking was developed transport safety and its changes, which are shown in Fig. 6.

Based on changes in the ranking of European Union countries in terms of the level of safety development in transport, a significant decrease was observed in Bulgaria, Germany and Malta. It should be emphasized that the analysis was used statistical data on the effects of road accidents, compiled with the size of the population, the number of vehicles and the transport work performed, therefore, insufficient development in the analyzed category should be seen in the weakening actions by the governments of individual Member States and an insufficient change in the model of social behavior.

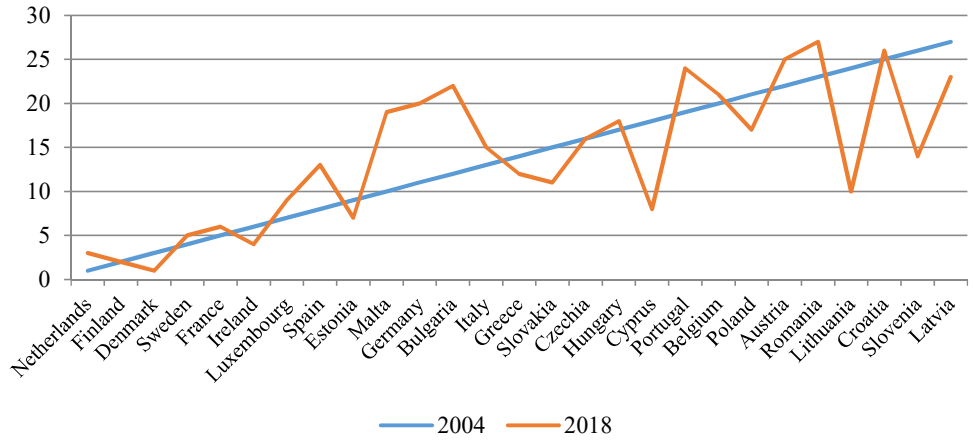

Fig. 6. Change in the ranking of EU countries with regard to the development of the level of safety in transport in 2004 and 2018

Source: own study.

5. CONCLUSIONS

Based on the analysis, it can be concluded that the transport policy in the 21st century in the field of safety improvement is effective. Thanks to the analysis of the effects of road accidents in the years 2004–2018 in the European Union, there is a clear downward trend in both the number of fatalities and the number of serious injuries.

Despite a significant increase in the improvement of road safety in the European Union, the death rate in some Member States is still very high – in 2018 it was 23 374 people. In Poland, this number was as high as 2,900 people, which proves insufficient measures to ensure safe mobility, e.g. activities related to the enforcement of the permitted speed of vehicles, improvement of the quality of infrastructure and increase in vehicle safety.

The role of the road transport system is to provide people with the right to move, but it should be done safely. Death or injury cannot be seen as the inevitable cost of mobility (Narodowy Program BRD, 2013). As road users are the first link in the road safety system, education and enforcement are indispensable factors affecting road safety, as human mistakes are the biggest source of road traffic risk. These errors are most often committed by road users who ignore the applicable road law and use roads in an irresponsible way, posing a threat to themselves and others (www.ec.europa.eu). The road safety system should therefore take into account these mistakes and misbehavior and correct these factors as far as possible. All elements, in particular vehicles and infrastructure, should enable error correction to prevent the dire consequences of road accidents.

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