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ANALYSIS OF ROAD ACCIDENT CAUSES IN THE VOIVODSHIPS IN THE YEARS 2014-2021 IN THE ASPECT OF SOCIO-ECONOMIC COSTS – TOWARDS THE IMPLEMENTATION OF SUSTAINABLE DEVELOPMENT

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ABSTRACT: The article addresses the topic of road safety. The objective of the research was to assess road accidents caused by voivodships. The analysis took account of the socio-economic differences in the voivodships, which determine the unit costs of fatalities and injuries. A descriptive analysis is given to show the dynamics of changes in the years 2014-2021 in the voivodships and how different factors influenced change. The article analyses the relation between road safety and the region's socio-economic development. Data availability determined the time series applied. As we know from research, accidents fall in relation to the (demographic) density of improved roads. Accidents increase, however, in relation to the density of population and GDP per capita. These relations take the opposite direction if the (demographic) fatality rate or accident severity rate (fatalities per 100 accidents) is the dependent variable. Socio-economic losses were estimated using Statistics Poland data. To value the unit costs of road accidents, the PANDORA method was used. The analysis helped to group the voivodships for their highest and lowest socio-economic costs of road accidents with a special focus on the unit costs of road deaths. The originality of the research is related to the updated voivodship level research.

KEYWORDS: Agenda 2030, sustainable development, road accident, socio-economic costs, voivodships

Introduction

In the context of sustainable development, road accident injury and fatality reduction is of key importance, not only because of the human tragedies but also because of the socio-economic costs. Road accidents generate huge financial losses. The analysis takes into account the number of injuries and fatalities, broken down by voivodships, and their causes, i.e. accidents caused by drivers (including failure to adjust speed to the traffic conditions, failure to respect the right of way, incorrect overtaking, incorrect behaviour towards pedestrians, failure to keep a safe distance between vehicles) and by pedestrians. In addition, the types of roads and surfaces are taken into account and the type of the perpetrator's vehicle. Particular attention was paid to road accidents involving drunk road users. The analysis was carried out in the context of different rates of socio-economic development, which determines the unit costs of fatalities and injuries in individual voivodships.

The UN 2030 Agenda, which came into effect on 25 October 2015, consists of 17 Sustainable Development Goals and 169 targets. The main challenge is to achieve a more integrated approach to sustainable development. Building on the Millennium Development Goals of 2000, Agenda 2030 calls on each UN member state to implement the 17 goals and related targets and in addition to supporting the implementation of the goals in all other parts of the world by 2030 (Weiland et al., 2021; Venturelli & Pizzi, 2022). With regard to the subject of this work, Goal 3, which is to ensure a healthy life for all people of all ages and to promote well-being, should be considered key. Target 3.6. is to halve the number of global deaths and injuries from road traffic accidents (Venturelli & Pizzi, 2022) by 2020 compared to 2010. Poland as a whole and none of its counties have achieved the Agenda 2030's goal (Romanowska et al., 2022). From the point of view of road safety, research should focus on the causes of accidents with particular attention to infrastructural factors and the human factor, i.e. drunk road users. While a road accident happens in a fraction of a second, it causes different types of costs, including health, psychological and socio-economic costs. If treatment measures are to become more intensified in areas of the greatest risk, the goal should be to reduce road traffic fatalities and injuries and the resulting socio-economic costs. This is because road accidents involve very high costs paid by society as a whole. The Polish public cannot afford to pay the increasing costs of road accidents. Therefore, actions that are part of sustainable development focus on reducing casualties (KRBRD, 2021b). The people affected both perpetrators and victims of accidents, are usually of working age. In Poland, road accidents are the number one cause of death for men under 44 years of age (Goniewicz & Goniewicz, 2016). This translates into measurable negative

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economic consequences as measured by a country's economic growth (Decae, 2021; Neelakantan et al., 2017; Mohan, 2002; Nantulya & Reich, 2002).

Poland is among the top EU countries for the most dangerous roads. In 2021 there were 65 fatalities per one million population, while the EU average is 42 (Eurostat, 2022). The costs of all road accidents in Poland amounted to PLN 39.3 billion in 2021 (KRBRD, 2021b), representing 1.5% of GDP (BDM, 2022). The research results presented in the article are related to the voivodship level. The data comes from Statistics Poland's Local Data Bank (GUS, 2022a), the SEWIK database (SEWIK, 2021) and the National Road Safety Council (KRBRD, 2021a). The descriptive analysis is preceded by a brief characterisation of the causes of road accidents and the methodology for valuing their costs.

Causes and methodology for valuing the costs of road accidents

The literature usually distinguishes four groups of theories regarding the causes of road accidents, namely stochastic, causal, systemic and behavioural (Weszczak, 2018; Jamroz et al., 2018). We divide the aetiological factors of road accidents into environmental (e.g. the wealth of society and the road infrastructure, including road network loads, the quality and length of the network, the expenditure on its construction, upgrading and safety improvements) and human factors (concerning drivers, pedestrians and passengers), with the latter accounting for 90% of accidents (Rosiak, 2022; Singh & Kushwaha, 2016). The most common human errors responsible for accidents as regards drivers include: speeding, failure to respect road traffic regulations, intoxication (alcohol, substances), fatigue and drowsiness, and using the phone or texting while driving. From the point of view of pedestrians who cause accidents, the most common cause is carelessness when crossing the road, including the simultaneous use of a phone. Human factors are also related to the behaviour of passengers and may distract the driver. The causes of accidents can also be divided into environmental, socio-demographic, technological, medical, political, organisational and human factors (Yasmeen, 2019).

The methodology for valuing road accident consequences, i.e. their costs, is an extremely difficult task because human life cannot be expressed in simple mathematical operations, and not all costs can be estimated. In general, we divide the costs of road accidents into direct, indirect (long-term) and additional costs, which are difficult to estimate. Table 1 gives examples of costs associated with road accidents. As well as causing injuries, road acci-

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dents can lead to death, which in economic terms means lost GDP and unrealised consumption. The costs of serious road injuries are higher than those of fatalities.

Table 1. Socio-economic costs of road accidents

Costs of road accidents	Examples
direct	– medical expenses (costs of treatment and rehabilitation of injuries caused by road accidents) – costs of damage to vehicles, roads, roadside structures and cargo – administrative costs (operational and policing services, insurance, legal costs) – incapacity to do paid work – lost quality of life
indirect (long-term)	– deterioration of physical health (e.g. permanent disability) – psychological effects (on the victims, relatives of victims, on perpetrators, participants and witnesses) – social consequences (loss or change of job, situation of the victim's relatives, legal problems of the perpetrators) – economic consequences (medical, administrative, loss of property, loss of ability to work and deterioration of financial situation, costs of operational and policing services, e.g. personnel costs) – death (funeral and mortuary costs)
additional	– time lost – increased fuel consumption – carbon footprint

Source: authors' work based on Gwarda-Żurańska (2016); Jaździk-Osmólska (2014); Wijnen (2021).

Socio-economic costs are divided into internal (individual social consequences, costs covered by, e.g. insurers who pay out compensation) and external costs (the country's general economic losses, costs generated by individuals and paid by society as a whole at the same time) (Jaździk-Osmólska, 2014). Households pay huge costs of road accidents. In the case of disability or death of the main breadwinner, households can be plunged into poverty with road accidents incurring disproportionate costs, especially for low income households (Aeron-Thomas et al., 2004), which may lead people to take out loans and incur debt and may result in a drop in consumption.

The costs of road accidents are generally divided into medical costs, production losses, human costs, vehicle damage and administrative costs. The costs of road accidents are borne by society, with a significant part of the cost falling on the health sector (costs of medical rescue) and employers (a premature loss or disability of an economically active employee). While the costs of road accidents can be estimated and presented as financial consequences, it is extremely difficult to calculate the value of human life: pain, suffering, poorer quality of life of the casualties and their loved ones and how the fam-

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ily will cope in the case of death – both from an emotional and socio- economic point of view.

According to the welfare economics theory, human costs (loss of quality of life and years of life) as intangible costs should be included in road accident studies to reflect the full impact of road accidents on socio-economic welfare (Boardman et al., 2011; Freeman et al., 2014; Wijnen et al., 2019). Three methods are used to value the socio-economic costs of road accidents (Wijnen, 2021):

- restitution costs generated by the road accident,
- the cost of human capital,
- willingness-to-pay (WTP).

As regards the costs of restitution, the objective is to estimate the costs of treatment, property damage and administrative costs. The estimation includes the direct costs of resources (e.g. labour, equipment) for treatment, vehicle repair, rescue, legal, administrative and insurance matters. In most cases, market prices are used to estimate these costs (Alfaro et al., 1994). To calculate production losses, the human capital approach is followed. It values the loss of production capacity due to the victim's road accident (Wijnen & Stipdonk, 2016). To calculate human costs, the WTP method is used – how much people are willing to pay to reduce risk? This helps to define the value of a statistical life (VSL), which includes human costs and consumption losses (Wijnen et al., 2009). The share of human costs in overall road accident costs varies, depending on the methodology. In the WTP approach, human costs represent 34% to 91% of overall accident costs. In countries which use the alternative method, the share is less than 10%, with the main costs being property damage and production losses, while medical and administrative costs are relatively low (Wijnen et al., 2017).

In Poland, accident and collision costs are calculated using the PANDORA method. It is based on the valuation of human capital costs and restitution costs generated by a road accident. The method values total costs and unit costs of four categories: death, serious injury, slight injury, and financial consequence. Unit costs are valued based on: the work of police and rescue services, mortuary and funeral, hospitalisation, criminal proceedings, compensation and reparation, material consequences and the country's economic loss (KRBRD, 2022b). The method is designed to value the losses to the economy from the death and ill health of an individual as a result of a road accident. The valuation results are a function of the lost GDP and unrealised consumption due to the premature death and incapacity of accident victims. This means that working-age road accident victims have the highest social costs while older victims have the lowest (Jaździk-Osmólska, 2015). In Poland, the most common cause of casualty accidents is speeding. In addition to speeding, the causes of accidents in Poland are: not wearing a seatbelt,

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driver distraction and driving under the influence of alcohol. Despite a decrease in the overall number of road accidents, there has been an upward trend in Poland in the number of accidents caused by drunk drivers (ITS, 2022).

Road incidents are divided into: road accidents and road collisions. An accident is an event that has unintentionally happened that results in damage, injury or harm. A collision is an event that has unintentionally happened, but this may not result in damage, harm or injury. The costs of all road incidents in Poland in 2021 amounted to PLN 39.3 billion. In 2021 the unit costs of road accidents were as follows (KRBRD, 2022b):

- the cost of a fatality: PLN 2.6 m,
- the cost of a serious injury: PLN 3.5 m,
- the cost of a slight injury: PLN 51.3 thousand,
- the cost of a material consequence: PLN 4,700,
- the cost of a road accident: PLN 1.6 m.

The social costs of all road incidents (accidents and collisions) in Poland in 2021 decreased by PLN 17.3 billion (a decrease of 31%) compared to 2018 when these costs amounted to PLN 56.6 billion. The low value concerning the cost of a material consequence was because of the Covid-19 pandemic and the related road traffic restrictions. In 2021 the total value of material as a consequence result of collisions and road accidents amounted to PLN 3.3 billion, which is 73% less than in 2018 – then it was PLN 12.1 billion (KRBRD, 2022b). The unit cost of a material consequence amounted PLN 4,700 in 2021, while in 2018, it amounted to approx. PLN 16,000. To reflect the socio-economic differences between the voivodships, the costs and causes of road accidents are presented by voivodship.

Road safety diagnosis and socio-economic costs of road accidents in the voivodships

Between 2014 and 2021, there were a total of 242,679 road accidents in Poland (Figure 1), with 22,504 deaths (Figure 2) and 288,269 injuries (Figure 3). Over seven years (2014-2021), the number of accidents was reduced by 35% (34,970 to 22,816) and the number of fatalities by 30% (3,202 to 2,245). Despite that, the number of casualties is significantly higher than the targets set in the National Road Safety Programme 2013-2020 (KRBRD, 2021a) (the programme assumed fatality reduction down to 2,000 in 2020) and far from the Agenda 2030 target (Weiland et al., 2021).

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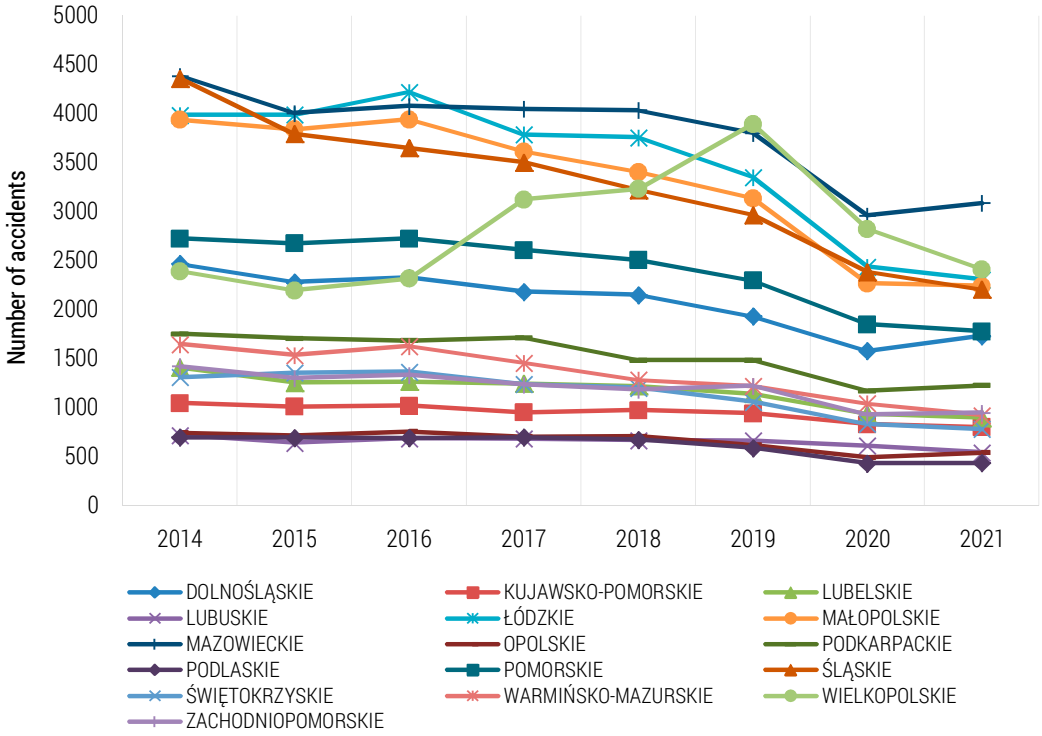

Figure 1. Number of road accidents in voivodships between 2014 and 2021

Source: authors' work based on GUS (2022b).

The highest number of road fatalities is recorded in the voivodship of Mazowieckie. In 2021 this was 375 people. However, because of the Covid-19 pandemic and the related road traffic restrictions, the year 2019 should be considered instead, with 469 fatalities. The lowest number of fatalities is in the voivodships of Lubuskie, Podlaskie, Opolskie and Świętokrzyskie. Similar variations at the voivodship level can also be seen in road accident injuries. In order to compare the data, the analysis must take into account the number of victims per 100,000 population, as presented further in the work.

The year 2021 shows a renewed upward trend in both the number of road accidents and fatalities and injuries. When analysing Poland's road safety data at the voivodship level, there are clear spatial differences. The fatality rate per 100,000 residents is the highest in the voivodships of Opolskie (8.32) and Łódzkie (7.87). The voivodships with the lowest rates include Śląskie (3.31), Małopolskie (4.22) and Podkarpackie (4.49). Accident severity (measured as the number of fatalities per 100 accidents) is the highest in the voivodship of Podlaskie (18.2), with the lowest rates observed in Małopolskie (6.4), Pomorskie (6.6) and Śląskie (6.7).

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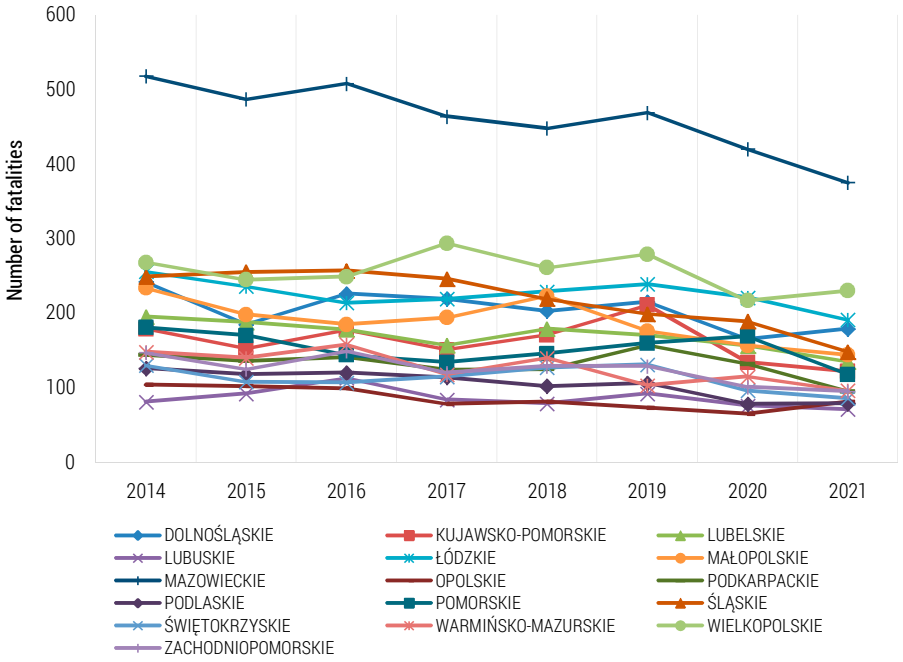

Figure 2. Number of road accident fatalities in the voivodships in the years 2014-2021

Source: authors' work based on GUS (2022b).

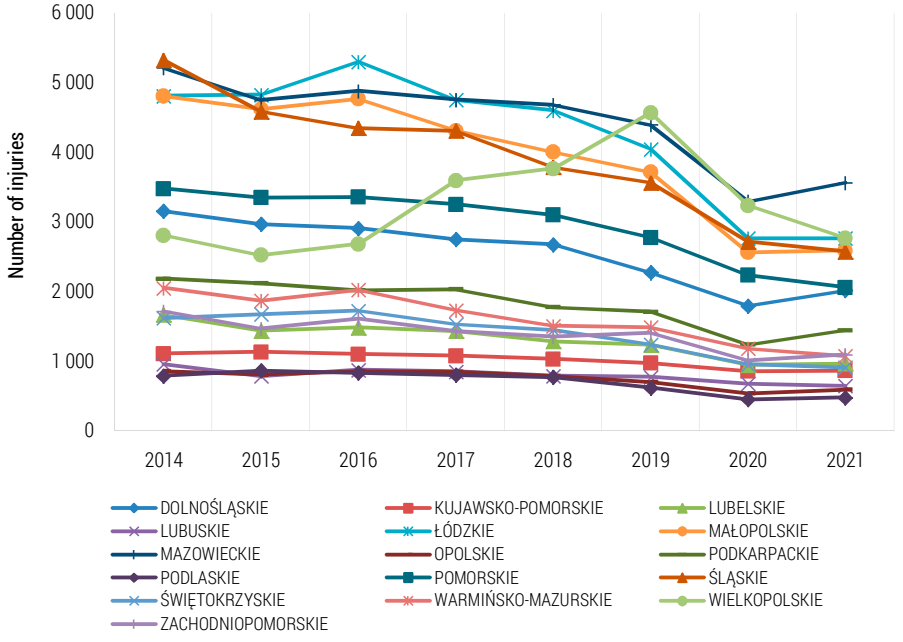

Figure 3. Number of road accident injuries in the voivodships in the years 2014-2021

Source: authors' work based on GUS (2022b).

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The highest reduction in fatalities was recorded in the voivodships of Śląskie (-41%), Małopolskie (-38%) and Podlaskie (-37%), and the lowest in Wielkopolskie (-14%) and Lubelskie (-12%). The map (Figure 4) shows that the decrease in fatalities was the highest in north and east Poland voivodships and the lowest in central and west Poland.

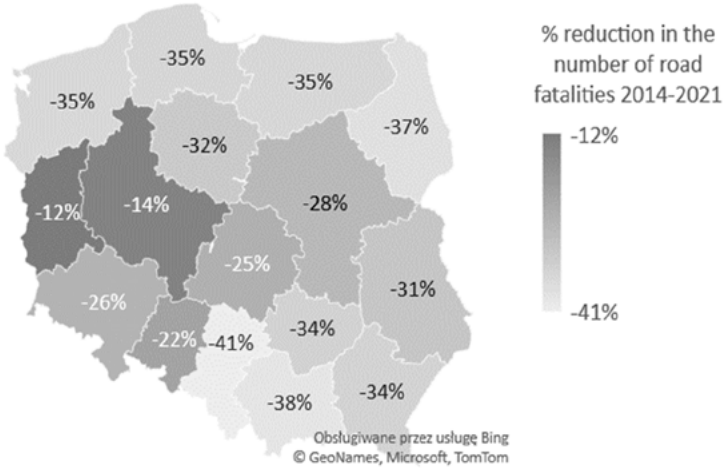

Figure 4. Fatality reduction in the voivodships in the years 2014-2021

Source: authors' work based on GUS (2022b).

The annual costs of accidents are the product of the number of fatalities, injuries and accidents (financial losses) and the respective unit cost. The basic source of data for valuating these costs in Poland, according to the PANDORA method, are police data from SEWIK and Statistics Poland, which provides socio-economic data required for the road accident unit cost valuation (KRBRD, 2022). The costs of victims differ from voivodship to voivodship, which is determined by regional differences in socio-economic development. Below are the unit costs of fatalities and injuries (Table 2) in the voivodships in 2021.

The costs of road accidents in Poland in 2021 amounted to PLN 35.8 billion, which represented 1.4% of Poland's GDP, at the same time and 91% of total costs of all road incidents in our country. It means that 9% were collision costs. The largest share of accident costs was production losses due to employee death or incapacity to work, which represented 71% of all costs. The share of administrative and operational costs was 19%, material losses 8%, and the remaining 2% where the costs of intangible losses and medical expenses (KRBRD, 2022).

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Table 2. Unit costs of road accidents in the voivodships in 2021 [PLN]

	fatality	serious injury	slight injury
DOLNOŚLĄSKIE	1 514 684	2 702 642	54 404
KUJAWSKO-POMORSKIE	1 551 562	2 444 507	81 575
LUBELSKIE	2 262 008	2 705 516	83 152
LUBUSKIE	3 359 895	3 481 045	66 401
ŁÓDZKIE	2 124 028	3 125 627	30 735
MAŁOPOLSKIE	2 271 327	3 031 816	39 237
MAZOWIECKIE	2 394 069	4 018 667	47 228
OPOLSKIE	3 323 760	3 644 542	61 154
PODKARPACKIE	2 521 899	3 199 676	49 167
PODLASKIE	2 101 360	2 985 847	77 246
POMORSKIE	3 407 663	3 795 534	42 904
ŚLĄSKIE	2 787 053	4 040 526	57 667
ŚWIĘTOKRZYSKIE	1 951 739	2 671 298	39 637
WARMIŃSKO-MAZURSKIE	2 810 808	3 427 377	51 171
WIELKOPOLSKIE	2 394 641	3 429 435	46 640
ZACHODNIOPOMORSKIE	2 826 447	3 633 801	49 972

Source: authors' work based on KRBRD (2022).

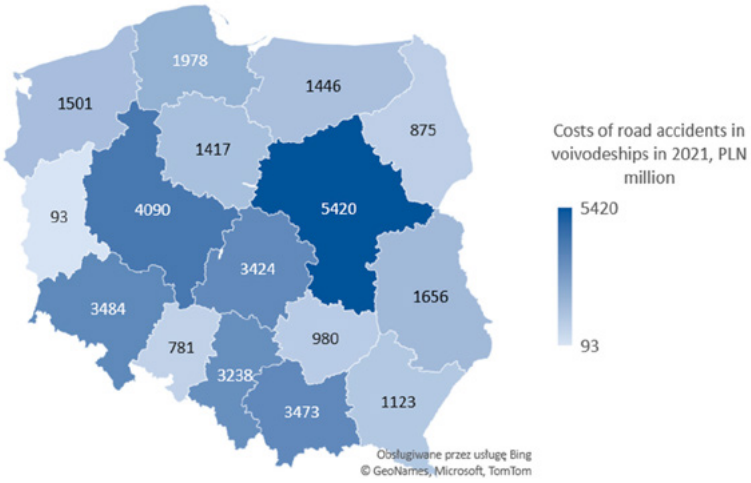

Figure 5. Costs of road accidents in the voivodships in 2021 [PLN million]

Source: authors' work based on KRBRD (2022).

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As shown in Figure 5, the highest road accident costs were paid in the voivodships of: Mazowieckie (PLN 5.4 billion) and Wielkopolskie (PLN 4.1 billion). Next are the voivodships of Dolnośląskie, Małopolskie and Łódzkie (PLN 3.4 billion each) and Śląskie (PLN 3.2 billion). The lowest costs are incurred by the voivodship of Lubuskie (PLN 93 m).

The above analysis looks at how road accident costs are generated. The causes of accidents should also be analysed.

Causes of road accidents by voivodship

Table 3. Causes of accidents in the voivodships to total accidents in 2019

Region	Caused by driver							Caused by pedestrian
		Speeding	Not giving priority	Unsafe overtaking	Inappropriate behaviour to pedestrians	Maintaining unsafe headway	Other	
DOLNOŚLĄSKIE	85%	22%	22%	4%	13%	6%	18%	7%
KUJAWSKO-POMORSKIE	89%	19%	22%	7%	19%	4%	19%	5%
LUBELSKIE	88%	22%	23%	6%	9%	5%	23%	7%
LUBUSKIE	88%	24%	20%	5%	11%	6%	22%	6%
ŁÓDZKIE	87%	22%	24%	3%	11%	6%	21%	5%
MAŁOPOLSKIE	87%	20%	20%	3%	11%	10%	23%	7%
MAZOWIECKIE	89%	22%	27%	5%	12%	6%	17%	7%
OPOLSKIE	88%	18%	24%	6%	8%	12%	20%	4%
PODKARPACKIE	90%	20%	25%	4%	10%	11%	21%	6%
PODLASKIE	88%	21%	22%	9%	14%	6%	16%	6%
POMORSKIE	87%	21%	22%	4%	13%	6%	20%	6%
ŚLĄSKIE	86%	13%	27%	3%	13%	10%	19%	7%
ŚWIĘTOKRZYSKIE	85%	21%	21%	3%	10%	7%	22%	6%
WARMIŃSKO-MAZURSKIE	87%	31%	18%	4%	10%	5%	18%	5%
WIELKOPOLSKIE	90%	21%	28%	4%	11%	8%	19%	5%
ZACHODNIOPOMORSKIE	86%	18%	23%	4%	16%	8%	18%	7%
POLAND	88%	21%	24%	4%	12%	7%	20%	6%

Source: authors' work based on GUS (2022b).

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Irrespective of the voivodship, drivers are responsible for almost 90% of road accidents, with only a few percent attributed to pedestrians (Table 3). Accidents caused by pedestrians are usually a result of stepping onto the road carelessly.

The main causes of accidents include speeding (21% of accidents) and failure to give the right of way to another road user (24% of accidents). Two voivodships stand out for their speeding accidents: Śląskie, with its lowest share of speeding accidents (13%) and Warmińsko-Mazurskie, with the highest share of speeding accidents (31%). Warmińsko-Mazurskie, on the other hand, had the lowest share of accidents caused by failing to give priority (18%). Other causes of accidents account for several to a dozen per cent of accidents in Poland: dangerous overtaking was the cause of 3% – 9% of road accidents, incorrect behaviour towards pedestrians caused 8% – 19% of accidents (the lowest share in Opolskie and Lubelskie, the highest in Kujawsko-Pomorskie), maintaining unsafe distances between vehicles was the cause of 4% – 12% of road accidents (the highest share was observed in south Poland voivodships).

Analysis of the relationship between road safety and the socio-economic development of the voivodships

The data comes from Statistics Poland's Local Data Bank (GUS, 2022a) and the road accident database (SEWIK, 2021). The data covered the years 2014-2021 and the main indicators of socio-economic development and road safety at the voivodship level in Poland.

To assess road safety at the voivodship level, five road safety measures were selected: the number of fatalities in the voivodships was chosen as an absolute measure; the relative measures include road fatality rate, accident severity, the share of accidents involving drunk road users and the share of accidents caused by excessive speed. The fatality rate (FR) was calculated as the total number of fatalities and serious injuries per 100,000 population in a given voivodship. Accident severity was calculated as the number of fatalities per 100 accidents. In addition, variables related to demographic, socio-economic and road infrastructure characteristics were included in the analysis and treated as potential independent variables in the analysis (Table 4).

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Table 4. Variables used in the analysis, 2019

Variable	Abbrev.	Unit	Min	Max	Avg.	Std.
Demographics						
Density of population	POPD	people/km^2	58.0	366.0	128.7	75.8
Urbanisation	URB	%	41.4	76.6	58.5	9.7
Motorisation						
Motorisation rate	MOTR	cars/1,000 people	548.3	706.6	625.8	46.2
Economy						
GDP per capita	GDPC	thous. PLN	40.7	96.6	53.6	14.2
Public expenditures for transport per capita	TEXC	PLN	75.2	146.4	105.0	21.7
Road network						
Density of roads	RD	km/100 km^2	87.6	206.8	139.1	33.4
Density of roads with improved pavement	RDIA	km/100 km^2	53.2	168.9	94.0	33.1
	RDID	km/10 thous people	46.1	108.1	79.6	17.0
Density of motorways	RDM	km/100 km^2	0.5	2.8	1.4	0.7
Road safety (dependent variables)						
Road fatalities	F	fatalities	73.0	469.0	181.8	95.2
Fatality rate	FR	F/100,000 people	4.4	10.6	7.9	1.7
Accident severity	AS	F/100 accidents	5.6	22.4	11.3	4.5
Accidents involving drunk road users	ALC	% of all accidents	4	10	7	2
Accidents caused by speeding	SPD	% of all accidents	13	31	21	4

Source: authors' work based on GUS (2022a).

Table 5 shows the values of the variables in each voivodship in 2019 (this year was chosen because of the possible impact of COVID-19 on the 2020-2021 results). The table shows that Polish voivodships are strongly differentiated in terms of socio-economic development. In this respect Mazowieckie clearly stands out due to its highest GDPC and MR. The most densely populated voivodship is Śląskie. The highest density of RDIA improved roads is also observed there. Voivodships with a low degree of urbanisation generally have lower GDPC, compared to voivodships with a high degree of urbanisation. The lowest TEXC is allocated in Łódzkie, highest in the voivodships of north Poland (Pomorskie, Warmińsko-Mazurskie, Zachodniopomorskie) and Mazowieckie. The highest density of improved roads per RDIA area is found in Śląskie and Małopolskie, which are also the most densely populated voivodships in Poland. Considering the demographic indicator of road density RDID, Śląskie has the lowest rate among the voivodships.

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Table 5. Socio-economic and road safety characteristics in the voivodships in Poland, 2019

VOIVODSHIP	POPD	URB	GDPC	MR	RDIA	RDID	TEXC	F	FR	AS	ALC	SPD
	people/km^2	%	thous. PLN	cars/1,000 people	km/100 km^2	km/10,000 people	PLN	number	F/100,000 people	F/100 accidents	%	%
DOLNOŚLĄSKIE	145	68	65.2	655	97.4	67.0	111	215	7.4	11.1	6.3	21.7
KUJAWSKO-POMORSKIE	115	59	47.5	624	95.9	83.2	86	211	10.2	22.4	6.5	18.9
LUBELSKIE	84	46	40.7	619	86.8	103.4	93	170	8.1	14.9	10.4	21.6
LUBUSKIE	72	65	48.4	679	57.3	79.2	116	92	9.1	13.9	7.9	23.8
ŁÓDZKIE	135	62	56.1	643	107.2	79.6	75	239	9.7	7.1	7.1	22.4
MAŁOPOLSKIE	225	48	54.5	598	157.4	70.1	83	176	5.2	5.6	6.5	20.5
MAZOWIECKIE	153	64	96.6	707	105.2	69.0	123	469	8.7	12.3	7.1	22.1
OPOLSKIE	104	53	47.0	674	84.6	81.1	103	73	7.4	11.9	8.0	18.4
PODKARPACKIE	119	41	41.8	573	92.1	77.2	88	157	7.4	10.6	5.9	20.4
PODLASKIE	58	61	43.0	548	63.1	108.1	97	106	9.0	18.1	9.2	20.7
POMORSKIE	128	63	58.0	621	71.8	56.1	146	160	6.8	7.0	5.3	21.2
ŚLĄSKIE	366	77	61.0	606	168.9	46.1	77	199	4.4	6.7	6.8	13.2
ŚWIĘTOKRZYSKIE	105	45	42.7	596	113.3	107.5	98	131	10.6	12.4	8.8	21.5
WARMIŃSKO-MAZURSKIE	59	59	40.8	572	53.2	90.4	133	103	7.2	8.5	9.3	30.6
WIELKOPOLSKIE	117	54	64.6	695	93.7	79.9	115	279	8.0	7.2	4.4	20.5
ZACHODNIOPOMORSKIE	73	68	50,7	634	58.7	75.2	128.4	101	6.0	10.9	7.9	18.3
POLAND	129	59	53.6	626	94.0	79.6	105.0	2909	7.92	11.3	7.3	21.0

Source: authors' work based on GUS (2022a).

In terms of safety measures, the highest number of fatalities was recorded in Mazowieckie (469) and the lowest in Opolskie. On the other hand, the FR demographic rate was the highest in Kujawsko-Pomorskie and Świętokrzyskie, and the lowest in Śląskie (however, please note its very high population density). In terms of accident severity, Kujawsko-Pomorskie stands out strongly in comparison with others, even though its socio-economic situation is not much different from the other voivodships. The lowest accident severity AS was recorded in Łódzkie and Małopolskie. In terms of the share of drink-driving accidents ALC, the rate was clearly higher in east Poland voivodships (>9%). The same voivodships featured the lowest GDPC. On the other hand, the lowest share of drink-driving accidents ALC was observed in Wielkopol-

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skie (<5%). Speeding accidents SPD, as mentioned in the previous sections, were most prominent in Warmińsko-Mazurskie, with nearly every third accident caused by excessive speed. It should be mentioned that Warmińsko-Mazurskie is one of the voivodships with the highest public spending on transport. In terms of the SPD, the best performing voivodship is Śląskie, with only 13% of accidents caused by speeding.

To test the relationship between safety measures and measures of socio-economic development, Pearson's linear correlation analysis was conducted, which is a statistical method for determining strength of the linear relationship between variables (Kirch, 2008). The relationship between the variables was considered strong, if [r]>=0.7 and moderate if 0.4=<|r|<0.7.

Table 6. Correlations between variables 2019

	POPD	URB	MR	GDPC	TEXC	RDIA	RDID	RDM
Dependent vs. independent variables								
F	0.31	0.19	0.55*	0.89*	-0.01	0.35	-0.32	0.25
FR	-0.66*	-0.22	0.15	-0.13	0.00	-0.44	0.66*	-0.23
AS	-0.45	-0.09	-0.08	-0.25	-0.13	-0.36	0.54*	-0.38
ALC	-0.38	-0.13	-0.37	-0.46	-0.06	-0.29	0.68*	-0.41
SPD	-0.61*	-0.21	-0.05	-0.14	0.42	-0.54*	0.41	-0.31
Collinearity of independent variables								
POPD	-	0.34	0.04	0.39	-0.45	0.89*	-0.70*	0.62*
URB		-	0.22	0.44	0.27	-0.01	-0.57*	0.62*
MR			-	0.66*	0.19	0.03	-0.31	0.33
GDPPC				-	0.20	0.32	-0.55*	0.35
TEXPC					-	-0.66*	-0.12	-0.30
RDIA						-	-0.42	0.46
RDID							-	-0.62*
RDM								-

* Statistically significant with p-value<0.05

Table 6 gives the results of the analysis. It shows that the number of fatalities F is strongly dependent on GDPC and the motorisation rate MR – the higher the GDPC and MR, the higher the number fatalities in the voivodship; it should be taken into account that both variables (GDPC and MR) are strongly correlated. However, considering the demographic fatality rate FR, its value increases with POPD population density and road density rate per capita RDID. As the road density per capita increases RDID, so does accident

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severity AS. Voivodships with a high RDID rate have a higher share of drink-driving accidents. The analysis also shows that a higher share of speeding accidents is observed in voivodships with a low population density POPD and the lowest density of improved roads relative to the size of the voivodship RDIA. The analysis did not show any effects of motorway density RDM and transport spending TEXC on road safety measures in the voivodships.

What is notable in the results of the correlation analysis is the reverse direction of their relationship between FR and improved roads density per capita RDID and improved roads density per RDIA area (Figure 6). The fatality rate increases with the road density per population RDID. It falls, however, as road density per RDIA area increases. The situation is similar with the accident severity rate – voivodships that have a dense road network (a high RDIA) have a lower accident severity, while voivodships with more roads per capita, observe a higher accident severity (Figure 7).

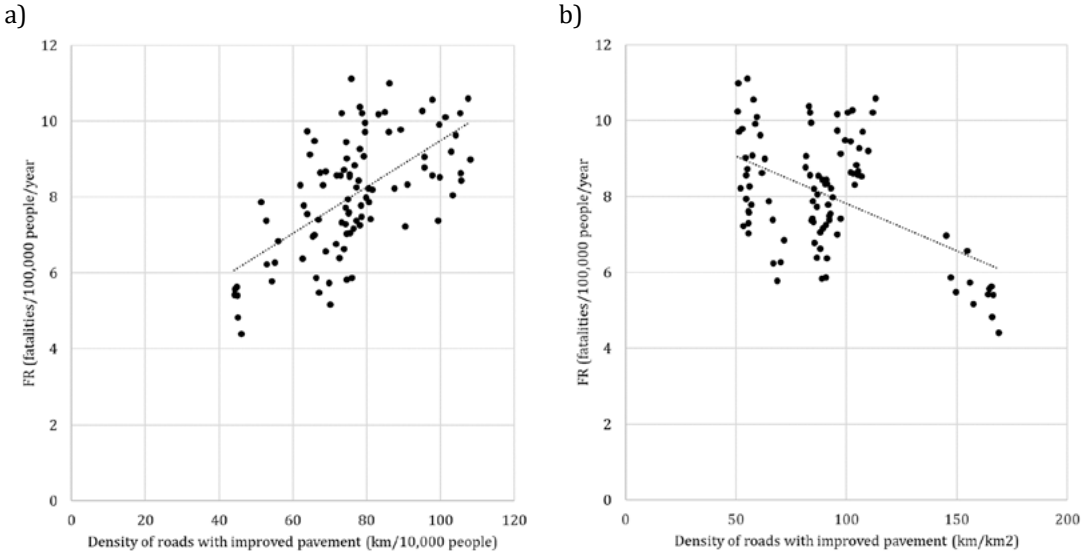

Figure 6. Relationship between fatality rate FR and density of improved roads: a) in km per 10,000 population, b) in km per km^2 of land

Source: authors' work based on Statistics Poland data for the years 2014-2019 (GUS, 2022a).

The relationships between FR and the density of improved roads RDIA and RDID can be partly explained by the interdependencies between the independent variables. Table 5 shows that a high density of high quality road network (per area) RDIA is found in densely populated voivodships. On the other hand, the per capita length of these roads is higher in sparsely populated voivodships with a low rate of urbanisation and a lower GDP per capita

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(GDPC). The relationships between AS and RDID and RDIA, on the other hand, may suggest that a higher density of high quality roads is associated with lower consequences of road accidents.

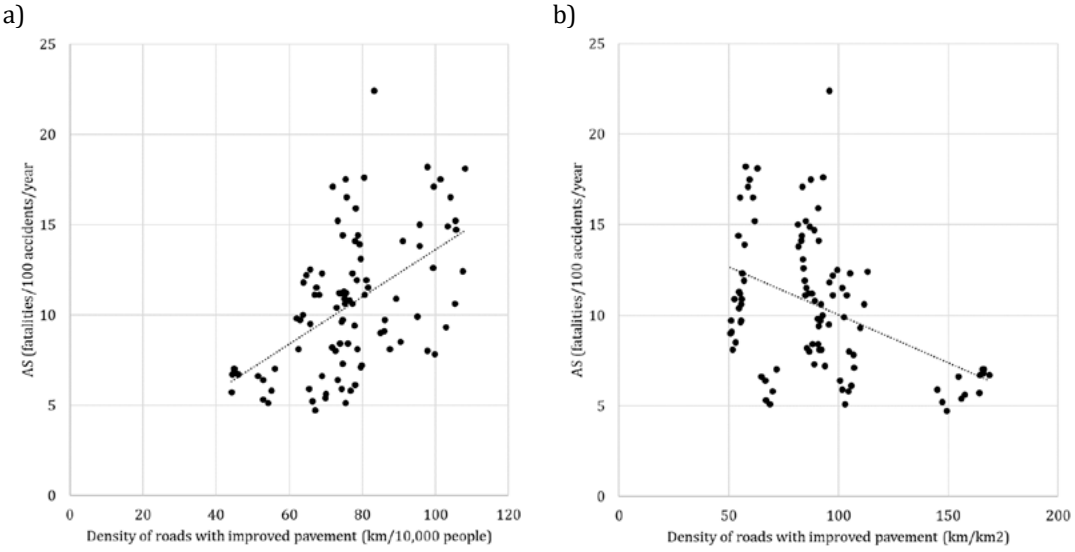

Figure 7. Relationship between accident severity rate AS and density of improved roads: a) in km per 10,000 population, b) in km per km^2 of land

Source: authors' work based on Statistics Poland data from the years 2014-2019 (GUS, 2022a).

Conclusions

The results of the descriptive analysis of accident statistics, their consequences and causes in the voivodships may be helpful with analysing the costs and benefits of road safety spending in the voivodships and of other projects designed to improve road safety.

The data presented in the article shows that voivodships differ significantly from one another in the area of road safety and accident causes. For example, voivodships in east Poland tend to have a higher share of accidents with drunk road users, while the least populated voivodships have the lowest fatalities per 10,000 population. The analysis of the relationship between road safety measures and socio-economic development in the voivodships was conducted to explain the differences between the voivodships. The results of the analysis confirm the conclusions of previous Polish studies at the national and regional level which studied the effects of socio-economic conditions of a region on its road safety level. The analysis shows among

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other things that the fatality rate decreases with increasing population density. Voivodships with a high road density per capita, which are at the same time less populated and less urbanised, have a higher demographic fatality rate, a higher share of accidents with drunk road users and a higher share of speeding accidents. On the other hand, voivodships that have a high road network density (per area) and are more populated, have lower rates of fatalities, accidents involving drunk road users or speeding accidents. The analysis shows that the density of improved roads may be an interesting variable when analysing the causes and consequences of road accidents at the regional level. It reflects the population density and socio-economic development of the voivodships. More research is required to formulate clear-cut conclusions. This article could be a starting point for future research concerning other variables including the impact of location.

The contribution of the authors

Conception, A.R., S.P.-K., M.B., K.W. and J.P.; literature review, A.R., S.P.-K., M.B., K.W. and J.P.; writing, A.R., S.P.-K., M.B., K.W. and J.P.

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