



IMPACT OF SELECTED ROAD INVESTMENTS ON TRAFFIC SAFETY

Piotr Rosik, Sławomir Goliszek

Institute of Geography and Spatial Organization

Polish Academy of Sciences

Twarda St. 51/55, 00-818 Warsaw, Poland

rosik@twarda.pan.pl, sgoliszek@twarda.pan.pl

Abstract. The study of influence, exerted by the road projects on road traffic safety was carried out on the basis of data, contained in the System of Registry of Accidents and Collisions (Polish acronym: SEWIK) for the years 2006-2012, and the questionnaire-based survey. The level of safety on the motorways and expressways, or, more broadly – on the separate traffic roads, is being assessed as much higher than on the remaining national roads. Construction of a motorway results in a significant drop in the number of persons harmed in the accidents over the connections between the cities considered. The fast traffic roads, including the ring roads, being the segments of expressways, significantly improve the safety over the routes of national roads, but do not entail any important change in the accident rates on other roads.

Keywords: road safety, road accidents, individual accident risk, traffic intensity.

Introduction

Road safety has been constituting for years an important element of numerous investment programs and the undertakings, aiming at the improvement of travelling conditions in Poland¹. The literature reviews on the traffic crashes, injuries or fatalities are, among other in Huges at al. (2015) and Novoa et al. (2009). The present paper considers the subject of road safety first of all in the context of road accidents, with special emphasis on deaths and injuries, associated with accidents.

Thus, a road accident is an event, having taken place in connection with traffic of vehicles over public roads, which resulted in a death or injury of a person. A fatality is the victim of an accident who died due to the injuries, having arisen from the accident, either on place, or during the next 30 days. The seriously injured persons are the ones, who became seriously handicapped, seriously incurably ill, or have been ill for a long time, their illness threatening their life, who have become seriously mentally ill, have become fully or significantly and permanently incapable of actively working in their profession, have undergone an essential deformation or disfiguring of the body, as well as those who suffered

¹ The paper presents the findings from the research project under the grant agreement no. NN 306 564940 financed with the resources from the National Science Center.

from injuries such as bone breaking, damages to internal organs, serious cut wounds and lacerations. On the other hand, the persons with minor injuries are all those, who suffered from a negative health effect different than defined for the seriously injured persons, such that the functioning of an organ or the general health deficiency, stated by a physician, lasted for at most seven days (these definitions being derived from the Ordinance No. 635 of the Commander In Chief of the Police, of June 30th, 2006, concerning the methods and forms of statistical reporting on road accidents). Then, a collision is an event, having taken place in surface traffic, caused by the involuntary infringement of the principles of safety, valid for the road traffic, having as consequence material losses.

The present study was conducted mainly on the basis of the data, contained in the accident reports and collected by the Road Traffic Bureau of the Police Headquarters in the framework of the System of Registry of Accidents and Collisions (Polish acronym SEWIK) for the years 2006–2012. In this manner, the road number and the kilometre, as well as the hectometre, within which the road event took place, having the form of a road accident (for the detailed analysis of accidents for A1 motorway over the segment Swarozyn – Nowe Marzy node and for the parallel national road DK91, as well as the ring roads of Wyszaków and Garwolin) were obtained. An additional information base was constituted by the base of accidents and collisions in the years 2004–2012 according to municipalities, which constituted the foundation for the assessment of changes in the accident indicator (an indicator, WWiK, developed by the authors), having occurred in the period 2006–2012.

The role of infrastructure in the process of road safety improvement

One of the five objectives of the Strategy of Transport Development for the years 2007–2013 (with an outlook until the year 2030) (see *Strategia Rozwoju Transportu...* 2013) is exactly the “Safety in Road Traffic”. Then, the primary objective of the National Program of Road Safety for the years 2013–2020 (2013) is to limit the number of deaths and serious injuries in the accidents until the year 2020 by at least, respectively, 50% (i.e. down to 2 000) and 40% (i.e. down to 6 900). Generally, in Poland, the numbers of the accidents, persons injured, and persons killed in the accidents have been decreasing systematically, and in the perspective of the last dozen years we can speak of a very important advance in the domain of improvement of safety in road traffic (Fig. 1).

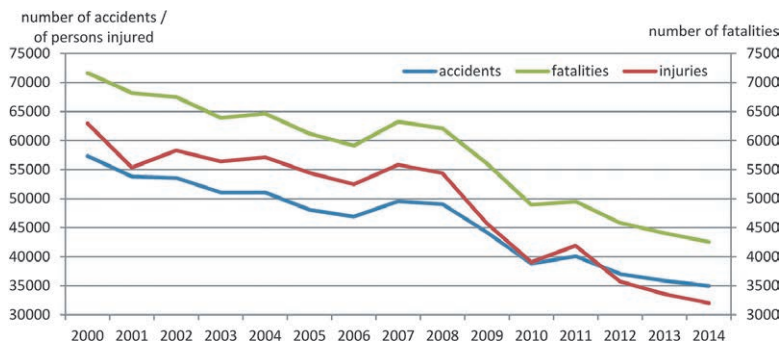


Figure 1. Numbers of road accidents, persons killed and injured in Poland in the years 2000–2012
Source: own elaboration on the basis of annual reports from the period 2001–2012, entitled Road accidents in Poland, Police Headquarters, Warsaw.

On the other hand, though, the remaining European countries noted in the recent decades even bigger advances. It ought to be emphasised that since 2007 Poland is the dishonourable leader among the countries of the European Union regarding the numbers of persons killed in road accidents. Thus, for instance, in 2011 the number of fatalities in road accidents in Poland amounted to 4 189 and was absolutely the highest in Europe, higher than in such much bigger countries as Germany, France, Italy, or United Kingdom. The mortality indicator, equal the number of road accident deaths per 1 million inhabitants is the highest in Poland (110), almost twice as high as the average for the European Union (60) (see Narodowy Program... 2013).

In the perspective of the international comparisons the risk of a road accident for an owner of a vehicle might also be calculated by dividing the number of accidents involving fatalities in a given country by the number of passenger vehicles, registered in this country. And so, among the European countries, in which more than 2 million vehicles are registered, the highest risk of a deadly accident is observed in Romania and Turkey (exceeding 0.05%). The value of this indicator in Poland is 0.023%, meaning that it is also relatively high compared to the majority of countries of Western Europe, where it usually does not exceed 0.015%. The risk of accident is negatively correlated with the share of motorways in the total length of roads (Fig. 2). This share ought to be calculated with respect to the joint length of the main and national roads. It is the highest in Switzerland, where as much as close to 80% of the main roads are the motorways, while it is the lowest in Norway, Romania and Poland, where – in 2009 – the share was lower than 5%.

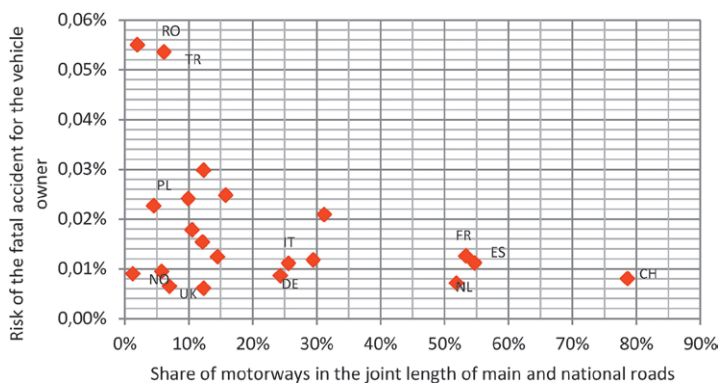


Figure 2. Risk of fatality for an owner of a vehicle vs. the share of motorways in the joint length of main and national roads in selected countries of Europe (based on the data for the years 2009–2010)
Source: own calculations on the basis of *EU transport in figures*, Statistical pocketbook 2012.

Construction and maintenance of a safe road infrastructure constitute, therefore, one of the basic (alongside with topographical conditions, urban pattern, weather conditions, vehicle population, numbers and individual characteristics of the traffic participants) factors, influencing road safety (Gaca 2002; Tracz & Gaca 1995). Safe road infrastructure is, as well, one of the four areas of concentration of activities, as forwarded and described in the National Program of Road Safety for the years 2013–2020 (2013).

The fact that traffic safety depends upon numerous factors makes it certainly difficult to draw general conclusions as to the interdependence between the outlays into the transport infrastructure and the level of safety, both for the entire country, and for the individual case studies. It is, however, suggested that the road itself and its surroundings account for 28–35% of the accident risk, while

motorways and expressways are, in this sense, the place of the lowest number of fatalities in road traffic (European Road Assessment Program EuroRAP www.eurorap.org). Thus, regarding Poland, in 2012 there were 16.7 accidents and 3.7 fatalities per 100 km of motorways and expressways, while for the remaining national roads the respective numbers were many times higher (218.7 and 20.8).

Taking into account the fact that yet in 2010 the average traffic intensity on the motorways was more than 23 000 vehicles / 24 hours, and on the expressways – 19 500 vehicles / 24 hours, while the analogous value for the national roads in total did not exceed 10 000 vehicles, it can be concluded that the probability of an accident for the participant of the traffic on a national road is roughly 25 times higher than on the motorway or the expressway, and the probability of fatality is approximately 15 times higher.

The lower ratio of probabilities for the fatality results from the fact that with higher speeds the share of fatalities in the overall number of accidents is correspondingly higher on the motorways and on the expressways than on the remaining road categories. The most frequent cause of accidents in Poland in the recent years on the motorways and expressways (as well as on other road categories) was excess speed. The shares of such accident reasons as lack of adequate distance between vehicles, tiredness, falling asleep, or irregular change of the lane, were much lower.

Besides, the fast traffic roads are increasingly safer in Poland. Despite the unprecedented increase of the share of the length of expressways and motorways in the total length of roads in Poland in the years 2004–2012 (from 4.3% to 12.3%), the share of the number of accidents on these roads increased only slightly – from 0.6% to 1.1%, while the analogous share of fatalities increased from 1.2% to 2.2% (Fig. 3).

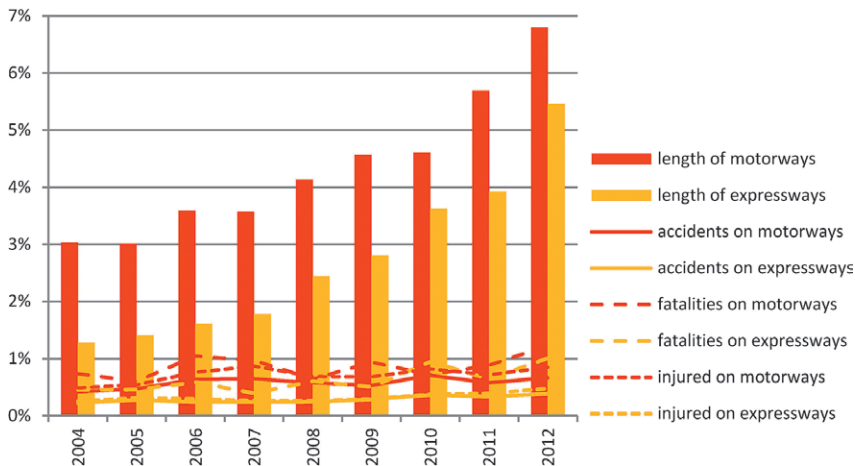


Figure 3. Shares of lengths, accident numbers, fatalities, and injured persons on the motorways and expressways in relation to the totals for the national roads in Poland in the years 2004–2012

Source: own elaboration on the basis of *Wypadki drogowe w Polsce* (Road accidents in Poland), Police Headquarters – cyclical publication, 2004–2012, and *Transport – wyniki działalności* (*Transport – activity effects*), annual publications for the years 2004–2012.

The accident and collision indicator WWiK

For purposes of analysing the data on accidents, the macro-indicators are applied, for global analyses, and the micro-indicators, that is, the indicators accounting for the traffic intensity, accident categories, as well as the lengths of network segments, serving to identify the dangerous locations (Gaca et al., 2008). Among the macro-indicators one can mention: the number of accidents per definite number of vehicles, the number of accidents per definite number of inhabitants, as well as the fatality indicator, that is – the number of deaths per 100 accidents. On the other hand, the micro-indicators include, in particular, the accident density indicator (the number of accidents per 1 km of the road), or the relative accident intensity indicator (the number of accidents per definite number of vehicle-kms during some period of time). Numerous other indicators are also being applied, accounting, in particular, for the costs of accidents (Gaca et al. 2008).

For purposes of analysis of the data on accidents in global considerations (e.g. at the national level) the macro-indicator (synthetic) approach was applied. One can distinguish among the macro-indicators those related to the number of accidents, persons killed, persons injured, as well as the collisions over a certain area (e.g. a municipality), related to the number of inhabitants of this area. Given that the unit cost, associated with an injured person is more than four times lower than the unit cost of the fatality (See *Instrukcja oceny efektywności ekonomicznej (...)* 2008), while the consequences of an accident (with injuries and/or deaths) are many times over worse than the consequences of a collision, the following accident and collision indicator (Polish acronym *Wskaźnik Wypadkowości I Kolizyjności WWiK*) was developed by the present authors:

$$WWiK_i = \frac{4 \cdot W_i + 8 \cdot Z_i + 2 \cdot R_i + K_i}{L_i}$$

where:

$WWiK_i$ – macro-indicator of accidents and collisions in municipality i ,

W_i – number of accidents in municipality i ,

Z_i – number of road fatalities in municipality i ,

R_i – number of injured persons in municipality i ,

K_i – number of collisions in municipality i ,

L_i – population number in municipality i .

Collection of information on road accidents is entrusted in OECD with IRTAD (*International Road Traffic and Accident Database*), while in Poland data collection is performed by the General Police Headquarters within the framework of the System of Registry of Accidents and Collisions (Polish acronym SEWIK). In the study here reported the source of data, concerning the numbers of accidents, fatalities, injured persons, and collisions, was constituted by the General Police Headquarters. The WWiK indicator was calculated for all the municipalities in Poland for the years 2004 and 2012. The changes in the values of the indicator were compared to the locations of the case studies.

A significant decrease was observed of the WWiK values (improvement of safety) for the areas of the majority of bigger towns (treated formally as urban counties), first of all in the large cities and in agglomerations. These areas do still dominate, of course, in the absolute numbers of accidents and collisions, but the situation in the domain of road safety improved there significantly, so that nowadays the share of the towns being counties in the totality of road accident fatalities is at 14% only, while the county and municipal roads outside of the towns-counties account for more than

30% (Narodowy Program... 2013). Situation worsened especially within the peripheral areas of the provinces, particularly so in the south-western part of the Warmian-Masurian province, and also within the peripheries of the provinces of Masovia and Lubusza. It is characteristic for the areas, where the situation worsened in terms of accidents and collisions, that they are located far from the main transport corridors. The case studies are placed within the areas where improvement took place concerning road safety in the years 2004–2012 (with exception of individual municipalities), this fact being reflected in the decrease of value of the WWiK indicator.

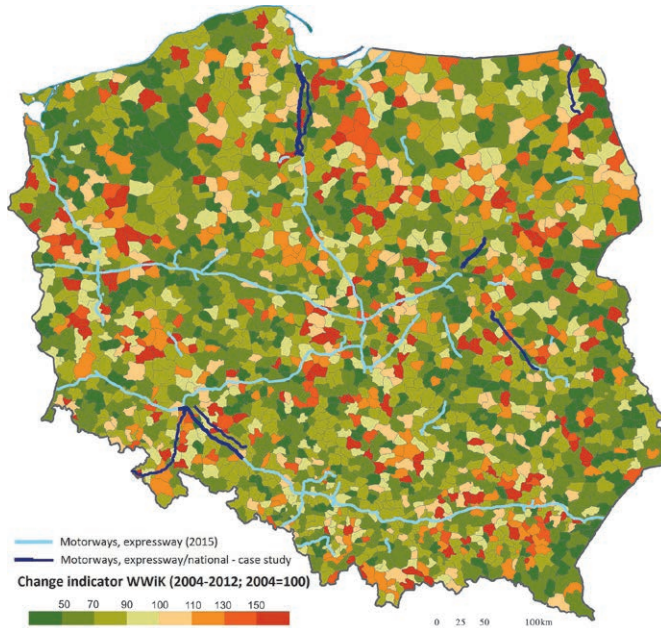


Figure 4. Changes in the value of the WWiK indicator in the years 2004–2012 against the background of the case studies

Source: own elaboration on the basis of data from SEWiK database.

Analysis of safety improvement in the framework of the case studies

The analysis of safety improvement in the framework of the case studies was carried out with the use of three methods of investigation:

- analysis of the questionnaire responses of the road users, that is – the inhabitants of the municipalities, in which the analysed road segments are situated;
- analysis of the numbers of accidents classified into categories for the connection between Tczew and Grudziądz in 12–6 months before and 6–12 months after the construction of the motorway A1 over the segment between the nodes of Swarozyn and Nowe Marzy;
- analysis of the numbers of accidents classified into respective categories in the municipalities of Wyszaków and Garwolin in the years 2006–2012 in the context of the newly constructed ring roads of these towns, with distinction of accidents occurring along the national road/expressway.

Survey of road safety among the road users

Responses, obtained from the road users are unequivocal in that the safety on the motorways (assessments at 4.28–4.90) and the expressways (4.49), that is – generally on the separate traffic roads, is held to be much higher than on the remaining national roads (assessments ranging from 1.95 for the national road no. 8 on the segment between Augustów and Suwałki, up to 3.36 on the national road no. 17 between Garwolin and Kurów). An especially low assessment of road safety was given by the inhabitants of municipality of Nowinka, located between Augustów and Suwałki. The overall assessment in this municipality amounted to 1.61, but for those residing in the direct vicinity of the road – to only 1.38. The respondents pointed out the nuisance, associated with the high traffic intensity, especially of the heavy loads, resulting in the increased hazard within the area of the municipality (Table 1).

Table 1. The level and the improvement of safety in the road corridors (case study areas)

Case study	Safety level according to survey responses (mean)	Changes in the value of the accident and collision indicator WWiK between 2004 and 2012 according to selected municipalities
A1 Pruszcz Gdański–Grudziądz	4.90	Improvement of safety along A1, except for two municipalities: Smętowo Graniczne and Morzeszczyn
DK 91 Pruszcz Gdański–Grudziądz	3.11	Improvement of safety along the national road DK91
A4 Wrocław–Opole	4.28	Improvement of safety, except for the municipalities of Kobierzyce and Żorawina, next to Wrocław
DK 94 Wrocław–Opole	3.36	Improvement of safety, except for the municipalities of Skarbimierz and Komprachcice
DK 8s Kudowa Zdrój–Wrocław	2.66	Improvement of safety, except for the municipalities of Kłodzko and Lewin Kłodzki
DK 8n Augustów–Budzisko	1.95	Improvement of safety over the entire segment considered
S8 Radzymin–Wyszaków	4.49	Improvement of safety over the entire segment considered
DK 17 Garwolin–Kurów	3.18	Improvement of safety, except for the municipality of Trojanów

Source: own elaboration on the basis of the questionnaire survey and data from SEWiK database.

The analysis of the data on the municipal level implies, though – with exception of single cases – that there has been, in the years 2004–2012, an improvement of safety along the road corridors considered. Thus, for instance, in the so poorly assessed by the inhabitants municipality of Nowinka, there were in 2012, according to the statistics, only 6 accidents, with just a single fatality. It is paradoxical that in 2012, among the rural municipalities in Poland, the highest number of fatalities was registered in the commune of Stryków (13 fatalities in 28 accidents), this fact being most probably associated with the important road works on the crossing of the motorways A2, A1, and DK 14.

Generally speaking, the selected case studies are characterised by a relatively wide range of accident risks. A part of the cases, with the separate traffic roads (motorways and expressways), are characterised by the low or very low individual risk, risk of running over a pedestrian, and risk

of head-on collision. On the other hand, traffic participants on the remaining roads, with two-way traffic, are in most cases exposed to high or even very high risk of accidents (Table 2).

Table 2. Distribution of accident risks in the years 2009-2011 according to selected categories of accidents and road segments

Case study	Individual risk*	Individual risk / running over a pedestrian	Individual risk / head-on collision
A1 Pruszcz Gdański-Grudziądz	Low	Very low	Very low
DK 91 Pruszcz Gdański-Grudziądz	Average/High	Very high/High	High/Average
A4 Wrocław-Opole	Low	Low	Very low
DK 94 Wrocław-Opole	High	Very high/High	Very high/High
DK 8s Kudowa Zdrój-Wrocław	High/Very high	Very high/High/Low	Very high/High
DK 8n Augustów-Budzisko	High	Very high	Average/Low
S8 Radzymin-Wyszków	Low	High	Very low
DK 17 Garwolin-Kurów	High / Low (ring road of Garwolin)	Very high/High	High/Very high/Very low (ring road of Garwolin)

	Dominating high or very high risk
	Dominating average risk
	Dominating low or very low risk

* Individual risk, measured with concentration of accidents, i.e. average risk of being killed or injured in a traffic accident on the national roads in Poland in the years 2009–2011. This risk concerns every individual user of the roads and is measured with the frequency of serious accidents on each segment of the road, related to the number of vehicles, which travel over this segment of the road during a year (the number of accidents with fatalities and injuries per 109 vehicle-kilometres of the road, covered by the vehicles).

Source: own elaboration on the basis of <http://www.eurorap.pl/>.

Analysis of the number of accidents before and after putting A1 motorway to use on the segment between the nodes of Swaróżyn (Tczew) and Nowe Marzy (Grudziądz)

The segment of the A1 motorway between Rusocin (Gdańsk) and Nowe Marzy (Grudziądz) was executed in two stages: the part between the nodes of Rusocin (Gdańsk) and Swaróżyn (Tczew), which started functioning in December 2007, and the part between the nodes of Swaróżyn (Tczew) and Nowe Marzy (Grudziądz), which started functioning in October 2008. The analysis of the number of accidents was carried out with the use of the SEWiK database and concerned the accidents, which occurred 12–6 months before, and 6–12 months after the segment Swaróżyn-Nowe Marzy started to function. The cartographic analysis of the locations and the character of accidents encompassed more than ten municipalities within the area considered (Fig. 5), while the detailed results, referring to the numbers of accidents, with distinction of the accident categories, concerned only two roads – the national road no. 1/91, and the motorway A1 (Fig. 6). The total numbers of victims of accidents having taken place between Tczew and Grudziądz were calculated for both roads (before A1 motorway was put to use, for obvious reasons this is the number of accidents for the half-year period only for the national road no. 1). Additionally, in order to represent the shift of the traffic flows over to the A1

motorway and the decrease of traffic intensity on the parallel national road, the changes in traffic intensity were visualised for the years 2005–2010 (Fig. 5, right-hand diagram).

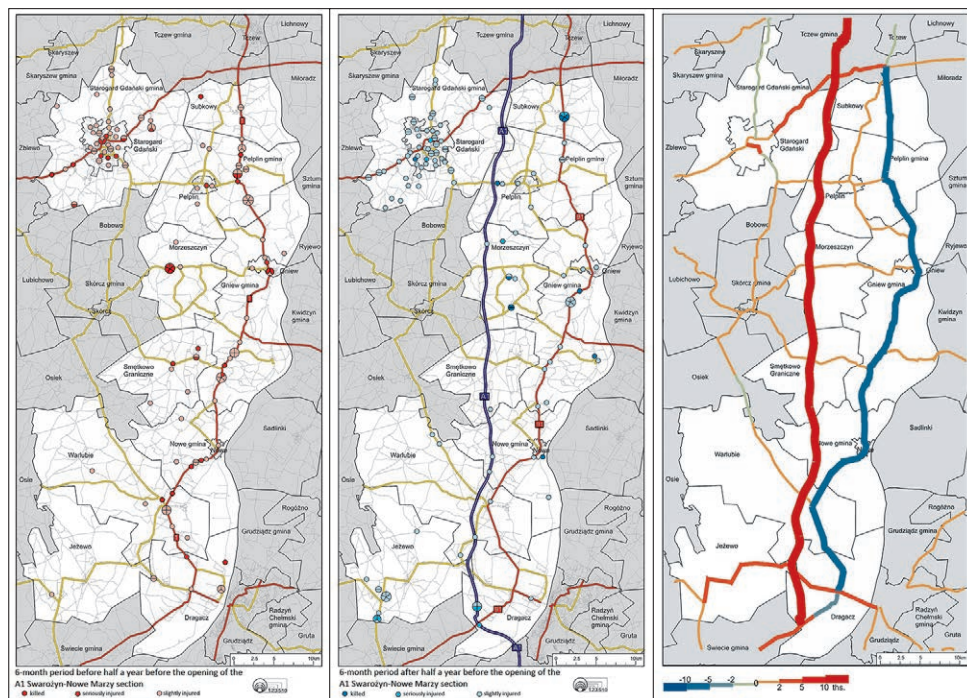


Figure 5. Locations and character of accidents within 12-6 months before and 6-12 months after the motorway A1 was put to use over the segment between the nodes of Swarozyn (Tczew) and Nowe Marzy (Grudziądz), along with the change in traffic intensity in the years 2005–2010
 Source: own elaboration on the basis of data from SEWiK database, and from GPR 2005 and GPR 2010.

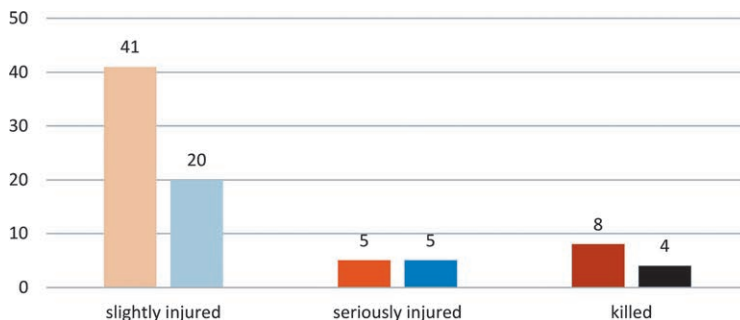


Figure 6. Total numbers of victims of accidents on the national road DK1/DK91 and on the motorway A1 between Tczew and Grudziądz
 Source: own elaboration on the basis of data from the SEWiK database.

The number of victims of road accidents having occurred between Tczew and Grudziądz on the motorway and the parallel national road is much lower than before the motorway had been put

to use. The difference concerns mainly the number of the slightly injured persons and the fatalities (decrease by half).

In addition to the here analysed case studies, an analogous situation took place also on the segments of the remaining motorways considered, constructed in the years 2000–2010, that is, for the segment of close to 50 km length of the A4 motorway between Zgorzelec and Krzyżowa (analysis of accidents on the motorway A4 and the parallel national road no. 94 up to the node of Krzywa), which started to function in 2009, and the segment of the motorway A2 between Konin and Koło, which was put to use in July 2006 (analysis of accidents on the motorway A2 and the parallel national road no. 92).

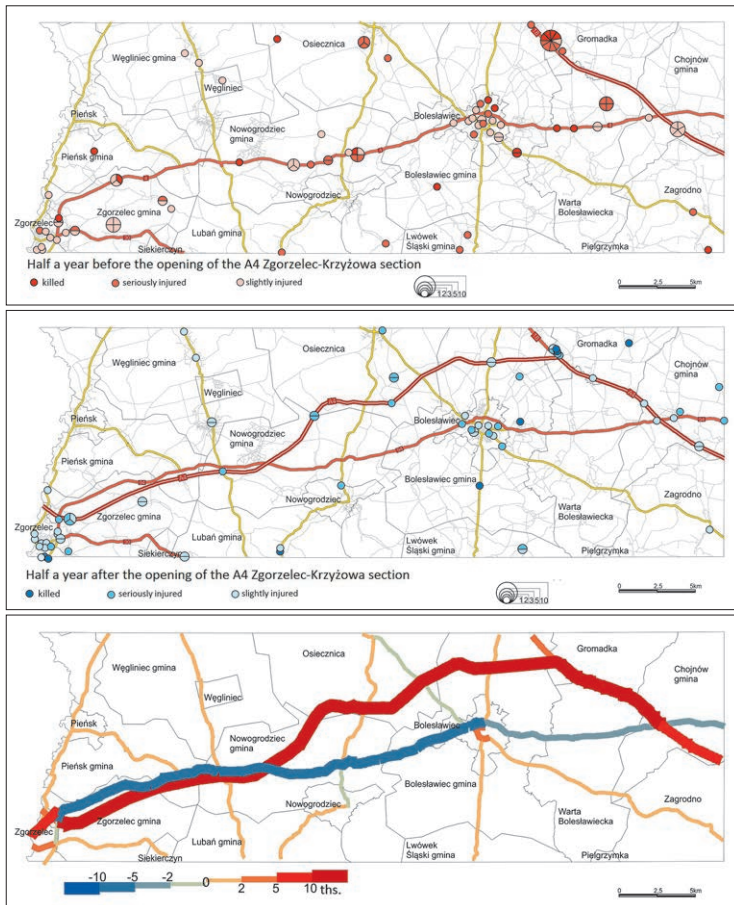


Figure 7. Location and character of accidents over 6 months before and 6 months after the motorway A4 was put to operation on the segment between the nodes of Zgorzelec and Krzywa, along with the change in traffic intensity in the years 2005–2010

Source: own elaboration on the basis of data from the SEWiK database and from GPR 2005 and GPR 2010.

In both cases the analysis of changes in the locations and numbers of accidents was complemented with the study of changes in traffic intensity in the period 2005–2010. The study of the changes in the numbers of accidents concerns the period of half a year before and half a year after the analysed segments of the road were put to operation (in distinction from the study of the fragment of A1 motorway Tczew–Grudziądz, which concerned the periods 12–6 months before and 6–12 months after putting this fragment to use). This was due to the fact that over a longer time period the study of accident numbers would overlap with the studies GPR 2005 or GPR 2010 (Fig. 7–10).

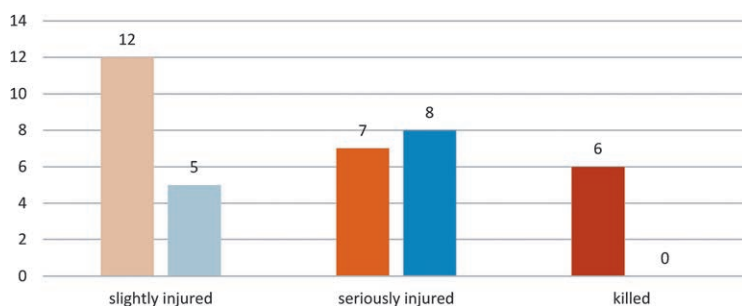


Figure 8. Total number of victims of accidents on the national road DK4/DK94 and the motorway A4 between Zgorzelec and Krzywa

Source: own elaboration on the basis of data from SEWiK database.

The total number of the persons being victims of accidents, having taken place between Zgorzelec and Krzywa on the motorway and on the parallel national road is also much lower after the motorway was put to use than before. The difference is particularly pronounced for the slightly injured persons and the fatalities.

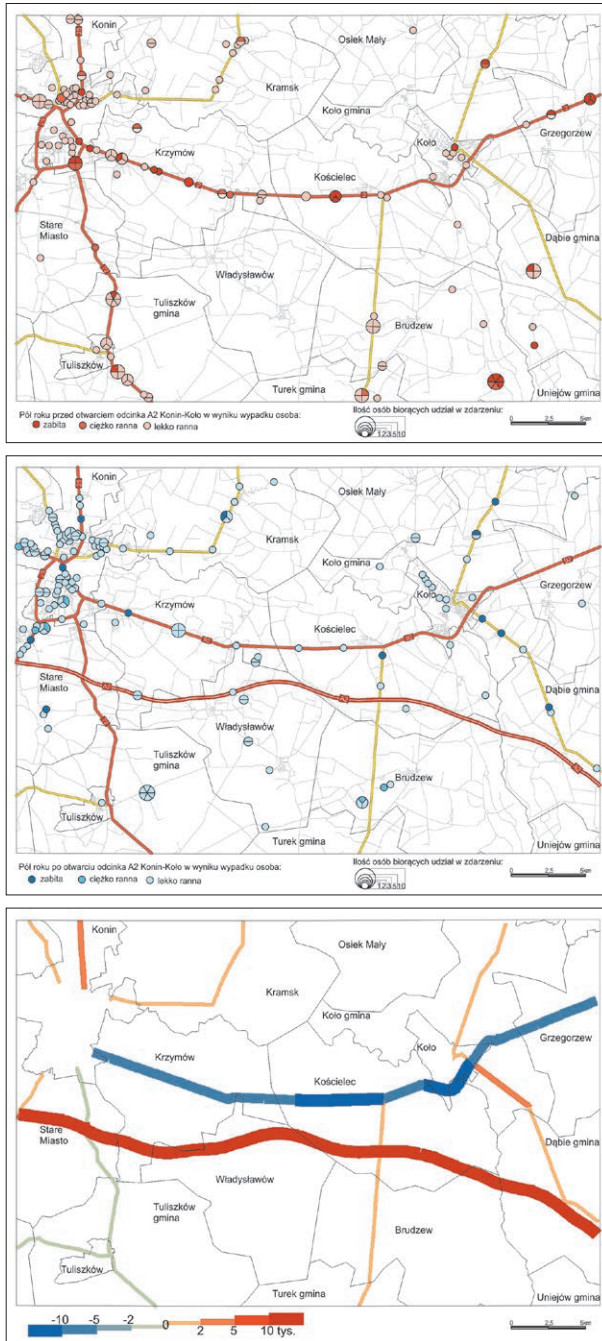


Figure 9. Location and character of accidents for 6 months before and 6 months after the motorway A2 was put to operation over the segment between Konin and Koło, along with the change in traffic intensity in the years 2005–2010

Source: own elaboration on the basis of data from the SEWiK database and from GPR 2005 and GPR 2010.

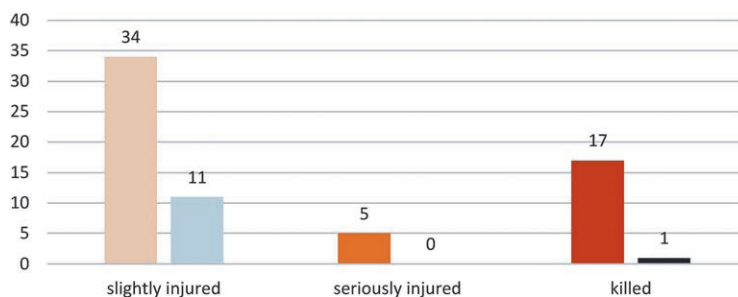


Figure 10. Total number of victims of accidents on the national road DK 2/DK 92 and the motorway A2 between Konin and Koło

Source: own elaboration on the basis of data from SEWiK database.

The number of persons being victims of road accidents between Konin and Koło on the motorway and on the parallel national road was, similarly as for the cases of connections between Tczew and Grudziądz (motorway A1) and between Zgorzelec and Krzywa (motorway A4), much lower after the motorway has been put into operation than before. In this case the difference is pronounced for all types of victims and the improvement in safety on the segment considered is, indeed, enormous.

Analysis of changes in road safety in the municipalities of Wyszaków and Garwolin after construction of the ring roads bypassing the municipal seats

The analysis of changes in road safety over the years 2006–2012 at the local level in the network perspective is made possible by the availability of data, concerning the road events, in the SEWiK database. An exemplary study was performed for two ring roads of the county seats in the province of Masovia – those of Wyszaków and Garwolin. These two ring roads constitute essential elements of two case studies: S8 Radzymin–Wyszaków, and DK17 Garwolin–Kurów. There are numerous common elements for the two ring roads considered (see Table 3).

Table 3. Similarities between the ring roads of Wyszaków and Garwolin

	National road route/ functional connection	Length of ring road (km)	Starting date	Traffic intensity/24 h (2010)		Road distance to Warsaw (km)
				Total traffic	Heavy loads	
Wyszaków ring road	DK 8/S8 Warsaw –Białystok–border with Lithuania	12.8	14.11.2008	13669-14854	1640-1893	60
Garwolin ring road	DK 17/S17 Warsaw –Lublin–border with Ukraine	12.8	26.09.2007	13009-13296	1458-1511	63

Source: own elaboration on the basis of GPR 2010.

The county seats, for which the analysed ring roads were constructed, are inhabited by similar population numbers (Wyszaków: 27 000, Garwolin: 17 000). The population number of the municipality of Wyszaków is at around 39 000, while the urban and rural municipalities of Garwolin are

inhabited by approximately 30 000 persons. These two areas were selected for the detailed analysis of accidents on their territories in the years 2006–2012.

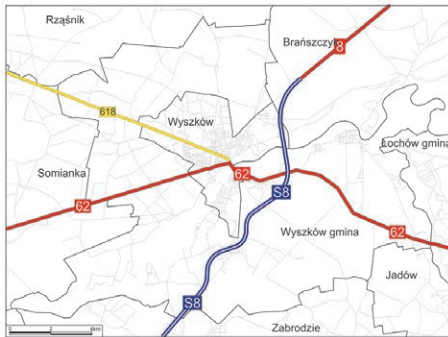


Figure 11. Wyszaków ring road and municipality
Source: own elaboration.

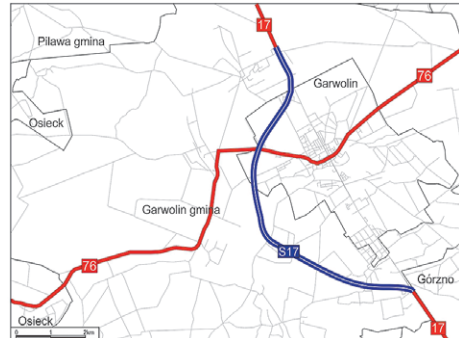


Figure 12. Garwolin ring road and municipality
Source: own elaboration.

It should also be added that both of these ring roads are situated close to the national roads: no. 62 (the ring road of Wyszaków crosses this road) and no. 50 (the ring road of Garwolin is situated a couple of kilometres to the south of this national road), these two national roads constituting the transit beltway of Warsaw. Charged with intensive heavy load traffic, with two-way traffic on quite long segments, this transit beltway of Warsaw is characterised by a very high individual accident risk. On the other hand, the new fragments of S8 and S17, similarly as the other separate traffic roads, significantly improve the safety, so that the accident risk is importantly lowered (Fig. 13).

Thus, two municipalities were selected for the detailed study of the road safety level, the two municipalities being traversed by the ring roads in question: the municipality of Wyszaków, and the double (urban and rural) municipality of Garwolin. In order to separate the accidents, which took place in direct connection with the analysed investment projects, a distinction was made between the events having occurred along the course of the national roads DK8/S8 (for Wyszaków) and DK17/S8 (for Garwolin) (both on the ring road proper and along the route through the town – Białostocka and Warszawska streets in Wyszaków, and Kościuszki, Legionów, Lubelska, and Warszawska streets in Garwolin) and the events outside of the courses of the roads DK8/S8 and DK17/S17, that is – on the remaining areas of the two municipalities considered. Regarding the course of the road across town, after the ring road has been put into operation, the analysis accounted also for the former course of the national road, having become, in the presence of the ring road, a municipal road. Hence, with the instant the ring roads considered start to function, the total length of the analysed roads is for both municipalities much bigger than before the construction of the ring roads. The victims of the accidents were classified, conform to the terminology adopted in SEWiK, into fatalities (ZM), seriously injured (RC), and slightly injured (RL).

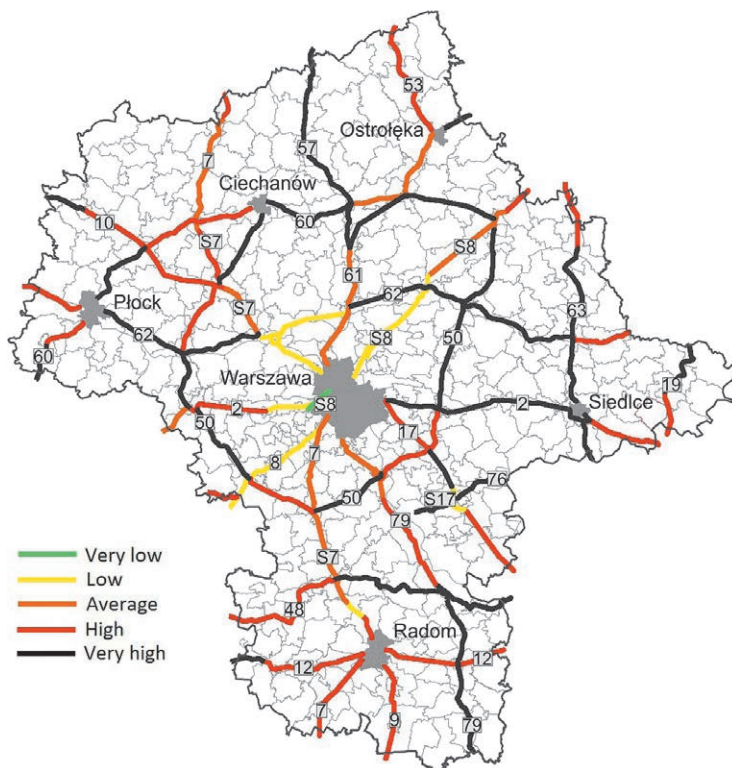


Figure 13. Individual accident risk on the national roads in the years 2009–2011 in the province of Masovia

Source: own elaboration on the basis of

http://www.eurorap.pl/index.php?option=com_content&view=article&id=102&Itemid=63.

The number of victims of the accidents decreased in the years 2006–2012 in the municipality of Wyszaków from more than 140 to less than 80. In the municipality of Garwolin the decrease was also well visible, by almost half, but at a lower overall level, namely from more than 80 to more than 40 victims per annum. For both of the analysed areas the majority of accidents took place outside of the routes of the national roads DK8/S8 and DK17/S17.

One of the most important conclusions is that the numbers of victims of the accidents along the courses of the national roads DK8/S8 and DK17/S17 have been decreasing much faster than on the remaining roads of both municipalities. For both municipalities the former decrease was truly spectacular: from more than 40 victims in 2006 down to less than 10 in 2012, and that despite the relative extension of the lengths of networks in the two cases considered.

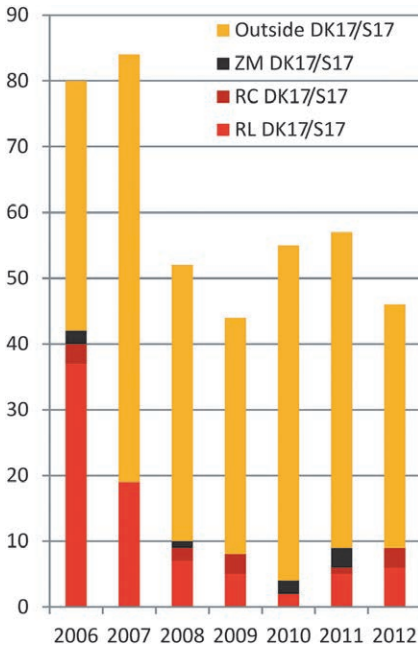


Figure 14. Victims of road accidents in the municipality of Wyszków in the years 2006–2012: outside of the course of DK8/S8 (fatalities (ZM), seriously injured (RC), and slightly injured (RL))

Source: own elaboration on the basis of data from SEWiK database.

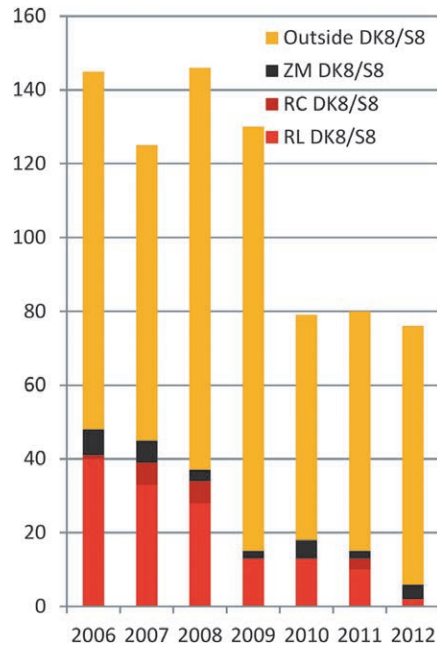


Figure 15. Victims of road accidents in the municipality of Garwolin in the years 2006–2012: outside of the course of DK17/S17 and within the course of DK8/S8 (fatalities (ZM), seriously injured (RC), and slightly injured (RL))

Source: own elaboration on the basis of data from SEWiK database.

It remains an open question whether this positive change in terms of improvement of safety is due solely to the opening of the ring roads, or, perhaps, there are also other factors, which have equal or even higher importance. It is worthwhile to consider that during the period analysed the number of road accident victims (first of all the fatalities) has been decreasing in the country as a whole. Besides, introduction, with November 1st, 2006, of the ban on the heavy load traffic for trucks of total admissible weight exceeding 16 tons through Warsaw, could have an influence on the situation on the roads considered, first of all through the increase of the truck traffic on the transit beltway of Warsaw. The traffic limitation mentioned could, first of all, entail the decrease of the heavy loads movements in Wyszków, where truck drivers, in order to circumvent the capital city, after 2006, could quit DK8 and join DK50 in Ostrów Mazowiecka, or DK62 in Wyszków itself. The number of trucks with trailers on the course of the national road no. 8 through Wyszków dropped in the years 2005–2010 by almost half, and the decrease is similar on both fragments of the ring road, before and after the crossing with DK62 (a large proportion of the heavy loads with trailers avoid the ring road of Wyszków, driving along Białostocka street in Wyszków westwards towards Serock). In the course of the national road no. 17 through Garwolin, on the other hand, the number of the heavy loads with trailers increased. It is characteristic that yet in 2005 the number of trucks with trailers, passing through Wyszków was two and a half times bigger than of those passing through Garwolin, while five years later the situation was tending to the opposite (Fig. 16).

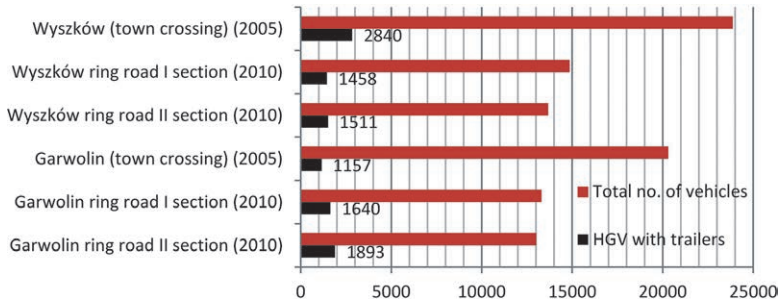


Figure 16. Changes in the intensity of total traffic and of the heavy loads with trailers in the years 2005–2010 over the segments of the ring roads of Wyszaków and Garwolin
Source: own elaboration on the basis of GPR 2005 and GPR 2010.

It should be emphasised that on both routes the overall intensity of traffic decreased in the years 2005–2010, which was due to the fact that in 2010 the local traffic partly took place over the municipal roads, crossing the towns of Wyszaków and Garwolin. The decrease of traffic intensity contributed to the improvement of safety and decrease of the accident indicators. Yet, this improvement concerned primarily the decrease of the number of slightly injured persons, while more severe accidents, in which the victims are seriously injured or killed, are still registered every year on the course of both of the national roads considered, across Wyszaków and Garwolin alike. The reason may lie in the fact that the drivers attain on the ring roads the speeds often exceeding 120 km/h, along with the so-called motorway syndrome, which is observed on the exits from the ring roads.

Namely, when a driver, having covered a distance on the ring road, leaves it and enters a road with lower admissible speed, s/he is often still internally motivated to drive at a speed higher than the road signs allow. Hence, much more often than usually exceeds the admissible speeds and overtakes other vehicles. According to the data, collected by NaviExpert, on a route passing from an expressway to a road with admissible speed of 70 km/h, drivers travel with the average speed of 85 km/h (<http://www.blognavi.pl/badania-naviexpert/332-rednio-jeden-pirat-drogowy-na-minut>).

Independently of the visible improvement in safety in terms of the decreased number of persons injured in road accidents along the courses of the national roads through Wyszaków and Garwolin, it should be emphasised that construction of these two ring roads has not solved the problems of safety concerning the remaining roads on the territory of the two municipalities considered. The number of persons having fallen victims of road accidents on these remaining roads persisted over the analysed time period at an approximately similar level, this being yet another argument, confirming the proposition that the construction of expressways, including ring roads, improves significantly the safety along the respective routes of the national roads, but does not find reflection in changes of accident rates on other roads.

Conclusions

Even though the numbers of accidents, persons injured and fatalities continuously decrease in Poland, our country is still among those in Europe, which feature the highest numbers of fatalities in road accidents. That is why road safety has been for years an essential element of numerous investment programs and undertakings aiming at the improvement of travelling conditions. Definitely, construction

and maintenance of modern road infrastructure are among the most important factors, influencing road safety. The probability of an accident for a participant of traffic on the two-way national road is approximately 25 times higher than on the motorway or the expressway, and the risk of being killed in an accident is 15 times higher. Lower ratio for the fatalities results from the fact that with high speeds the share of accidents with fatalities in the total number of accidents is appropriately higher on the motorways and expressways than on the remaining road categories. In the years 2004–2012 a significant improvement of safety was observed within the areas of the majority of the county-towns, primarily in large cities and in agglomerations. The situation worsened, on the other hand, within the peripheral areas of individual provinces. It is characteristic for these latter areas that they are significantly distanced in their majority from the main transport corridors.

The responses, obtained in the questionnaire-based surveys in the framework of the case studies from the users of the roads, confirm that safety on the motorways and expressways, or, more broadly, on the separate traffic dual roads, is assessed as much higher than on the remaining national roads. Generally speaking, the selected case studies are characterised by the relatively high differentiation of the accident risk. A part of the analysed roads, being separate traffic dual carriageways, feature low or very low individual risk – risk of running over a pedestrian or head-on collision. On the other hand, the traffic participants on the other roads, where the two-way traffic is not separated, are in their majority running high or very high accident risk.

The conclusions from the analysis of the locations and the character of accidents having taken place between Tzew and Grudziądz before and after construction of the respective segment of A1 motorway indicate that the construction of the motorway resulted in a significant drop in the number of persons fallen victims to accidents between the two localities. On the basis of the additional investigations, concerning the newly opened segments of the motorways A2, between Konin and Koło, and A4, between Zgorzelec and Krzyżowa, it can be concluded that the increase of road safety applies to all of the motorway segments, this safety being understood in terms of the total number of victims on the newly constructed segment of the motorway and on the two-way national road, parallel to it.

The analysis of changes in the numbers of accident victims in the municipalities of Wyszaków and Garwolin before and after the respective ring roads have been put to operation showed that the share of persons being accident victims in the courses of the national roads DK8/S8 and DK17/S17 decreased much faster than on the remaining roads in the municipalities of Wyszaków and Garwolin. In both cases the decrease was spectacular, from more than 40 victims in 2006 to less than 10 in 2012. Construction of the two ring roads, though, did not resolve the problems with safety on the remaining roads of the two analysed municipalities, and this is yet another piece of evidence supporting the proposition that the fast traffic roads, including the ring roads, constituting segments of the expressways, improve the safety in the course of the respective national roads, but do not make much difference concerning the accident rates on other roads.

References

- EU transport in figures*, 2012. Statistical pocketbook.
Europejski Program Oceny Ryzyka na Droгах EuroRAP <http://www.eurorap.pl/>
Gaca S., 2002. *Badania prędkości pojazdów i jej wpływu na bezpieczeństwo ruchu drogowego*. Zeszyty Naukowe Politechniki Krakowskiej, no. 75.

- Gaca S., Suchorzewski W., Tracz M., 2008. *Inżynieria ruchu drogowego. Teoria i praktyka*. Warszawa: WKiŁ.
- Hughes B.P., Newstead S., Anund A., Shu C.C., Falkmer T., 2015. *A review of models relevant to road safety*. *Accident Analysis and Prevention*, 74, pp. 250–270.
- Instrukcja oceny efektywności ekonomicznej przedsięwzięć drogowych i mostowych dla dróg wojewódzkich*, 2008. Warszawa: Instytut Badawczy Dróg i Mostów.
- Krajowy Program Bezpieczeństwa Ruchu Drogowego 2005–2007–2013 (National Program of Road Safety 2005–2007–2013; in Polish) GAMBIT 2005*, 2005, Warszawa
- Narodowy Program Bezpieczeństwa Ruchu Drogowego 2013–2020 (National Program of Road Safety 2005–2013–2020; in Polish)*, 2013. Warszawa: Krajowa Rada Bezpieczeństwa Ruchu Drogowego.
- Novoa A.M., Pérez K., Borrell C., 2009. *Evidence-based effectiveness of road safety interventions: a literature review*. *Gac Sanit.*, 23(6), pp. 553.e1–553.e14.
- Strategia Rozwoju Transportu do 2020 roku (z perspektywą do 2030 roku) (Transport Development Strategy until 2020 (with the perspective until the year 2030); in Polish)*, 2013. Warszawa: MTBiGM.
- System Ewidencji Wypadków i Kolidacji SEWiK (The System of Registering of Accidents and Collisions SEWiK; in Polish)*, Biuro Ruchu Drogowego Komendy Głównej Policji.
- Tracz M., Gaca S., 1995, *Analysis of the effects of roadway and roadside design on road safety*, *Slovak Journal of Civil Engineering*, STU, Bratislava.
- Wypadki drogowe w Polsce (Road accidents in Poland; in Polish), 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012. Warszawa: Komenda Główna Policji.
- Zarządzenie nr 635 Komendanta Głównego Policji z dnia 30 czerwca 2006 r. w sprawie metod i form prowadzenia przez Policję statystyki zdarzeń drogowych (Ordinance no. 635 of the Police Commander in Chief of June 30th 2006 on the methods and forms of conducting the road events statistics by the Police; in Polish)*.
- <http://www.blognavi.pl/badania-naviexpert/332-rednio-jeden-pirat-drogowy-na-minut>
- <http://www.eurorap.pl/>

