European Research Studies Journal
Volume XXIV, Issue 3B, 2021

pp. 615-632

Management of Infrastructure and Traffic Volume versus Road Traffic Safety

Submitted 15/07/21, 1st revision 05/08/21, 2nd revision 23/08/21, accepted 30/09/21

Monika Kozerska[1]

Abstract:

Purpose: *The objective of the article is to present the impact of the environment and the use of telematics on the safety of road users, paying particular attention to changes in the death rate in road accidents, comparing Poland and other European countries.*
Design/Methodology/Approach: *The author has applied the Delphi method, which uses the knowledge, experience and opinions of experts in a given field. In addition, the focus was on the use of IT systems, e.g., by using them to monitor intersections, creating a system of informing drivers about the existing hazards, weather conditions, possible bypasses in order to more effectively manage transport and ensure a better flow of information, which leads to the improvement of road safety, increasing the driver's comfort and significantly shortening the driving time. The dynamic development of road traffic is associated with the emergence of risks for road users. In the first part of the research method, variables were characterized by frequency (N), standard deviation (SD), minimum value, lower quartile value (Q1), below (or equal to) 25.0% of observations, median - average value, below (or equal to) 50.0% of the observations, the value of the upper quartile, below (or equal to) 75.0% of the observations, and the maximum value. The percentage of people choosing a particular assessment of a given answer variant is also presented. The Mann-Whitney U test was also used in the second research part for comparison of the number of fatalities in accidents in Poland and other European countries.*
Findings: *The results of the analyses made it possible to answer the question whether the use of modern telematics solutions can significantly affect road safety. In addition, subsequent analyses allowed to find an answer to the question of whether there were any changes in the accident fatality rate in Europe from 2009 to 2018. The research indicates an important role in the issues of road safety and hazards.*
Practical Implications: *The research provides pragmatic tips for practical road safety solutions. In addition, this research significantly expands the literature on the impact of modern telematics solutions on road safety.*
Originality/value: *It is an original research that can be used to solve specific problems on its own or also simultaneously with other research methods.*

Keywords: *Road infrastructure, safety, road transport, management, ITS.*

JEL classification: *L9, R4.*

Paper Type: *Research article.*

[1]*Ph.D., Częstochowa University of Technology, Faculty of Management; Chair of Logistics and International Management; Poland, monika.kozerska@pcz.pl;*

1. Introduction

The organization and management of road infrastructure in Poland is a system of legal and organizational solutions that divide the competences and responsibility of the relevant state and local government bodies for the development and maintenance of the established categories of public roads. The central government administration authority responsible for national roads is the General Director for National Roads and Motorways, whose tasks (in accordance with the amended Act on Public Roads) include (Kociolek-Pęksa, 2014):

- performing the tasks of the national road administrator,
- implementation of the state budget in the area of national roads,
- participation in the implementation of the transport policy in the area of roads,
- collecting data and preparing information on the public road network,
- supervision over the preparation of road infrastructure for the purposes of state defence,
- issuing permits for a single journey within a specified period and along a fixed route for non-standard vehicles,
- cooperation with road administrations of other countries and international organizations,
- cooperation with local government authorities in the development and maintenance of road infrastructure,
- traffic management on national roads,
- protection of road monuments,
- performing tasks related to the preparation and coordination of construction and operation, or only operation, of toll motorways.

2. Literature Review

The term telematics originates from the French language (télématique). It is a combination of two fields of technology: telecommunications and information technology. Telematics is mainly used as:

- structural solutions, where an integral element of the system, designed for its needs, is electronic communication and electronic acquisition and processing of information,
- technical solutions using universal IT and telecommunications systems (Wydro, 2018).

The most important benefits of using telematics in transport include:

- increasing transport efficiency,
- better use of resources,
- reducing the negative impact of transport on the natural environment,
- improvement of the economic and financial results of the enterprise,

- increasing traffic safety and reducing traffic congestion (Łacny, 2008).

Telematics, also known as an intelligent transport system, is gaining popularity and continues to expand its field of activity (Kot *et al.,* 2014). The growing demand for transport leads to a situation in which it is necessary to use modern systems enabling efficient traffic management and supporting the functioning of the entire transport system (State Transport Policy). Currently, over 80% of transport needs are met by road transport. It is emphasized that the share of road transport in the branch structure of cargo transport in the European Union is constantly growing, which is a reflection of general economic phenomena in the world and in Europe (Kozerska, 2017).

Another type of system aimed at detecting offenses affecting the danger of a traffic user is a red light run detection system. The system is based on an artificial intelligence system, and once installed it works fully automatically. It collects data in the form of a video of the passage, photos of the license plate, identification of the vehicle type and the time of committing the offense.

An overloaded vehicle detection system is a very important system with regard to the safety and protection of road infrastructure. Using sensors built into the road and cameras, this system is able to weigh and identify a moving vehicle. Another positive factor influencing the safety of journeys is the use of measuring systems. These systems are primarily designed to provide information about the current traffic situation. The most common devices of the transport infrastructure are variable information boards, containing notifications about the condition of the surface, weather conditions, temperature and hazards. The installation of variable message road signs has also become very popular in the last few years - depending on the circumstances.

The last system supporting the driver and improving road safety is the alarm system. Created in order to enable the driver to inform the relevant services about a road accident as soon as possible or to call for necessary assistance. Each of the activities carried out to improve safety should be spread over time:

- action before accidents - preventing accidents, creating "forgiving" road infrastructure, influencing the behaviour of road users (e.g., by striving to reduce speed),
- action in the event of an accident - minimizing the effects, early warning system, directing other road users to detours,
- post-accident action - victim rescue system, quick response and elimination of the consequences of accidents.

The advantages of Intelligent Transport Systems (ITS) when combining and updating various traffic, road infrastructure and user data for the operation and maintenance of transport infrastructure are increased traffic safety and increased efficiency in road transport (Pell *et al.,* 2016).

The Ministry of Infrastructure and Construction has published a report on the Mid-term NPBRD Evaluation Study (National Road Safety Program 2013-2020). The program is based on five pillars, these pillars are:

- Safe man
- Safe roads
- Safe speeds
- Safe vehicle
- Rescue and post-accident care

In terms of linear infrastructure, the pillars of safe roads and safe speeds will be analysed. Safe roads are related to the condition of the road infrastructure and its equipment. Safe speeds are mainly reflected in the maintenance of driving safety, thanks to the habits of driving at a safe speed with properly maintained intervals between vehicles. The report also raised an important issue regarding problems with a huge impact on road safety.

Table 1. *Selected issues related to the emergence of problems in road safety.*

No.	**Problems affecting road safety**
1.	Increase in the number of vehicles
2.	Increasing number of km of roads with good or very good technical parameters
3.	Over speed
4.	Adaptation of the existing road infrastructure to the standards compliant with the regulations
5.	Development of the road traffic management system from local to regional, ending with the national one
6.	Intoxicated road users

Source: *Own study based on: Final Report from the Mid-term Evaluation Study of the National Road Safety Program for 2013-2020.*

As shown in Table 1, the main problems affecting road safety can be seen. The first point describes the increase in the number of vehicles as a problem, it is true, because every year there are 700,000 more vehicles in our country, on average. More than half a million cars. This is what Poland is short of for Poland to be in the top five EU countries in the ranking of the number of passenger cars used. According to a report by the European Automobile Manufacturers Association (ACEA), we are currently in the 6th place with a result of 23.4 million cars and an increase of as much as 4.1% (data for 2018).

The second and third problem is the increasing number of roads with good technical parameters. The effects of this are visible on a daily basis. Believing that the roads are well-constructed, drivers often overestimate their driving skills, which is why they do not comply with the road traffic regulations. The sixth point also fits exactly into this view of the safety problem. Such behaviour is a failure to comply with the road law, which creates a danger for other road users.

Problems number four and five can only be explained as the cause of the failure of the investment management system and project execution, while not creating a unified global road control system. The safe roads pillar relies mainly on the need to transform the current road and road network in order to achieve a hierarchy of structure. The purpose of this is to prioritize the construction and repair needs of roads, which are essential elements on Polish roads.

3. Research Methodology

In the analyses comparing the distribution of a numeric (or ordinal) variable between the groups given by the nominal variable, the Mann-Whitney U statistical tests were used to compare the two groups. The Mann-Whitney U test was used to test the null hypothesis of the symmetry of probabilities that the values of the variable in one of the analysed groups are greater than the values in the other, i.e., that P(X> Y) =P(Y> X). Thus, a statistically significant result for this test tells us that the values of a given variable in one of the groups are greater than in the other. Using a simplified model of the hypothetical-deductive method, one should collect information about unit processes and formulate a research problem. Then formulate a hypothesis and, in the final stage, confirm it fully or partially (Lisiński, 2016). The following limitations were adopted in the research process (Wood, 2008):

- the research area is limited to Polish and European data on fatal accidents, due to the availability of the necessary statistical data;
- statistical data refer to the years 2009-2018.

In order to achieve the goal, to solve the research problem, a number of research tasks were performed:

- review of specialist literature on telematics and its ever-wider possibilities;
- analysis of the questionnaire completed by GDDKiA experts presenting the assessment of the elements contributing to the fall in the accident rate at the turn of ten years;
- assessment of solutions and possibilities to improve road safety;
- comparative analysis of the number of road fatalities per million inhabitants in Poland and Europe - conclusions and recommendations.

Table 2. *Synthetic presentation of the characteristics of the use of the Delphi method in the analysed case*

Criterion	Case
Research mechanism	Delphi method
Period of testing	X-XII 2020
Number of experts involved	21
Detailed methods used	Survey, questionnaire consisting of 11 questions
Form of communication	E-mail, interview

Source: *Own study based on the interviews carried out.*

The Delphi method presented in Table 3 was used to achieve the objective of the work (Matejun, 2012, Xu, Li, and Tang, 2007; Goicoechea, Nelson, and Truszkowski, 1987) The purpose of the research was to collect opinions of independent experts, constituting the basis for identifying the impact of the changing road infrastructure, ITS systems used and the increasing number of vehicles on Polish roads on road safety and reduction of accidents.

The general research mechanism using the Delphi method is based on four foundations and includes (Plummer and Armitage, 2007):

(1) a group of participants (experts) deliberately selected for their expertise related to the issue under study,
(2) a process of multiple interactions thanks to which experts' opinions are discovered and unanimity is achieved,
(3) feedback applied to participants, aimed at interaction and reflection,
(4) opinions generated by experts that contribute to solving a given problem or predicting the future. (Gnatzy, Warth, von der Gracht, Darkow, 2011).

The aim of the study was to answer the question: what is the impact of the quality of infrastructure and the number of vehicles on European roads on improving road safety. Are the existing telematics solutions helpful in reducing road fatalities?

Over the period of three months (October-December 2020), the author conducted research using the Delphi method to verify the question posed. The research technique adopted at work was surveying. For this purpose, a questionnaire tool was used – the questionnaires were addressed to a group of 21 experts working in the General Directorate for National Roads and Motorways. The questionnaire consists of 11 questions, including a record and a part assessed using the Likert scale, which was designed to measure the varying degree of agreement with a given statement.

The use of the Delphi method in empirical practice is associated with the observance of appropriate methodological rigors and the adoption of an appropriate research procedure. (Weber, 1990; Brzozowski, Kopczyński, and Przekiczka, 2001).

The conclusions that resulted from literature studies, available research conducted by Polish and European research centres, as well as on the basis of the analysed expert surveys, became the basis for verifying the answers to the questions about road safety posed in the article. Tables, figures and charts were used to make appropriate comparisons and statistical analyses of the obtained research results.

The goal adopted in the article has been achieved. The variables were characterized by cardinality (N), standard deviation (SD), minimum value, lower quartile value (Q1), below (or equal to) 25.0% of observations, median – value the average, below (or equal to) 50,0% of the observations, the value of the upper quartile, below (or

equal to) 75.0% of the observations, and the maximum value. The percentage of people choosing a particular assessment of a given answer variant is also presented. All calculations were made with the R package, version 3.5.3.

Figure 1. *Graphical structure of the research sample*

Source: *Own research.*

4. Data Analysis and Findings

Road safety systems are some of the key solutions aimed at increasing road safety. In recent years, including thanks to the development of safety improvement systems, a decrease in the number of accidents in Poland can be noticed. The development of information technology allows for more and more advanced systems that can control more aspects affecting the safety of road users.

The variables were characterized by cardinality (N), standard deviation (SD), minimum value, lower quartile value (Q1), below (or equal to) 25.0% of observations, median – the average value, below (or equal to) 50.0% of the observations, the value of the upper quartile, below (or equal to) 75.0% of the observations, and the maximum value. The percentage of people choosing a particular assessment of a given answer variant is also presented.

Important information is constituted by the answers to the following question included in the questionnaire: How do you assess what contributed to the decrease in fatal accidents on Polish roads in 2008-2018? The assessment used a Likert scale from 1-7 points, 1-insignificant, 7- very significant.

The largest percentage of respondents (52.4%; N = 11) assessed the better quality of roads in Poland as a very significant factor (7 points) in the context of its impact on the decrease in the number of fatal accidents on Polish roads in 2008-2018. The next factors most often indicated as the most important in the context of the decrease in the number of fatal accidents on Polish roads in 2008-2018 were the increased number of motorways and the improvement of road infrastructure. Both factors were assessed as the most important by 9 respondents (42.9%). The factor with the lowest median rating (4) were restrictions in legal regulations.

The studies show that experts have proved that better road quality, improvement of road infrastructure and an increased number of motorways have the greatest impact on the decline in fatal accidents on Polish roads in the 10-year period of 2008-2018. The next question of the questionnaire is: Which of the following safety systems have the greatest impact on improving road safety in Poland?

The largest number of respondents (28.6%; N=6) indicated speed surveillance cameras as the safety system most influencing the improvement of road safety in Poland. The next most frequently indicated as the most important system was traffic control and traffic management on expressways in cities. Both these factors were indicated as the most important by 4 (19%) respondents. The smallest number of respondents indicated road incident management systems as the most important. This system was indicated by only three people.

Table 3. *Distributions of responses to selected questions in the questionnaire – question 2*

Question	Answer	Parameter/rating	Total (N=26)
Which of the following safety systems have the greatest impact on improving road safety in Poland?	Traffic control	N	21
		3	4.8% (N=1)
		4	14.3% (N=3)
		5	33.3% (N=7)
		6	28.6% (N=6)
		7	19% (N = 4)
		Median (IQR)	5 (5 - 6)
		Scope	3 - 7
	Traffic management on highways in cities	N	21
		3	9.5% (N=2)
		4	23.8% (N=5)
		5	28.6% (N=6)
		6	19% (N = 4)
		7	19% (N = 4)
		Median (IQR)	5 (4 - 6)
		Scope	3 - 7
	Road incident management system	N	21
		2	4.8% (N=1)
		3	9.5% (N=2)
		4	14.3% (N=3)
		5	38.1% (N=8)
		6	19% (N = 4)
		7	14.3% (N=3)
		Median (IQR)	5 (4 - 6)
		Scope	2 - 7
	Speed surveillance cameras	N	21
		1	4.8% (N=1)
		3	4.8% (N=1)
		4	9.5% (N=2)

	5	9.5% (N=2)
	6	42.9% (N=9)
	7	28.6% (N=6)
	Median (IQR)	6 (5 - 7)
	Scope	1 - 7

Source: *Own research.*

Another question from the questionnaire was: What impact do you think the increasing number of cars on Polish roads have on road safety every year? The largest number of people (76.2%; N = 16) participating in the survey replied to the negative impact of the annual increase in the number of cars on the safety of Polish roads. Two people described this impact as significant. Two people also replied that the increasing number of cars was irrelevant to road safety. One person, giving a more comprehensive answer, pointed out that cars have more and more safety systems and the improvement in the age of vehicles in use.

Table 4. *Distributions of respondents' answers to the next question in the questionnaire*

Question	Answer	Total (N=26)
What impact do you think the increasing number of cars on Polish roads have on road safety every year?	Negative	76.2% (N=16)
	Has no impact	9.5% (N=2)
	Vehicles have more and more safety systems. The age of the vehicles in use is improving.	4.8% (N=1)
	Significant	9.5% (N=2)

Source: *Own research.*

As can be seen from the above distribution of responses, the increasing number of cars on Polish roads every year has a negative impact on safety. Another important question that should be presented is: Do you think that road safety is influenced by the improvement of road infrastructure capable of handling traffic with higher traffic capacity between the largest Polish cities? All experts answering this question agreed with the statement that road safety is influenced by the improvement of road infrastructure capable of handling traffic with greater traffic capacity between the largest Polish cities.

Table 5. *Distributions of experts' answers to a given question of the questionnaire*

Question	Answer	Total (N=26)
Do you think that road safety is influenced by the improvement of road infrastructure capable of handling traffic with greater traffic capacity between the largest Polish cities?	Yes	100% (N = 21)

Source: *Own research.*

And another question from the questionnaire: What do you think, which of the above-mentioned factors have a significant impact on improving road safety in Poland?

The highest percentage of people answering this question (42.9%; N = 9) described the length of motorways and the number of cars on roads as very important factors (7 points) in the context of their impact on improving road safety in Poland. The next most frequently mentioned factors were the driving culture of drivers and the efficiency of cars, indicated by 33.3% and 381% of the respondents, respectively. The factor which was indicated by the least number of people were penalties for drivers not complying with the road traffic regulations, indicated by only 9.5% (N = 2) of the respondents.

Below are the experts' answers to the question about telematics solutions: What do you think, which of these telematics solutions have a significant impact on increasing road safety in Poland? The largest number of experts (42.9%; N = 9) identified information for drivers while driving as the most important in terms of its impact on increasing road safety. Six experts (28.6%) indicated accident actions management, infrastructure maintenance management and intelligent intersections as solutions with a very significant impact on increasing road safety. The factor that was indicated as a factor of very significant importance (7 points) by only 2 (9.5%) persons was anti-collision immune systems.

Another question for the experts concerned the tools to improve road safety. The highest percentage of experts answering this question (38.1%; N=8) described speed measurement on a selected section as the most effective safety improvement tool. Seven experts (33.3%) described red light sensors and segmental speed measurement as the most effective (7 points). One expert (4.8%) assessed the most effective factor as vehicle recognition and tracking and maintenance-free control of vehicle access to parking lots and separate zones.

Table 6. *Distribution of expert answers for the question of effective repair tools*

Question	Answer	Parameter/rating	Total (N=26)
Which do you think are the most effective security enhancement tools?	Red light sensors	N	21
		2	4.8% (N=1)
		3	9.5% (N=2)
		4	4.8% (N=1)
		5	23.8% (N=5)
		6	23.8% (N=5)
		7	33.3% (N=7)
		Median (IQR)	6 (5 - 7)
		Scope	2 - 7
	Vehicle speed measurement on a selected road section	N	21
		3	4.8% (N=1)
		4	4.8% (N=1)
		5	23.8% (N=5)
		6	28.6% (N=6)
		7	38.1% (N=8)
		Median (IQR)	6 (5 - 7)
		Scope	3 - 7
		N	21

Supporting the functioning of intersections in terms of traffic intensity	4	19% (N = 4)
	5	14.3% (N=3)
	6	57.1% (N=12)
	7	9.5% (N=2)
	Median (IQR)	6 (5 - 6)
	Scope	4 - 7
Vehicle recognition and tracking	N	21
	2	4.8% (N=1)
	3	9.5% (N=2)
	4	19% (N = 4)
	5	28.6% (N=6)
	6	33.3% (N=7)
	7	4.8% (N=1)
	Median (IQR)	5 (4 - 6)
	Scope	2 - 7
Maintenance-free vehicle access control to parking lots and separate zones	N	21
	2	9.5% (N=2)
	3	4.8% (N=1)
	4	23.8% (N=5)
	5	28.6% (N=6)
	6	28.6% (N=6)
	7	4.8% (N=1)
	Median (IQR)	5 (4 - 6)
	Scope	2 - 7
Sectional speed measurement	N	21
	4	19% (N = 4)
	5	14.3% (N=3)
	6	33.3% (N=7)
	7	33.3% (N=7)
	Median (IQR)	6 (5 - 7)
	Scope	4 - 7
Overloaded vehicles detection	N	21
	2	4.8% (N=1)
	3	4.8% (N=1)
	4	4.8% (N=1)
	5	38.1% (N=8)
	6	23.8% (N=5)
	7	23.8% (N=5)
	Median (IQR)	5 (5 - 6)
	Scope	2 - 7
Variable information arrays	N	20
	4	25% (N=5)
	5	10% (N = 2)
	6	50% (N = 10)
	7	15% (N=3)
	Median (IQR)	6 (4.75 - 6)
	Scope	4 - 7
Variable message traffic signs	N	21
	3	4.8% (N=1)
	4	23.8% (N=5)

	5	19% (N = 4)
	6	42.9% (N=9)
	7	9.5% (N=2)
	Median (IQR)	6 (4 - 6)
	Scope	3 - 7
An alarm to inform the services about a road accident	N	21
	2	4.8% (N=1)
	4	14.3% (N=3)
	5	23.8% (N=5)
	6	23.8% (N=5)
	7	33.3% (N=7)
	Median (IQR)	6 (5 - 7)
	Scope	2 - 7

Source: *Own research.*

The experts' answers to the next question of the survey are described below: How much (in how many%) can the number of fatal accidents in Poland be reduced thanks to artificial intelligence used in cars? The largest percentage of experts (27.3%; N=6) identified the possibility of reducing the number of fatal accidents in Poland thanks to artificial intelligence used in cars as 31-40% and 41-51%. Only two described this possibility as 51-60%.

Table 7. *Distributions of respondents' answers to the next question*

Question	Answers	Total (N=26)
How much (how many%) can the number of fatal accidents in Poland be reduced thanks to artificial intelligence used in cars?	from 5-20%	13.6% (N=3)
	from 31-40%	27.3% (N=6)
	from 41-50%	27.3% (N=6)
	from 51-60%	9% (N=2)
	from 61-70%	22.7% (N=5)

Source: *Own research.*

The last of the questions discussed is as follows: In what percentage do you think the accident rate in Poland is influenced by bad road surface? The highest percentage of experts (32%; N=7) defined the impact of poor road surface on the accident rate in Poland as 21-30%, as shown in the table below.

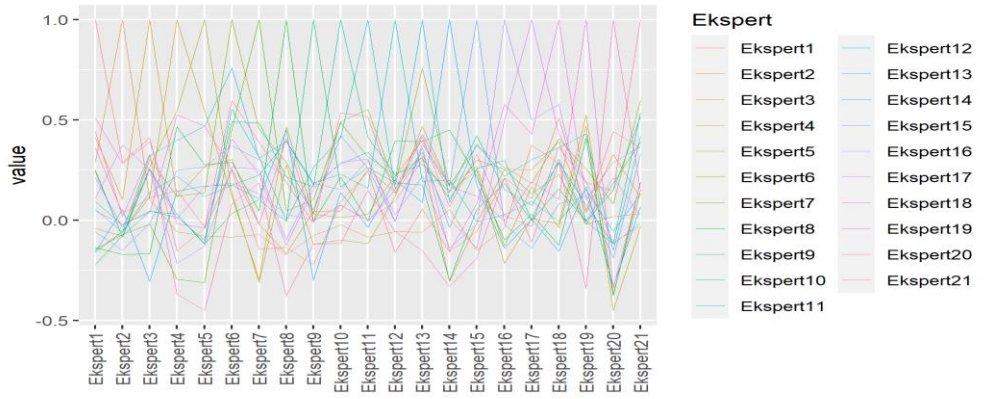
Table 8. *Distributions of respondents' answers to the question about the impact of poor road surface on accident rates in Poland*

Question	Answers	Total (N=26)
In what percentage do you think the accident rate in Poland is influenced by poor road surface?	from 5-10%	22.7% (N=5)
	from 11-20%	13.6% (N=3)
	from 21-30%	32% (N=7)
	from 31-40%	9.5% (N=2)
	od 56-60%	4.5% (N=1)
	from 61-70%	4.5% (N=1)
	from 71-80%	13.6% (N=3)

Source: *Own research.*

Below, an analysis of the correlation between the results obtained by the experts is undertaken.

Figure 2. *Values of correlation coefficients between the responses of individual experts*



Source: *Own research.*

5. Results

According to the conducted research (Mann-Whitney U test; p <0,001), the number of fatalities in car accidents per million inhabitants over the years 2009-2018 was significantly higher in Poland than the number of fatalities in other European countries. On average, in a year, almost 90 people died on the roads for every million of its inhabitants, while in other European countries the rate was 51.3 victims / 1 million people.

Table 9. *The results of the analysis of fatal accidents in Poland and other European countries*

Variable	Parameter	Total (N=20)	Europe (N = 10)	Poland (N = 10)	test	p-value
Number of fatalities / 1 million population	N	20	10	10	U Mann - Whitney	**<0,001**
	Average (SD)	70.48 (22.89)	51.32 (6.45)	89.63 (15.79)		
	Median (IQR)	69.4 (48.06 - 84.21)	47.89 (47.06 - 54.92)	85.21 (77.01 - 99.22)		
	Scope	45.59 - 119.79	45.59 - 65.15	73.66 - 119.79		

Source: *Own research.*

Trend lines for the number of car fatalities for Poland and other European countries are presented below.

Figure 3. *Number of fatalities in car accidents in Poland and other European countries*

Source: *Own research.*

In 2018, there were around 25,100 road fatalities in the EU-28. This is a decrease of 21% compared to 2010 and 1% compared to 2017. With an average of 51 road deaths per million inhabitants, it can be confirmed that the roads are by far the safest in the world. The EU countries with the best road safety results in 2018 are the United Kingdom (28 deaths / million inhabitants), Denmark (30 / million), Ireland (31 / million) and Sweden (32 / million). Countries with a higher-than-average decrease in the number of fatalities from 2017 to 2018 are Slovenia (-13%), Lithuania (-11%), Bulgaria (-9%) and Slovakia and Cyprus (both -8%). The countries with the highest mortality rates are Romania, Poland, Bulgaria, Latvia and Croatia.

6. Discussion

Technological progress is a necessary factor in enabling development. Vehicles have come a long way when it comes to evolution. They gained modern technological solutions in order to improve safety. They underwent processes of strengthening their structure in an attempt to reduce the mass. The technological development of mankind significantly influenced the faster process of changes in safety systems.

To improve safety, solutions such as the Global Automotive Assistant will require a large technological background that will serve as the vehicle's senses to assess the situation. (Dimitrakopoulos, Uden, Varlamis, 2020) The most important elements of such equipment are:

● artificial intelligence module – artificial intelligence supports the driver in adjusting the safe speed and distance between vehicles. A global network that would connect each vehicle allows the route to be suggested in order to optimize it. In the future, when cars will become fully autonomous, this will allow vehicles to travel at speeds previously not allowed on the roads.
● proximity sensors – the most important element of the car's equipment, right after the artificial intelligence module. The optimal number of sensors in the entire vehicle is 16 pieces and placed 4 each on each side of the vehicle will reduce the blind spot effect where the sensors would not be able to detect an object approaching the vehicle. Sensors located on the front and rear of the vehicle would detect an approach of less

than 1.5 meters, while sensors located on the sides of the vehicle would detect an approach of 0.5 meters, allowing the use of an additional safety system.
● radar – located at the front of the vehicle, used to detect pedestrians without reflective elements The radar's operating range would be 250 meters, which is a sufficient distance to allow time for the driver to react in order to avoid a collision.
● internet module – an essential element for connection with weather databases and communication between other vehicles. Supported by the satellite internet network, the infrastructure of which is already being developed (Kim *et al.,* 2017).

In order to implement appropriate measures influencing the improvement of road safety, systematic studies, analyses and assessments of road safety are carried out (Capanni *et al.,* 2018). An example of the activities undertaken is research and analysis of the behaviour of road users (Smith, 2006). Thanks to subsidies from the European Union, Poland has built many hundreds of kilometres of new roads, and has been given the opportunity to reconstruct and modernize the existing ones.

According to preliminary data published by the European Commission, fewer people died on EU roads in 2019 compared to previous years. It is estimated that 22,800 people died in road accidents in 2018, almost 7,000 fewer fatalities than in 2010 - a decrease of 23%. Compared to 2018, this number decreased by 2%. Although there are currently around 60 million more cars on our roads than in 2001, the number of accidents has still significantly decreased. The European Union also has the safest roads in the world, with 51 deaths per million annually, while the world average is 174 fatalities.

While the Member States' road safety performance is increasingly converging, the worst performing country still has four times more road fatalities than the best. Roads in Sweden (22 deaths / million inhabitants) and Ireland (29 / million) turned out to be the safest, while Romania (96 / million), Bulgaria (89 / million) and Poland (77 / million) recorded the highest death rates in 2019. The EU average was 51 deaths per million inhabitants.

Some countries have made great progress: Greece, Spain, Portugal, Ireland, the three Baltic countries (Latvia, Lithuania and Estonia) and Croatia have recorded an above-average reduction in road fatalities 30-40% in 2020). The reduction in the number of fatal accidents may be related to changes in the habits of drivers who have gradually adopted a safe driving style, maintaining safe distances between vehicles as well as the overall driving culture. The falling statistics in various European countries are covered by the improvement of infrastructure and changes in fines provided for drivers not complying with the road traffic regulations.

7. Conclusions

The changes taking place on the global market create the need for the most effective use of this mode of transport by creating modern transport systems, modernizing

means of transport and improving the operation of road infrastructure. Increasing the level of road safety requires, first of all, a broader view and taking actions at various levels of management. Basic action should be aimed at reducing the number of road accidents, largely consisting in pursuing a strong transport policy aimed at limiting car traffic in cities as well as in rural areas. (Raczyńska-Buława, 2016) Modern telematics and IT systems are a great opportunity. The use of intelligent transport systems brings positive effects in every aspect. From improving the capacity of urban roads, through improving road safety (e.g., collision prevention), reducing carbon dioxide emissions to the environment, to increasing the detection of traffic crimes (Kozerska *et al.*, 2018).

The benefits of using IT systems in road transport, consisting in increasing road safety on Polish and European roads, have been confirmed by comparing the number of fatalities in car accidents per million inhabitants over the period 2009-2018. The data obtained from the study clearly confirms the thesis about the positive impact of ITS use on road safety. The statistical data presented in the article show that the process of reducing the number of road accidents is very difficult. Despite the actions already taken related to the implementation of modern solutions and despite the ongoing research in the field of road safety, the number of accidents still remains at a fairly high level.

References:

Bergel-Hayat, R., Żukowska, J. 2015. Road Safety Trends at National Level in Europe: A Review of Time-series Analysis Performed during the Period 2000-2012. Transport Reviews, 35(5), 650-671.

Brzozowski, M., Kopczyński, T., Przeniczka, J. 2001. Metody organizacji i zarządzania. Materiały do ćwiczeń, Wydawnictwo AE w Poznaniu, Poznań, 169.

Cafiso, S., D'agostino, C., Kieć, M., Pappalardo, G. 2017. Wykorzystanie danych z kontroli bezpieczeństwa ruchu drogowego jako pośredniej miary bezpieczeństwa- badania na polskich drogach, Roads and Bridges - Drogi i Mosty 16, 115-130.

Capanni, L., Berzi, L., Barbieri, R., Capitani, R. 2018. A method to assess and model the risk for road accidents using telematics devices. Journal of Transportation Safety & Security, 10(5), 429-454.

Dimitrakopoulos, G., Uden, L., Varlamis, I. 2020. ITS standardization bodies and standards. The Future of Intelligent Transport Systems, 157-163.

Gnatzy, T., Warth, J., von der Gracht, H., Darkow, I.L. 2011. Validating an innovative real-time Delphi approach - A methodological comparison between real-time and conventional Delphi studies. Technological Forecasting and Social Change, 78(9).

Goicoechea, A., Nelson, R.W., Truszkowski, W. 1987. A Decision-Support System for Systems Engineering and Management: The SEMS Experiment at NASA. In: Y. Sawaragi, K. Inoue and H. Nakayama (Eds). Toward Interactive and Intelligent Decision Support Systems. Lecture Notes in Economics and Mathematical Systems, 286(71-79) Springer, Berlin: Heidelberg.

https://ec.europa.eu/transport/media/news/2020-06-11-road-safety-statistics-2019_en.

https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/2015_round_tables/canard.pdf.
https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/vademecum_2018.pdf.
https://roadsafetyfacts.eu/road-safety-what-progress-has-been-made/.
Huddart, K.W. 2003. Traffic control. In Advances in Mobile Information Systems. Edited by: Walker, J. 140-153. Boston: Artech House.
Kaleta, A., Moszkowicz, K. 2006. Plan operacyjny foresight. Projekt badawczy: Priorytetowe technologie dla zrównoważonego rozwoju województwa podkarpackiego. Politechnika Rzeszowska, Rzeszów, 30.
Kim, J., Canny, J. 2017. Interpretable Learning for Self-Driving Cars by Visualizing Causal Attention. IEEE International Conference on Computer Vision.
Kociolek-Pęksa, A. 2014. O reżimie prawnym zarządzania pasem drogowym i drogami publicznymi - wybrane uwagi. Kwartalnik Kolegium Ekonomiczno-Społecznego „Studia i Prace" nr 17, 20.
Komunikat Komisji do Parlamentu Europejskiego, Rady, Europejskiego Komitetu Ekonomiczno-Społecznego i Komitetu Regionów „W kierunku europejskiego obszaru bezpieczeństwa ruchu drogowego: kierunki polityki bezpieczeństwa ruchu drogowego na lata 2011–2020", Bruksela.
Kot, S., Ślusarczyk, B., Marczyk, B. 2014. Identification of Information Systems Application in Road Transport Companies in Silesia Region. TST 2014: Telematics - Support for Transport, 273-283.
Kowalewski, M., Pękalski, A., Siergiejczyk, M. 2014. Normalizacja współpracy inteligentnych systemów transportowych w pojazdach. Roads and Bridges - Drogi i Mosty 13, 357.
Kozerska, M. 2017. Systemy GPS jako element telematyki w działalności transportowej. Zeszyty Naukowe Wydziału Ekonomicznego Uniwersytetu Gdańskiego Ekonomika Transportu i Logistyka, Nr 74.
Łacny, J. 2008. Systemy telematyczne i informatyczne nowoczesnych przedsiębiorstwach transportu drogowego. Wydawnictwo Polskiego Kongresu Logistycznego, Poznań.
Linstone, H.A., Turoff, M. 1975. The Delphi Method: Techniques and Applications., Addison-Wesley, New Jersey Institute of Technology.
Matts-Åke, B., Tillgren, P., Vedung, E. 2012. Vision Zero – a road safety policy innovation. International Journal of Injury Control and Safety Promotion, 19(2), 171-179.
Mbiydzenyuy, G., Persson, J.A., Davidsson, P. 2012. Optimization Analysis of Multiservice Architecture Concepts in Road Transport Telematics. Journal of Intelligent Transportation Systems Technology, Planning, and Operations, 16(4).
Partnership for a Walkable America. Walkability Checklist. Transportation (Amst). 2002.
Pell, A., Nyamadzawo, P., Schauer, O. 2016. Intelligent transportation system for traffic and road infrastructure-related data. International Journal of Advanced Logistics, 5(1), 19-29.
Plummer, R., Armitage, D.R. 2007. Charting the New Territory of Adaptive Co-management: A Delphi Study, Ecology and Society, 12(2, 3).
Polityka Transportowa Państwa na lata 2006-2025. 2005. Ministerstwo Infrastruktury. Warszawa.
Ran, B., Jin, J.P., Boyce, D., Qiu, T.Z., Cheng, J. 2012. Perspectives on Future Transportation Research: Impact of Intelligent Transportation System Technologies on Next-Generation Transportation Modeling. Journal of Intelligent Transportation Systems Technology, Planning, and Operations, 16(4), 226-242.

Raczyńska–Buława, E. 2016. Bezpieczeństwo w ruchu drogowym w Europie – założenia polityki UE i ocena podejmowanych działań z perspektywy danych statystycznych. Autobusy, 10, 8-9.

Road safety 2018. How is your country doing? https://op.europa.eu/en/publication-detail/-/publication/f483a9a9-0b50-11ea-8c1f-01aa75ed71a1.

Smith, B.L., Venkatanarayana, R. 2005. Realizing the Promise of Intelligent Transportation Systems (ITS) Data Archives. Journal of Intelligent Transportation Systems Technology, Planning, and Operations, 9(4), 175-185.

Szumska, E., Jurecki, R., 2020. The Effect of Aggressive Driving on Vehicle Parameters. Energies, 13(24).

Thomas, P., Morris, A., Yannis, G., Lejeune, P., Wesemann, P., Vallet, G. 2005. Designing the European road safety observatory. International Journal of Injury Control and Safety Promotion, 12(4), Injury Research Methods and Measuring the Burden of Injury, 251-253.

Wood, R.E., Goodman, J.S., Beckmann, N., Cook, A. 2008. Mediation testing in management research: A review and proposals. Organizational Research Methods, 11(2), 270-295.

Wydro, K.B. 2018. Usługi i systemy telematyczne w transporcie. Telekomunikacja i Techniki Informacyjne, nr 3-4.