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ANALYSIS OF ROAD NETWORK INFRASTRUCTURE AND ROAD TRAFFIC SAFETY IN POLAND COMPARED TO EUROPE

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Abstract

The main objective of the article is to compare the impact of road infrastructure in Poland and Europe on transport efficiency and safety. Furthermore, the article analyses and compares transport in Poland against Europe in terms of various factors. The first part of the article is of an introductory nature, which includes a literature review. The next part is the analytical part, which includes the analysis of road accidents in Poland, the analysis of road accidents in Europe, the discussion of road transport infrastructure in Poland and Europe with a breakdown into the density of roads in Poland and Europe. The structure of the network and the length of road surfaces in Poland and Europe are also analysed. On the basis of the research carried out, it can be concluded that the condition of the road transport infrastructure has an impact on the efficiency of transport and its safety both in Poland and Europe. Furthermore, the quality of roads in Europe is a determinant of road safety. The increase in car traffic in recent decades has caused countries to face a serious challenge in developing and building road infrastructure. In recent years, the state of safety on Polish roads has improved, thanks to the construction of better-class roads (highways, expressways), the construction of modern road infrastructure and the introduction of increasingly modern systems such as signalling, lighting.

Keywords: road infrastructure; safety; road transport

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1. Introduction

Rapid technological advances are affecting every area of human life. Automobile development and manufacturing capabilities have gone so far in recent years that many hundreds of thousands of cars now come off the production lines every day [24]. Intense traffic growth in recent decades has meant that road infrastructure in some countries or entire regions has not grown in direct proportion to the number of vehicles. The result is the occurrence of transportation delays, most often through the phenomenon of congestion.

The attribute of road accident severity is used to assess the seriousness of traffic crashes. In order to minimize accidents, reduce injuries, fatalities, and property damage, it is crucial for relevant authorities to adopt road safety policies [2, 21, 22]. Similar themes were analysed in the following works [26, 28].

The data on accidents comes from various sources. They are often gathered and examined by government officials through certain government institutions. Police reports, insurance databases, and hospital records are used to gather data. The transport industry is then processing incomplete data on traffic incidents on a bigger scale [9].

Another possible source of traffic and accident data is social media, however due to the inexperience of the reporters, its accuracy may fall short [27].

Work with several data sources and approach them carefully in order to ensure the relevancy of accident data. The accuracy of analysis results can be improved by combining various data sources and combining heterogeneous road accident [1].

Vilaça et al. [25] did a statistical analysis to evaluate the seriousness and determine the connection between traffic accidents and road users. The study's conclusion makes recommendations for raising road safety standards and implementing additional transport safety laws. Based on the number of accidents, Bak et al. [4] did a statistical analysis of road safety in a specific Polish region and sought to understand the numerous factors that contribute to accidents. Their study examined safety statistics on those who were missing using multivariate statistical analysis.

This phenomenon was studied, among others, by Pawel Kozubek in his work Strategies of sustainable development and the development of transport infrastructure in Poland in 1989–2018. He noted, among other things, that a very important element of the transport system, with a significant impact on socio-economic development, is infrastructure. However, as the author rightly noted, its peculiar characteristics, such as a long period of formation and use, spatial and functional immobility, as well as high capital intensity and high abundance, mean that changes in the entire transportation system take time and large capital expenditures [11].

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Despite the fact that, infrastructure investments require huge expenditures they have a positive impact on the development of the entire economy. They allow the creation of jobs, wealth, geographic accessibility or increased mobility of citizens and trade. There is a correlation between expanded road infrastructure and economically developed countries.

As noted in the article Expansion of road infrastructure, and the location and development of businesses by Piotr Pawlak, the competitiveness of the Polish economy depends, among other things, on the completion of basic transport networks and their modernization by 2030, as a developed, modern, good quality transport infrastructure is very important for economic growth and sustainable regional development [18].

But does the above data exhaust the topic? What about the human factor? They explore this in their article entitled. "Methods for assessing the impact of the human factor on safety in transportation" Nowakowski, Ciszewski and Lukasik [16]. It turns out that a proper assessment of human behavior and mistakes made by humans allows for proper risk assessment and rational decision-making in the safety management process. Minimizing the occurrence of risk is possible by conducting human error analysis using HRA methods. The article points out the need to take into account human subjectivity in these methods.

And what is the "external dominance of infrastructure security of Poland's transport system in the opinion of transport companies and their customers" According to authors [15] it is a factor of international politics. Masello et al. [13] presented the influence of various factors on the number of traffic accidents in their study; specifically, they evaluated the effect of driver aid technologies on enhancing road safety. The research was carried out in a variety of traffic and weather circumstances.

Other researchers have undertaken similar experiments. For example, Cubrani-Dobrodolac et al. [6] suggested an evaluation and decision support model based on the estimation of the driver's psychological traits for use when a driver should be assessed for his likelihood to be engaged in traffic accidents. In contrast, the authors of another work [7] investigated the relationship between speed and drivers' capacity to estimate space in terms of their relationship with the incidence of a driver's proclivity to be engaged in traffic accidents. Another paper [10] describes an assessment and knowledge of research trends in mining accidents and contemporary circumstances relevant to this topic. The issue of road safety, was also addressed in publications [3, 5, 12].

There are several main advantages of road transport, and one of them is the possibility of door-to-door transport. The use of this type of transport is made possible by an adequately developed road infrastructure. Road transport also has disadvantages. One of the most serious disadvantages is low safety, since the transport of goods by vehicle has the highest risk of accidents of all modes of transportation. Another disadvantage is longer delivery times when transporting over longer distances.

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2. Research

The aim of the research is to analyse the road transport infrastructure and road traffic safety in Poland against the background of Europe. For this purpose, the article analyses the state of road traffic safety in Poland. Statistical data was analysed. In the next step, the state of road traffic safety in Poland was compared with Europe. In the next step, the road transport infrastructure and the density of circular roads in Poland are presented and compared with Europe. The research was carried out in MS Excel using the statistical tools available therein.

2.1 Road traffic safety in Poland

The improvement of safety on Polish roads was made possible by the adoption of National Road Safety Program in June 2013. This is a comprehensive safety strategy for Polish roads for 2013–2020. The program's goal was to reduce the number of fatalities to 2,000 and serious injuries to 6,900 by 2020. In 2022, 21,322 road accidents occurring on public roads, in residential zones or traffic zones were reported to the Police (Figure 1) [19]:

- compared to 2020, in which there were 23,540 accidents, the number decreased by 2218 accidents (–9.4%),
- compared to 2021, in which there were 22,816 accidents, the number decreased by 1494 accidents (–6.5%).

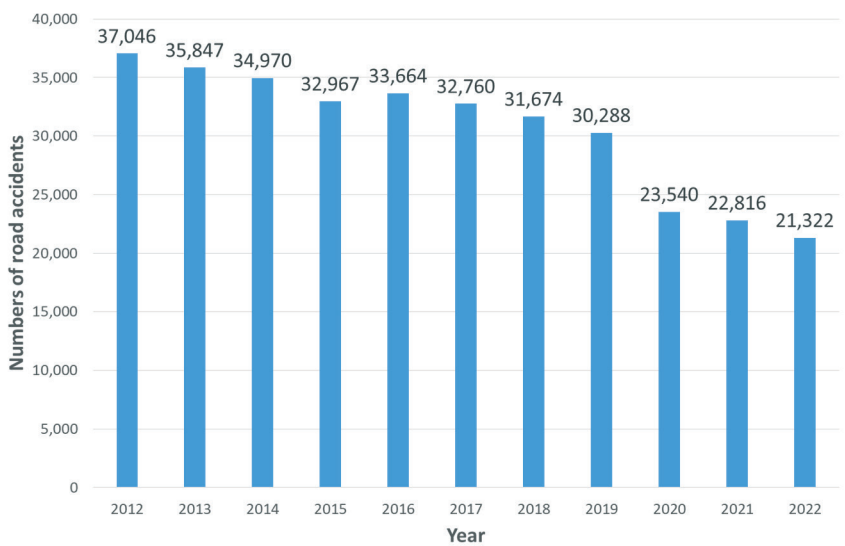

Fig. 1. Traffic accident incidence trend from 2012 to 2022 [19]

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Such a large recorded decrease in 2019–2020 and 2021–2022 is due to the COVID-19 pandemic. In 2019, traffic decreased significantly, which had a positive impact on the number of accidents on Polish roads. Table 1 shows statistics on the improvement of road user safety.

Tab. 1. Number of road accidents and their consequences in 2012–2022 [19]

Year	Accidents		Killed		Injured	
	total	2012=100%	total	2012=100%	total	2012=100%
2012	37,046	100.0	3,571	100.0	45,792	100.0
2013	35,847	96.8	3,357	94.0	44,059	96.2
2014	34,970	94.4	3,202	89.7	42,545	92.9
2015	32,967	89.0	2,938	82.3	39,778	86.9
2016	33,664	90.9	3,026	84.7	40,766	89.0
2017	32,760	88.4	2,831	79.3	39,466	86.2
2018	31,674	85.5	2,862	80.1	37,359	81.6
2019	30,288	81.8	2,909	81.5	35,477	77.5
2020	23,540	63.5	2,491	69.8	26,463	57.8
2021	22,816	61.6	2,245	62.9	26,415	57.7
2022	21,322	57.6	1,896	53.1	24,743	54.0

Table 2 shows traffic accidents that occurred on different types of roads. By far the safest roads are those with the best classes, namely highways and expressways, despite the fact that drivers develop the highest speeds on them. In 2021, 20,623 accidents (90.4% of the total) were caused by drivers. These incidents resulted in 1,909 deaths (85.0%) and 24,307 injuries (92.0%). The main causes of accidents were (Figure 2):

- failure to give priority to pedestrians – 5,566 accidents,
- failure to adjust speed to traffic conditions – 5,254 accidents,
- failure to give priority to pedestrians at pedestrian crossings – 2,099 accidents.

Tab. 2. Number of road accidents by road type in 2021 [19]

Types of road		Accidents		Killed		Wounded	
		Total	%	Total	%	Total	%
Highway		372	1.6	74	3.3	510	1.9
Expressway		407	1.8	63	2.8	575	2.2
About two one-way roads		2,903	12.7	144	6.4	3,348	12.7
Road	**One-way**	889	3.9	37	1.6	968	3.7
	Two-way single carriageway	18,245	80.0	1927	85.8	21,014	79.6

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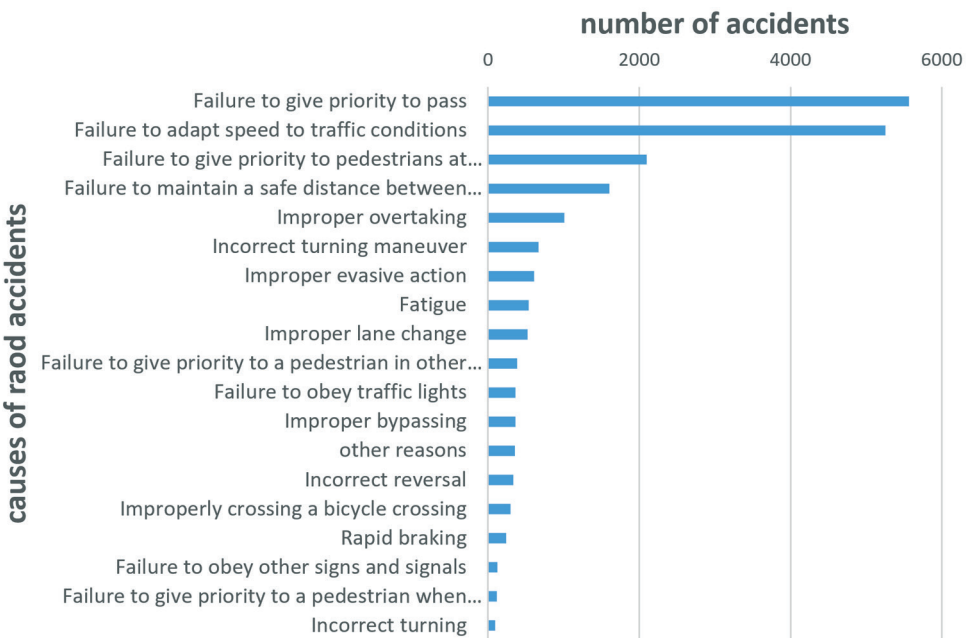

Fig. 2. Main causes of road accidents due to drivers in 2021 [19]

2.2 Road traffic safety in Europe

European roads are among the safest in the world. The European Commission's efforts to further improve road safety are based on the EU's adopted long-term goal of achieving zero deaths and serious injuries in road transport by 2050, or "Vision Zero" and "Safe System." Published on the European Commission's website, the document sets the goal of reducing road fatalities and serious injuries by 50% by 2030 compared to 2020. Across the EU, an average of 51 people per million inhabitants were killed in road accidents in 2019. In 2020, there were statistically 42 fatalities per million EU residents. The large decrease is due to reduced mobility due to the spread of the pandemic – COVID-19. Despite the pandemic, which lowered the European average of fatalities per million inhabitants, the goal of the BRD Decade 2011–2020 – a 50% reduction in casualties – was still not achieved. A 36% reduction was achieved in years [17].

The countries with the lowest average road fatalities per million inhabitants in 2020 in the EU are: Sweden (20), Malta (21) and Denmark (28), and the countries with the highest average are Bulgaria (67), Latvia (73) and Romania (85). The countries that made the most progress between 2010 and 2020 were Greece (-54%), Portugal (-46%) and Spain (-45%) where the

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number of traffic fatalities decreased much. Poland saw a change of –36% which puts us in an infamous 20th place out of 28 listed. The average of traffic fatalities in European countries varies widely (Table 3, Figure 3) [8].

Tab. 3. Fatal accidents in Europe – number of people per 1 million population killed in 2021 [8]

Countries	Year				Change 2010–2020 [%]
	2010	2018	2019	2020	
Austria	66	46	46	39	–38
Belgium	77	53	56	43	–41
Bulgaria	105	87	89	67	–40
Croatia	99	77	73	58	–44
Cyprus	73	57	59	54	–20
Czech Republic	77	62	58	48	–35
Denmark	46	30	34	28	–36
Estonia	59	51	39	45	–24
Finland	51	43	37	40	–18
France	64	49	48	39	–36
Greece	113	65	65	54	–54
Spain	53	39	36	29	–45
Netherlands	32	35	34	30	–4
Ireland	47	29	29	30	–30
Lithuania	95	62	66	63	–41
Luxembourg	64	60	36	42	–19
Latvia	103	78	69	73	–36
Malta	31	38	32	21	–15
Germany	45	40	37	33	–25
Poland	103	76	77	66	–36
Portugal	80	66	61	52	–46
Romania	117	96	96	85	–31
Slovakia	65	48	51	45	–33
Slovenia	67	44	49	38	–42
Sweden	28	32	22	20	–23
Hungary	74	65	62	47	–38
United Kingdom	30	28	28	No data	–3
Italy	70	55	55	40	–42
EU	67	52	51	42	–36

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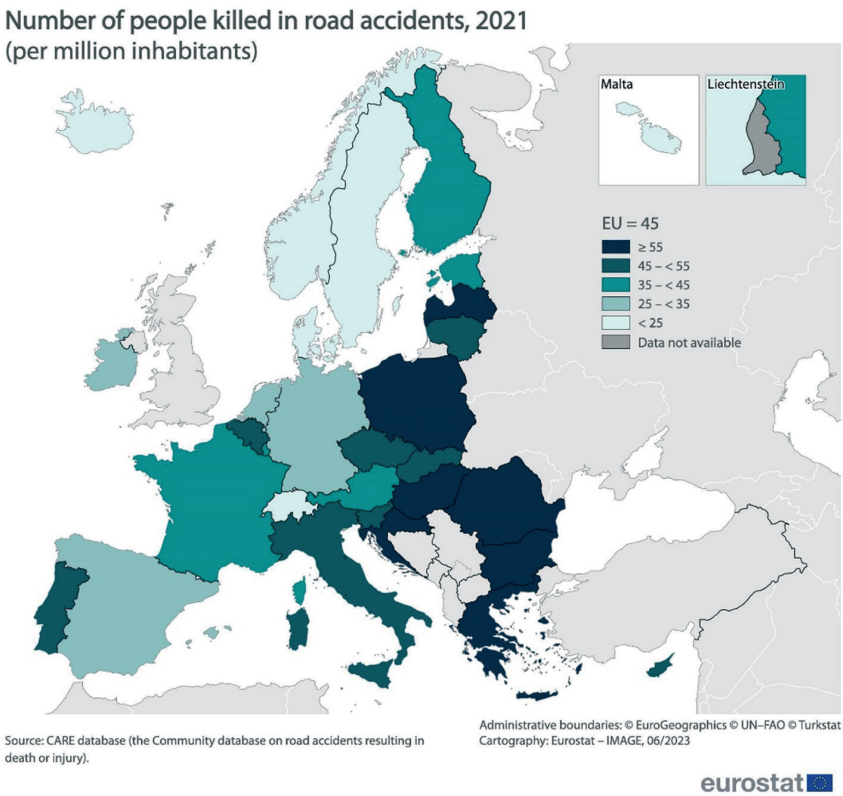

Fig. 3. Number of people killed in road accidents [20]

2.3 Road transport infrastructure

Richly developed road infrastructure is not only high class roads (highways, expressways). Their density is also an important factor, as a high density highway network allows the route to be more efficient and faster. Other factors describing a developed road infrastructure are road markings and the condition of the road surface. Signage in European countries is very similar, as a result of the Vienna Convention on Road Traffic. This convention unifies regulations for signage.

For national roads, including expressways and highways, the manager is the General Director of National Roads and Highways, provincial roads are managed by the board of a given province, county roads are managed by county boards, and mayors are responsible for municipal roads. The administrator's duties include monitoring the condition of managed roads, verifying road features and pointing out defects, performing maintenance work, conducting cleanup work and coordinating work in the road lane [20] (Table 4, Figures 4–5).

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Tab. 4. Structure of the road network in Poland in 2019 [23]

Road categories	Length of public road network [thousand km]	Type of pavement [%]	
		hard	ground
national	19.5	100.0	–
provincial	29.3	99.9	0.1
district	124.3	92.3	7.7
municipal	251.8	57.0	43.0

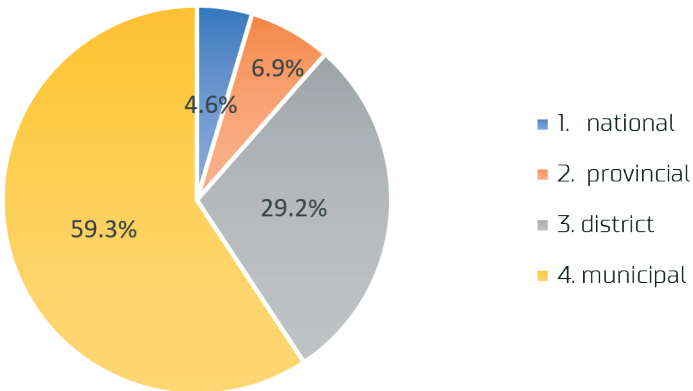

Fig. 4. Percentage structure of public roads in Poland in 2019 [23]

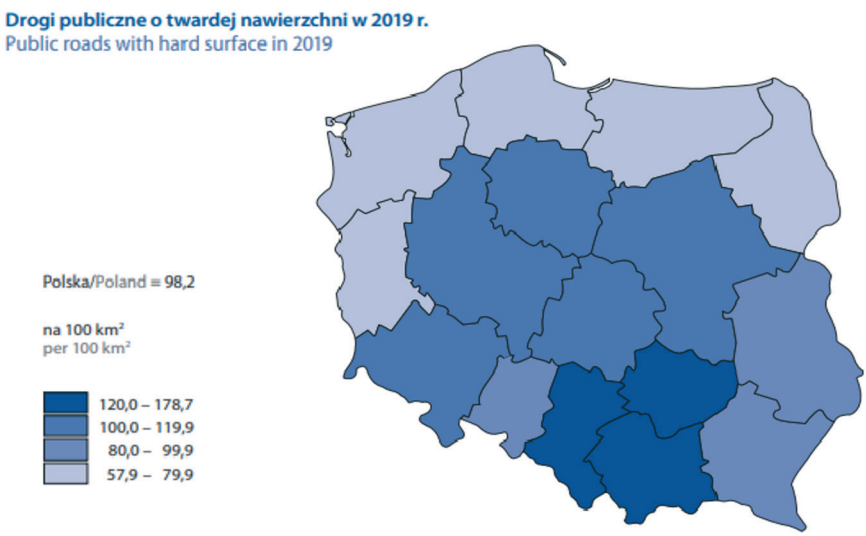

Fig. 5. Public hard-surfaced roads in Poland in 2019, in km/100 km² [23]

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In 2019, the density rate of hard-surfaced roads was 98.2 km per 100 km^2. There is a large territorial variation in Poland. This means that the density of public roads in some regions can be significantly higher or lower than in others. The lowest values were recorded in the north of Poland in the Warmińsko-Mazurskie (57.9 km/100 km^2) and Zachodniopomorskie (60.9 km/100 km^2) provinces, and the highest in the south of Poland in the Silesian (178.7 km/100 km^2) and Małopolskie (172.8 km/100 km^2) provinces.

Highways are a very important element in the economy of any country, as a well-developed highway network is an amenity for business, logistics or tourism. The total length of highways in the European Union countries in 2020 was 77,866 km, and the total number of all roads is estimated at 4,930,119 km. In 2020, Western countries such as France (1,103,774 km of roads) and Spain (666,679 km of roads) had the largest road network. This is followed by Poland (424,564 km of roads), which connects Western European countries with Eastern European countries.

Among the countries compared in the survey in terms of road length, the order is as follows: France (1,103,774 km), Spain (666,679 km), Poland (424,564 km), United Kingdom (418,897 km), Italy (256,567 km), Germany (229,826 km), Hungary (213,300 km), Belgium (155, 210 km), Netherlands (139,690 km), Czech Republic (130,663 km), Austria (127,498 km), Romania (84,234 km), Lithuania (72,227 km) and Slovakia (56,939 km). Poland ranks 20th, out of 28 countries in the period under review, between Germany and Portugal, ahead of Italy and the United Kingdom, among others, and far behind Austria and Belgium (Table 5).

Tab. 5. Data on the area and length of roads in European countries in 2020 [23]

Countries	Area of the country [km^2]	Total [km]	Density of vehicular roads [km/1000 km^2]
Austria	83,871	127,498	1,520.2
Belgium	30,528	155,210	5,084.2
Bulgaria	110,910	19,693	177.6
Croatia	56,542	26,691	472.1
Cyprus	9,251	12,996	1,404.8
Czech Republic	78,866	130,663	1,656.8
Denmark	43,094	74,763	1,734.9
Estonia	45,226	59,008	1,304.7
Finland	338,145	77,943	230.5
France	674,843	1,103,774	1,635.6
Greece	131,990	117,861	893.0
Spain	506,030	666,679	1,317.5
Netherlands	41,526	139,690	3,363.9
Ireland	70,273	98,898	1,407.3
Lithuania	65,303	72,227	1,106.0

Tab. 5. Data on the area and length of roads in European countries in 2020 [23]; cont.

Countries	Area of the country [km^2]	Total [km]	Density of vehicular roads [km/1000 km^2]
Luxembourg	2,586	2,914	1,126.8
Latvia	64,589	68,821	1,065.5
Malta	316	2,640	119.0
Germany	357,050	229,826	643.7
Poland	312,683	424,564	1,357.8
Portugal	92,391	14,313	154.9
Romania	238,391	86,234	361.7
Slovakia	49,037	56,939	1,161.1
Slovenia	20,273	51,962	2,563.1
Sweden	449,964	215,690	479.3
Hungary	93,030	213,300	2,292.8
United Kingdom	242,495	418,897	1,727.4
Italy	301,318	256,567	851.5

2.4 Circular road density

Circular road density is the ratio of the length of roads to the area for which the density is studied, in this case the area of a country. The comparison is dominated by two Benelux countries – Belgium (5084.2 km/1000 km^2) and the Netherlands (3363.9 km/1000 km^2). The worst vehicular road density in Europe is found in countries such as Finland (230.5 km/1000 km^2), Bulgaria (177.6 km/1000 km^2) and Portugal (154.9 km/1000 km^2). Low density of all roads does not mean that a country can move faster. This is because many roads are of a local nature, that is, of an inferior class. Portugal is such an example, as it has a very well-developed highway network, with a low density of all roads. Poland (1357.8 km/1000 km^2) ranks 12th in this comparison, which is quite a good result when comparing this to the large area of the country (Figures 6–7).

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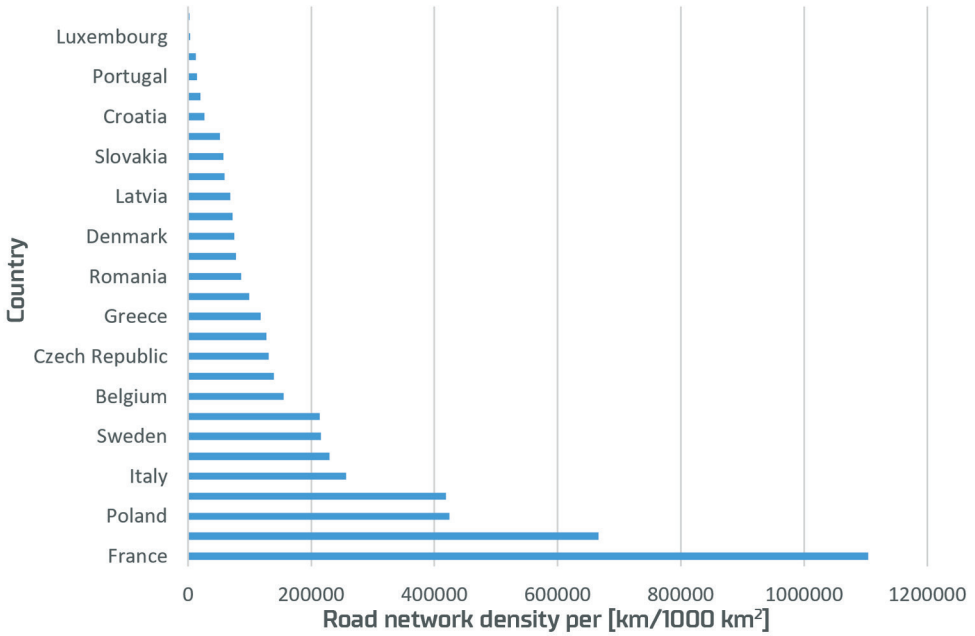

Fig. 6. Comparison of road network density per 1000 km² in European countries in 2020 [23]

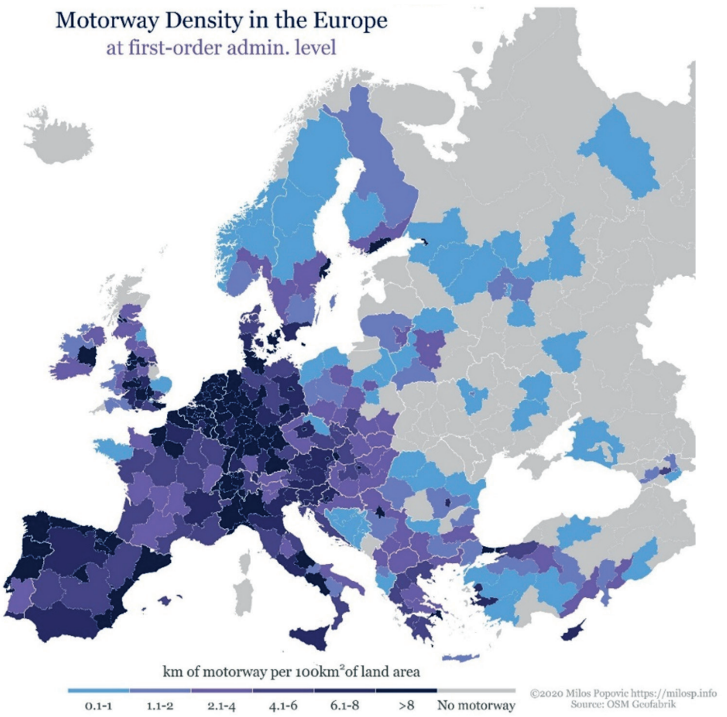

Fig. 7. Motor Density in the Europe [14]

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The longest highway network in Europe is, in order: Spain (17,228 km), Germany (13,183 km) and France (11,671 km). These are countries with a large area, and with a very well-developed road infrastructure, it is possible to move around the country efficiently. There are also small or very underdeveloped countries that do not have highways, namely Malta and Latvia. Poland ranks 12th in this ranking with 1,712 kilometers of highways, a dismal result considering the country's area. Germany, which is a slightly larger country in terms of area,

has as many as 11,471 km more freeways than Poland. Countries that have a smaller area than Poland (312,683 km^2, 1,712 km), but have a longer length of highway network are:

- Italy (301,318 km^2, 6,943 km of highways),
- Great Britain (242,495 km^2, 3,838 km of highways),
- Portugal (92,391 km^2, 3,065 km of highways),
- Netherlands (41,526 km^2, 2,790 km of highways),
- Greece (131,990 km^2, 2,320 km of highways),
- Belgium (30,528 km^2, 1,763 km of highways),
- Austria (83,871 km^2, 1,749 km of highways).

Among the countries compared in the study in terms of the length of the highway network, the order is as follows: Spain (17,228 km), Germany (13,183 km), France (11,671 km), Italy (6,943 km), United Kingdom (3,838 km), Netherlands (2,790 km), Belgium (1,763 km), Austria (1,749 km), Poland (1,712 km), Hungary (1,646 km), Czech Republic (1,306 km), Romania (940 km), Slovakia (498 km) and Lithuania (403 km) (Table 6, Figures 8–9).

Tab. 6. Data on the area and length of highways in European countries in 2020 [23]

Countries	Area of the country [km^2]	Highways [km]	Density of highways [km/1000 km^2]
Austria	83,871	1,749	20.9
Belgium	30,528	1,763	57.8
Bulgaria	110,910	831	7.5
Croatia	56,542	1,310	23.2
Cyprus	9,251	257	27.8
Czech,Republic	78,866	1,306	16.6
Denmark	43,094	1,329	30.8
Estonia	45,226	161	3.6
Finland	338,145	926	2.7
France	674,843	11,671	17.3
Greece	131,990	2,320	17.6
Spain	506,030	17,228	34.0
Netherlands	41,526	2,790	67.2
Ireland	70,273	995	14.2
Lithuania	65,303	403	6.2
Luxembourg	2,586	165	63.8

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Tab. 6. Data on the area and length of highways in European countries in 2020 [23]; cont.

Countries	Area of the country [km^2]	Highways [km]	Density of highways [km/1000 km^2]
Latvia	64,589	0	0.0
Malta	316	0	0.0
Germany	357,050	13,183	36.9
Poland	312,683	1,712	5.5
Portugal	92,391	3,065	33.2
Romania	238,391	940	3.9
Slovakia	49,037	498	10.2
Slovenia	20,273	623	30.7
Sweden	449,964	2,132	4.7
Hungary	93,030	1,646	17.7
United,Kingdom	242,495	3,838	15.8
Italy	301,318	6,943	23.0

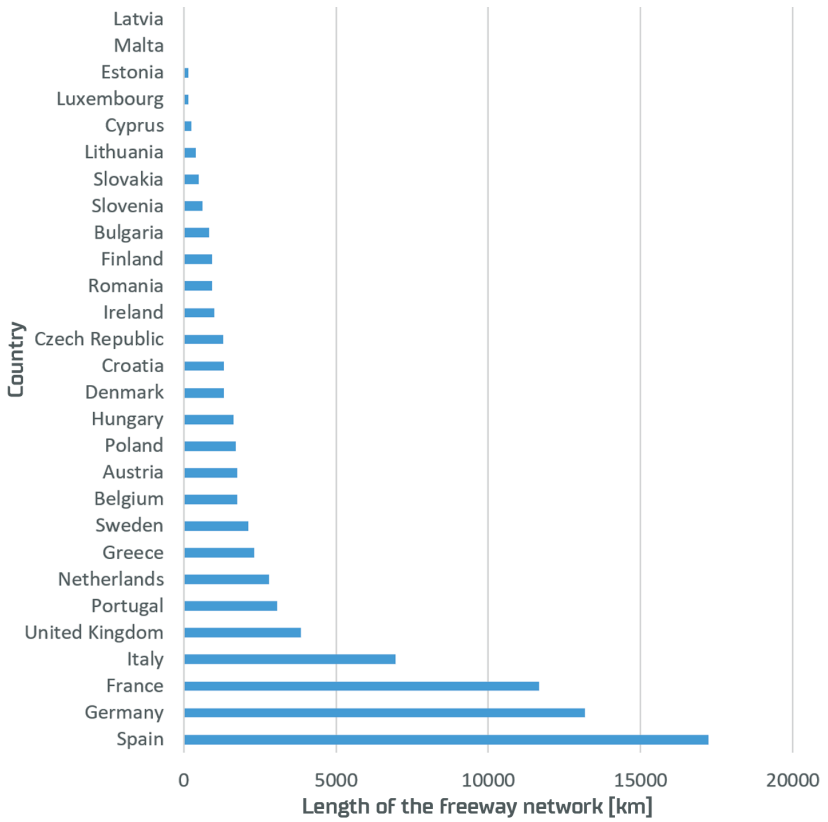

Fig. 8. Comparison of the length of the freeway network in European countries in 2020 [23]

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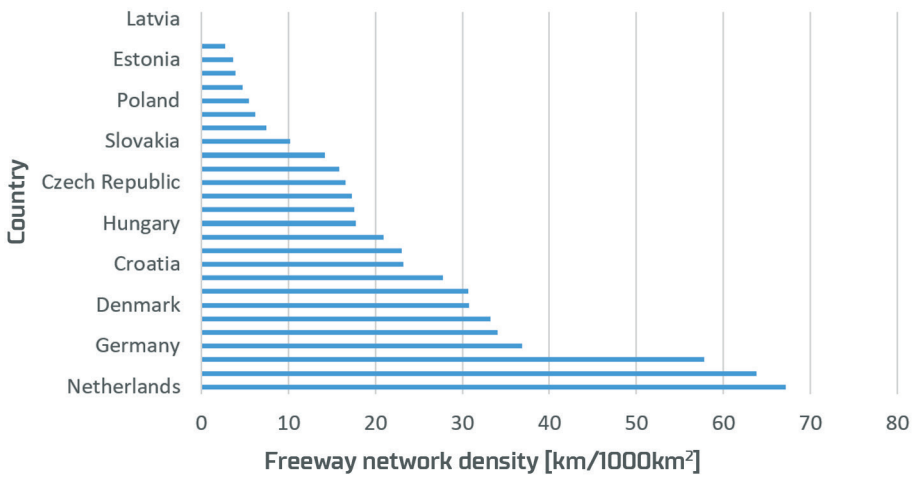

Fig. 9. Comparison of freeway network density in European countries in 2020 [23]

Another very important infrastructure element is the road surface. The increased frequency of truck traffic causes many deformations (including ruts). In turn, potholes, damage that usually appears after winter and changes in the angle of the roadway are the result of neglected maintenance. These deformations result in reduced drainage, and snow and ice in winter. The World Economic Forum's 2019 report addresses, among other issues, the quality of the world's road infrastructure – the condition of road surfaces.

After taking into account countries belonging only to the European Union, Poland ranked 20th out of 27 countries. The poor performance against EU countries coincides with the General Directorate of National Roads and Highways' 2018 report. The information contained therein says that almost 37% of our country's road surfaces are eligible for repair.

3. Conclusion

Road infrastructure in European countries varies widely, even in some neighbouring countries. The number of roads expressed in kilometre's does not show the state of a country's road infrastructure, as in many cases these are of a lower class than highways or expressways. A country's well-developed highways will make driving safer, faster and more comfortable. Also of great importance is the climate and terrain of a country, and consequently the population. Another aspect of an extensively developed infrastructure is roads connecting the country's most important logistical, transhipment points, such as seaports, airports. Roads in countries with well-developed road infrastructure (highways) must be designed to provide adequate capacity and integrate air, rail, sea and road transport.

A country that stands out is the Netherlands, which ranks very high in all lists. All Benelux region countries (Netherlands, Belgium, Luxembourg) are very well connected with each other. Spain, Portugal and Germany are countries that have an excellent highway network. Central and Eastern European countries (Romania, Bulgaria, Latvia, Lithuania or Estonia) have the least developed road infrastructure. Northern European countries (Denmark, Sweden, Finland) are quite specific, as the distribution and condition of infrastructure in these countries is heavily influenced by climate and terrain. Poland, despite continuous development in the field of transport infrastructure and visible progress, still cannot compare with Western European countries. Poland's biggest problem is an inadequate network of highways and the poor condition of road surfaces.

The increase in car traffic in recent decades has caused countries to face a serious challenge in developing and building road infrastructure. In recent years, the state of safety on Polish roads has improved, thanks to the construction of better-class roads (highways, expressways), the construction of modern road infrastructure and the introduction of increasingly modern systems such as signalling, lighting. As can be seen from the above analysis, road transport infrastructure has an impact on the efficiency of transport implementation and its safety, both in Poland and in Europe.

Taking into account the above analysis, the following measures should be introduced to reduce the number of accidents on the roads: Education and more effective enforcement of penalties. This is, according to the drivers themselves, the key to reducing the number of accidents on Polish roads. Driving at unauthorised speeds and not adapting the driving style to the road conditions – these are the most common sins of drivers.

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