

## WYBRANE PROBLEMY ANALIZY PRZYCZYŃ WYPADKÓW DROGOWYCH W POLSCE W LATACH 1995 –2004

### CHOSEN PROBLEMS OF ROAD ACCIDENTS ANALYSES IN POLAND IN THE PERIOD BETWEEN 1995 AND 2004

*W niniejszej pracy dokonano klasyfikacji zderzeń samochodów ze względu na statystycznie najczęściej występujące wypadki oraz testy, jakim poddawane pojazdy są nowo dopuszczane do sprzedaży. Niniejsza praca dotyczy rozważań na temat bezpieczeństwa ruchu drogowego w Polsce. Na jej łamach podjęto próbę analizy przebiegu i skutków najpowszechniej występujących na drogach zderzeń. Ważnym jest problem stateczności jako elementu podlegającego zmianom w przypadku eksploatacji pojazdów powypadkowych. Problem ten jest przedmiotem oddzielnych badań. Kolejnym ważnym punktem jest przedstawienie danych statystycznych i próbę analizy poziomu bezpieczeństwa na ich podstawie. Jako ważny etap należy postrzegać tu chęć porównania niektórych wskaźników w Polsce i we Francji, co pozwoliło na próbę zweryfikowania niektórych opinii o poziomie bezpieczeństwa ruchu na drogach w Polsce.*

**Słowa kluczowe:** bezpieczeństwo, wypadki, kolizje, przyczyny, skutki.

*This article offers classification of car collisions from the point of view of the most frequent accidents and crash tests. The most important problems are the consequences of incomplete control of a car which has been repaired after an accident. As a result, further use may lead to defective work of systems responsible for steering, driving comfort, and contact with the road surface as well as suspension. Firstly, the article focuses on the safety of road traffic in Poland and presents an attempt to analyze the course of most frequent collisions and their consequences. Stability is an important problem as it changes in a car driven after an accident, and should be analyzed in separate research. Secondly, it gives statistical data and attempts to analyze the level of road traffic safety. Some important indicators are shown here to compare the situation in France and Poland, which enabled verification of some opinions about the safety of road traffic in Poland.*

**Keywords:** safety, accidents, collisions, reasons, consequences.

#### 1. Introduction

Road traffic safety in Poland has become an important issue due to an increase in both the number of registered cars and road accidents. Efforts to improve road traffic safety have been taken for many years in many countries including Poland. This article presents results of analyses and improvements in driving safety. They were based on an analysis of sample publications describing the actual situation and the main trends for future. Countries leading in research towards better safety are those having the greatest experience in this matter, i.e. Sweden, Germany, France, USA and Great Britain. Thanks to combined work of car manufacturers, organizations such as EuroNCAP (assessment of new car safety) and scientific teams it was possible to create state-of-the-art car bodies offering maximum passenger safety which got top marks in crash tests. Besides, there have been attempts to protect pedestrians from the effects of being hit by a car. Initially, the results were unsatisfactory, but the latest tests show improvements in this area. Examples of dissertation in this area include those by M. Huang [6] and D.C. Viano [11] and many other publications, e.g. by J. Reimpell [9]. Moreover, it is important to refer to scientific conferences in Poland, such as TRANSED 2001. Except for research into better safety of the car body [2] there are activities aimed at improvement of road traffic [1]. These include the building and modernization of road and motorway networks, as well as regulations to adapt the traffic to the surrounding area. Until now, the main parameter in this respect was the speed limit.

The main product of such work in Poland is a stream of publications concerning car body construction, crash mechanics, as well as accident reconstruction and biomechanics of human body at the moment of crash. A different issue is the relationship between road infrastructure [3] and the occurrence of road accidents [4]. There are numerous publications covering this area of research, and those deserving the reader's attention include papers by Prof. J. Wicher [12], and other relating to recreation and analysis of road accidents. Numerous dissertations concerning road vehicle dynamics are also available.

The aim of this article is to describe different kinds of car accidents on the basis of the crash theory and consequences of accidents, especially body deformation. In its further part, the work discusses different causes of road accidents along with the actual level of road safety in Poland, based on an analysis of statistical data [7,8,10,13], comparison between some of the indicators in Poland and France, and the relationship between accidents and the condition of road infrastructure. The statistical analysis was made on the basis of the road accidents database for the period between 1995 and 2005. This database was compiled with the use of the Informix software.

#### 2. Classification of car crashes and the course of the related collisions

Primarily, road accidents involve contact of one body (here a car) with another one or more bodies (car, man, still barrier) or the ground. To present some basic examples of road accidents

as crashes of bodies, it is necessary to make a relevant classification which allows distinction of different types of accidents. Following this train of thought, it appears necessary to describe road accidents and their consequences according to the following guidelines.

This classification of car accidents was made on the basis of the existing divisions. J. Wicher divides impacts into front, side, rear and rollover ones, depending on which part of the car body was hit (Fig. 2.1). ISO 6813 (Fig. 2.2) offers a more detailed description of each type of crash, including other incidents, such as fire.

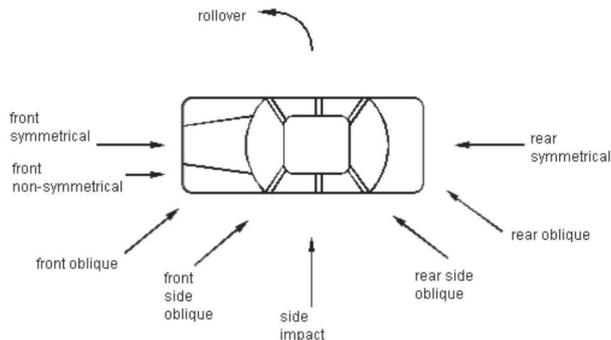


Fig. 2.1. Division of crashes based on direction of collision [12]

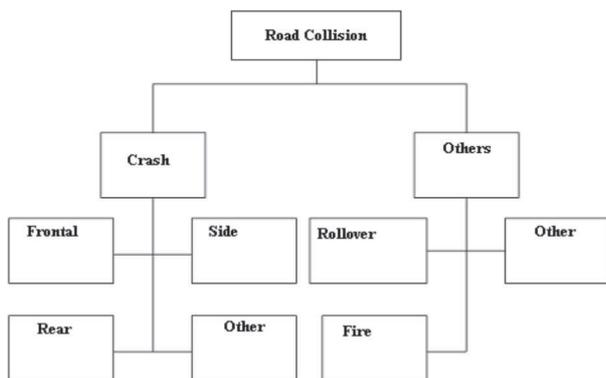


Fig. 2.2. Classification of crashes according to ISO 6813 [12]

In order to present road traffic as examples of two-body crash, it is necessary to use a third classification (Fig. 2.3) showing statistical data for the period between 1995 and 2005. It allowed a certain combination allowing separation of accidents resulting from the movement of road vehicles from other road occurrences.

**2.1. Side impact**

As it appears from figure 2.3, the side impacts constitute the highest percentage in the general number of accidents. This problem is caused by the increase in the number of cars in towns and cities, which is connected to congestion in these areas. The crash itself usually occurs close to the central pillar marked as B. However, considering the offset in relation to e.g. the driver's R point, we could expect that the resultant force would be received in another place at the side wall of the car. The crash itself can be both perpendicular and oblique. In the former case, the impulse vector of the crashing force is unknown, but the path

Procentowy udział rodzajów zderzeń w ogólnej liczbie wypadków na lata 1995 - 2004

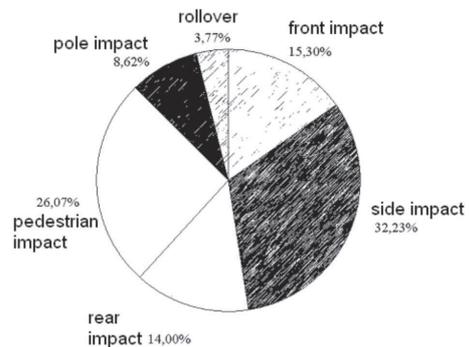


Fig. 2.3. Percentage of crashes in 1995 – 2004, source: own research

of the moving car before the collision is obvious to guess. The moving car is deflected, and the velocities of the cars are also changed. This information is important when considering an accident reconstruction.

As a result of an oblique crash, it is not certain how to define the orientation of the impulse vector. It can be defined only by using the known position of the vector of the car momentum before the crash, as well as some relevant geometric ratios.

Deformations occurring after side impact affect primarily all the closed profiles strengthening the car body construction. These profiles are located in the thresholds of the doorholes, A, B, C and D pillars if the body is a station wagon (Fig. 2.4) [14]. Deformations may also occur in the joints between the side wall of the car and its roof or between the frame of the side wall and the covering sheets.

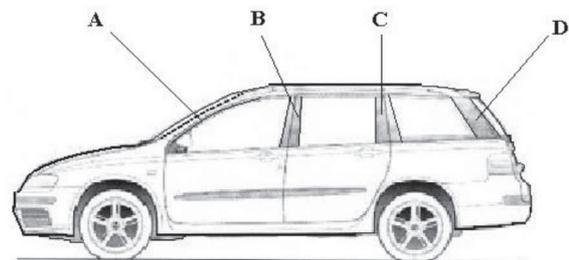


Fig. 2.4. Indication of car pillars, source: own research

Additionally, deformations which may disturb the geometry of the car body can occur in the longitudinal and transverse draw pieces of floorboard. While describing the pillars as energy saving and deformable elements, it is necessary to mention that they occur mainly in closed types of car body (the roof is an integral part of a car and is not disassembled). The number of pillars depends on the type of car body. In open bodies, where the roof can be taken out, there are mainly A pillars.

**2.2. Pedestrian impact**

This kind of accident holds the second place in the general classification of the number of accidents between 1995 and 2004. It is caused mainly by hitting a pedestrians walking right next to the road in its closest area and on zebra crossings. This type of

accident was classified as one of the EuroNCAP tests. The cases of a pedestrian being hit by the front part of a car are taken into account most frequently. Human body has then direct contact with the bonnet, whose deformations do not influence the car body geometry.

The most important criterion in the assessment of safety of a car exposed to pedestrian impact is the collection of characteristic points. They are placed on the bonnet and windscreen of each tested vehicle. Those points are marked with different colours depending on the probability of injuries as a result of contact with the places they cover. Such a situation is presented in figure 2.5

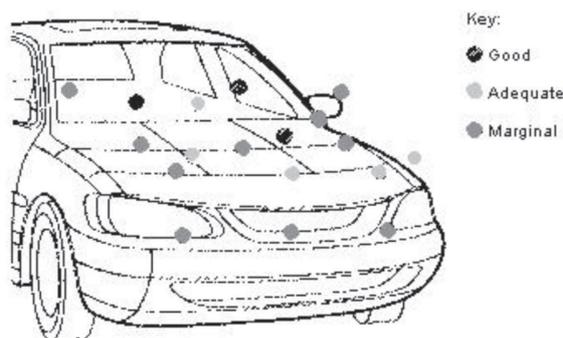


Fig. 2.5. Distribution of the points to evaluate the results of the pedestrian impact, source: www.euroncap.com

An accident with a pedestrian can occur in three phases: contact with vehicle, the flight of the human body and then sliding on the road surface. The most important factors generating the severity of pedestrian injuries are the shape of the front part of the vehicle body and the velocity at which it hits the pedestrian. These factors determine whether he falls down in front of or behind the colliding car, or flies to the side.

### 2.3. Parallel impacts

Front and rear impacts, also classified as parallel, occur in similar quantity relating to the general number of accidents in the described period. During this type of collision the cars are moving along parallel or nearly parallel paths. As a result of the crash, the parameters of both cars change. Parallel impacts are uniquely characterized by a moment at which the velocities of both cars are equal. The phase before is characterized by the impulse growth of the crashing force and deformations in car body [5]. This first phase is called the deformation phase.

In the second phase, after the velocities of both cars are equal, there is a decrease of the crashing force and the disappearance of deformations, provided the effort in the material of car body has not exceeded.

Deformations that could occur as a result of a crash cover the elements of the engine chamber (front belt, front side profiles often designed to have the suspension fixed to them, front barrier between the engine chamber and the passenger section) along with the elements of external sheets, as well as the additional underframe, front door, A pillars, windscreen and the front part of floorboard. The rear impact is dangerous for the structure of the boot, C and sometimes D pillars, rear window and fragments of external sheets along with the rear parts of the floorboard. In

the event of parallel impact, there is the highest probability of change in the geometry of the vehicle body.

### 2.4. Stiff barrier impact (pole impact)

Those accidents cover 9% of all the road misfortunes registered in the period between 1995 and 2004. This type of impact is especially dangerous, because its consequences may be very serious. Such an accident is very dangerous, especially when the side wall of a car hits the pole. The resulting deformations of the side thresholds, B pillars, roof, door, floorboard in transverse direction and the elements of the interior in the passenger section could cause serious injuries. The assessment of car damage resulting from this type of collision is also carried out by the EuroNCAP. This test is shown in figure 2.6.

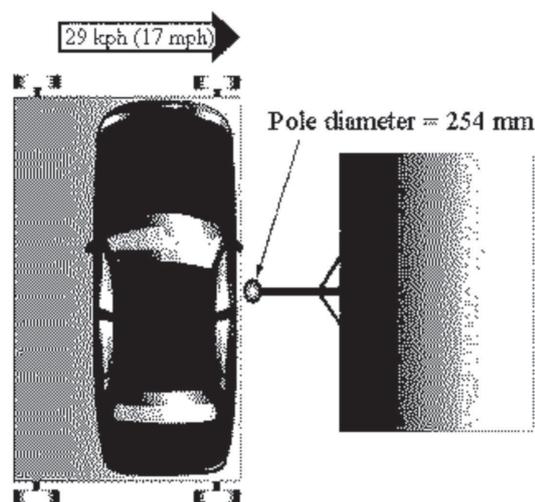


Fig. 2.6. Pole impact by the EuroNCAP, source: www.euroncap.com

### 2.5. Rollover

The last type of accidents mentioned earlier in the classification constitutes about 3.8% of all accidents from the described period. The rollover is when car hits the ground with its side walls or roof as a result of turning around one of its axis of symmetry. Although occurring less frequently, this type of accident may have very serious consequences, if considering the injury of passengers and the deformation of car body.

The fall on the roof may lead to damage of all pillars and windows, as well as the roof. However, micro deformations and micro cracks might reach as far as the floor board of the car. It can result in the change of the vehicle body geometry.

### 3. Analysis of statistical data

Road accidents and collisions registered by the police are stored as data in the evidence system of accidents and collisions called sewik. These data are used to update the database at the Warsaw University of Technology, Department of Transportation, created with the use of Informix. On the basis of the statistics received, an attempt to assess the level of road traffic safety in Poland was made. Furthermore, some trends for the future were analysed. A comparison between Poland and France in the years 1998 - 2000 was also developed as France is considered to be the country having better infrastructure and driving culture.

The research results presented in the bibliography contain different aspects concerning analysis of data than those presented in this paper.

3.1. Human factor

It is believed that the blame for most road accidents lies on the human side. Figure 3.1 shows the division of causes for road accidents caused by a human being. In this respect, only pedestrians are a group that really matters. It is noteworthy, however, that while the number of accidents caused by pedestrians fell during the period between 2000 and 2004, those caused by drivers remained at around the same level of 50,000 a year. It is a serious problem and it does not seem that the next years will show any decrease in this area, especially in the face of continuous growth of the number of cars in Poland. The reasons of collisions and accidents should also be searched among factors which influence fluidity and safety of traffic.

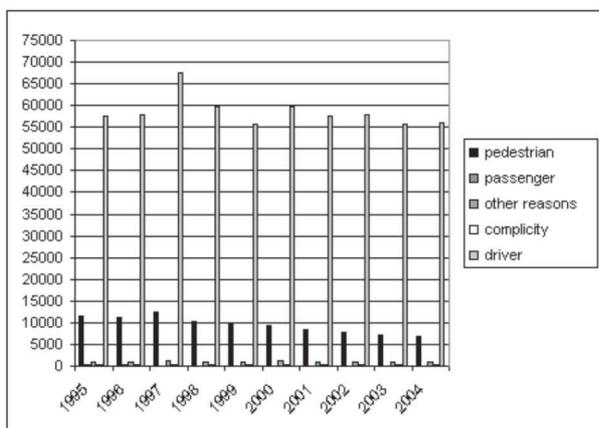


Fig. 3.1. Causes of accidents resulting from human error, source: own research

Figure 3.2 shows the number of killed and injured in road accidents in Poland. The period between 1995 and 2004 was taken into account as the comparison was made by relation to 100,000 registered vehicles. The second half of this period seems to have given better results in terms of both the killed and the injured. A clear decrease was reported in the injured rate, to

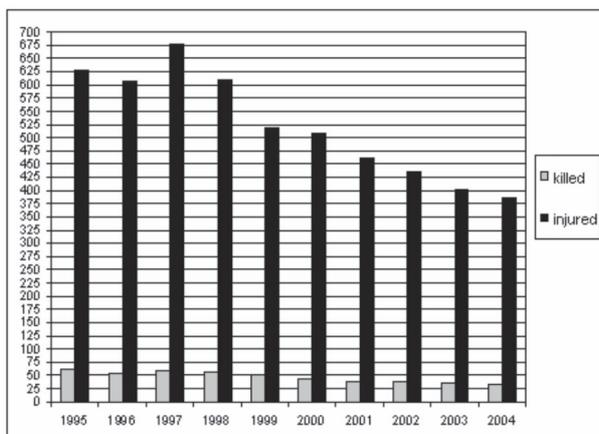


Fig. 3.2. Number of road deaths and injuries per 100,000 registered vehicles between 1995 and 2004, source: own research

about 400 per every 100,000 vehicles in 2004. By comparison, between 1995 and 1999 this indicator remained at about 600. The relative number of persons killed in road accidents after 2000 has stabilized at the level of around 40. Although there is no evident decrease tendency, we can say that there has been a significant improvement of safety in the period of the last ten years. This is largely due to the development of the car body construction. This factor, along with modern road infrastructure, can lead to further decrease of deaths at the expense of an increase in the number of injuries, e.g. per 100,000 of registered cars. It is also connected with the separation of pedestrians and bicycles from road traffic. In such a case we could expect more side and rear impacts during the lane change. The number of head, pedestrian, and bicycle collisions should decrease. Most rear collisions occur in urban area, so the decrease in their number is connected only with the improvement of the culture and skills of drivers.

The analysis of the changes in the number of road deaths and injuries is continued in Table 3.1, where the factors mentioned previously are shown in relation to 1,000 accidents in Poland in the period of five years. It is important that the number of deaths oscillate around 110 which allows one to predict some stabilization in this area. In the years 2000 – 2004 the number of injuries was around 1,300 per 1,000 accidents.

Tab. 3.1. The number of people killed and injured per 1,000 accidents in Poland, 1995 – 2004, source: own research.

	Year				
	2000	2001	2002	2003	2004
deaths	6294	5534	5827	5640	5712
injuries	71638	68194	67498	63900	64661
no. of accidents	55464	52022	51773	49451	49414
people killed per 1,000 accidents	113,5	106,4	112,5	114	115,6
people injured per 1000 accidents	1291,6	1310,9	1303,7	1292,2	1308,5

Table 3.2 shows the number of deaths due to accident in Poland in 1998 – 2000. This statistics was made to eliminate the factors having the influence on the road traffic safety mainly because of special characteristics of the Polish infrastructure. It is a noticeable fact that the number of pedestrians, horse-drawn cart drivers and another types mentioned in table 3.2 had fallen. Further comparisons prove that one of the basic assumptions of the improvement of road traffic safety should be the solution to the problem of using the same roads by cars, bicycles and all types of users mentioned in table 3.2. Moreover, limiting the risk of front impacts is also necessary.

Table 3.3 shows a comparison. It analyses the number of accidents, deaths and injuries per 100,000 registered vehicles from 1998 to 2000 in Poland and France. The period indicating the highest increase in the number of vehicles was chosen. As observed, the relative values for French road traffic are more than two times smaller for the people killed in accidents. As for the injured, in both countries the number per 100,000 registered vehicles fell in the given period. However, this fall is very signifi-

Tab. 3.2. The number of people killed in accidents in Poland in 1998 – 2000, source: own research.

year	Number of accidents	Deaths				total	Total deaths
		Pedestrians	Motorbike, motorcycle drivers	horse-drawn cart drivers	Front impact		
1998	59649	2655	575	15	1274	4519	7080
1999	53915	2446	643	11	1323	4423	6730
2000	55464	2226	616	9	1286	4137	6294

Tab. 3.3. The victims of accidents for the registered vehicles in the years 1998 – 2000. The minus in some boxes means that the data was unable to find. However, those factors for France are probably very low, source: own research.

	year					
	1998		1999		2000	
	Poland	France	Poland	France	Poland	France
accidents	59649	124000	53915	125000	55464	121220
deaths	7080	8400	6730	8000	6294	8079
deaths minus those in table 3.2	2561	-	2307	-	2157	-
injuries	77560	169000	68449	168000	71638	162000
$\frac{\text{killed}}{\text{accidents}} \cdot 100\%$	11,8	6,77	12,4	6,4	11,3	6,67
$\frac{\text{injured}}{\text{accidents}} \cdot 100\%$	130	136,3	127	134,4	129,1	133,6
registered vehicles	12709244	32575000	13169216	33355700	14106078	33601750
accidents per 100 000 vehicles	469,3	380,7	409,4	347,8	393,2	360,8
deaths per 100 000 vehicles	55,7	25,8	51,1	24	44,6	24
deaths per 100 000 vehicles but minus those from table 3.2	20,15	-	17,5	-	15,3	-
injuries per 100 000 vehicles	610,2	518,8	519,8	503,7	507,8	482

cant for Poland – it dropped to 100. It means a great improvement in the area of injuries. As far as deaths are concerned, the matter is still unsolved, as France has more cars and better roads. It does not indicate however, that road traffic safety in France is better than in Poland.

Despite the decrease in the number of accidents per 100,000 cars in Poland between 1998 and 2000, the death rate is still twice as high as in France. France reported fewer deaths, and the number of injured people was slightly lower in Poland. This fact can be explained only by greater average speed at which cars move in France on better roads. When comparing relative values it can be seen that the situation was more beneficial in France where, although three times more cars, the rate of deaths per 100 000 cars was in the given period slightly lower along with its general decrease in both countries.

To make full assessment of road traffic safety in both Poland and France, a comparison between every type of accident would be necessary. The results would probably show a great deal higher number of parallel impacts (mainly rear) in France. This is connected with roads and motorways, on which such accidents occur. On the other hand, old city and town centres are usually closed for traffic. Besides, there are ring roads, whose existence may influence the small number of side and pedestrian impacts in urban traffic. Although some indicators are close in value, there might be different root causes for this.

On the basis of data in table 3.3 some conclusions can be made. If problems of infrastructure in Poland had been solved in a different way, which means separation of bicycles and others

from car traffic and roads with bands between lanes of different direction, the number of accident deaths could have fallen even by 60%. It means that by comparing relative values, the number of deaths could fall from 45 – 55 to about 15 – 20 per 100, 000 registered cars.

If one observed a hypothetical decrease of about 5 people over 3 years, then it is obvious how better the situation would be today. The level of road traffic safety would be more competitive in comparison with the countries seen as having cultural drivers.

As for the number of pedestrians, horse-drawn cart drivers, bicycle and motorcycle drivers as well as the victims of front impacts in France, a hypothetical assumption of their lack was made because it was impossible to collect the relevant data. However, it is important to take their existence into consideration but probably at a smaller rate than in Poland.

According to data in table 3.4 the number of injured in car accidents per 100000 vehicles in 2004 was smaller than in Germany and Great Britain. There were also fewer accidents per 100000 vehicles than in those two countries. However it is necessary to mention that there are more cars in both Germany and Great Britain as well as in France. As for the death rate, it seems to be the greatest of all four. Relying on the previous considerations we can assume that, if there was the proper road infrastructure in Poland, then those factors would surely be more competitive, given the smaller number of cars than in compared countries.

Tab. 3.4. The number of accident victims in Poland in 2004 compared with the chosen European countries, source: own research.

	Poland	Germany	Great Britain	France
<i>registered vehicles</i>	16704000	54082000	31950000	38809000
<i>accidents</i>	51069	339310	207410	85390
<i>deaths</i>	5712	5842	3221	5530
<i>injuries</i>	64661	440126	277619	108272
<i>accidents per 100 000 vehicles</i>	305,7	1835	649,17	220
<i>deaths per 100 000 vehicles</i>	34,2	31,6	10,1	14,24
<i>injuries per 100 000 vehicles</i>	387,1	2380,3	868,9	279

### 3.2. Technical inefficiency

The faults of car as a cause for accident play an unimportant role in the general number of accidents and car collisions. On the basis of data in table 3.5 we can assess how many accidents happen because of technical disabilities on the background of all accidents between 1995 and 2004. These results are presented to show how insignificant those car faults are in relation to the causes of all road accidents.

### 4. Summary

To answer the question whether the relevant steps towards improvement of road traffic safety were taken, and if they proved to be effective, we should relate to above-mentioned considerations. On the basis of comparing relative values we could ascertain, that despite the growth in the number of cars, the number of accidents, deaths and injuries per 100, 000 vehicles in Poland fell during the given 10 years. Moreover, in the last two years, i.e. from 2002 to 2004, some stability in the number of people killed in accidents can be observed. On this conclusion we could assume a stabilization of road traffic safety on a concrete level. Especially some elements of accident had stabilized.

The analysis relating to accidents and their casualties between Poland and France in 1998 – 2000 does not allow to synonymously state if the safety level in all European countries is the same. The comparison of the number of accidents, deaths, and injuries proves that in the analyzed period the differences were favourable for France. It is necessary to notice the decreasing tendency of the accident and injured factors for both Poland and France. We can predict that until the present their values are close.

### 5. Conclusions

Taking into account the above-mentioned consequences, the loss of car stability in motion can be expected. The reasons for this phenomenon lie mainly in deformation of a floorboard or a frame of car body. The most important aspect in car repair after an accident is to make necessary measurements and operations leading to bring the body dimensions back to correct state. Above all it matters when repairing the elements carrying forces and loads.

From the presented statistical data above it is seen that the most frequent are side and pedestrian impacts. However, the second type does not involve great damage of the car, side impacts can lead to widespread deformations and disturbances in car body geometry. It is caused by the direct contact of stiff bodies with rough surfaces.

The analysis let to determine the chosen relations describing the level of road traffic safety in Poland and France. Those are not the results covering all the problems of assessment. Only a few factors were compared. It can be claimed that road traffic safety level (according to those factors) has stabilized on some concrete level, which is comparable with other European countries. As for injuries, there is not a big difference between the French and Polish situations. The matter which needs improvement is the reduction of the number of people killed in accidents. One of the answers to this question is the Polish road infrastructure. The presented results can lead to determine some directions for further improvement.

Tab. 3.5. Proportional participation of the faults detected to the mount of all accidents, source: own research.

	Year									
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
<i>the numer of registered vehicles</i>	11185469	11765401	12283503	12709244	13169216	14106078	14724040	15525476	15898983	16701072
<i>the numer of accidents per 100 000 registered vehicles</i>	498	484	526,2	469,3	409,4	393,2	353,3	333,5	311	295,9
<i>The numer of detected faults per 100 000 registered vehicles</i>	10,6	7,6	5,1	3,4	2,6	2,2	1,8	1,67	1,4	2,4

6. References:

- [1] Dąbrowska-Loranc M.: *IV Międzynarodowy Tydzień Bezpieczeństwa Ruchu Drogowego*. Biuletyn Informacyjny ITS, Nr 2/2004, s. 9.
- [2] Filipczyk J.: *Istota badań kontrolnych w zakresie diagnostyki bezpieczeństwa*. II konferencja naukowo-techniczna: Problemy bezpieczeństwa w pojazdach samochodowych, Kielce, 2000, s. 96.
- [3] Gołębiowski S.: *Bezpieczeństwo pieszych na wyznaczonych przejściach*. Biuletyn Informacyjny ITS, Nr 4/2004, s. 12.
- [4] Gołębiowski S.: *Wypadek drogowy i co dalej?* Biuletyn Informacyjny ITS, Nr 6/2004, s. 13.
- [5] Gryboś R.: *Teoria uderzenia w dyskretnych układach mechanicznych*. PWN, Warszawa 1969.
- [6] Huang M.: *Vehicle crash mechanics*, 2002, Hardbound.
- [7] Jurecki R. S.: *Wypadki drogowe w Polsce, skutki i przyczyny*. III konferencja naukowo-techniczna: Problemy bezpieczeństwa w pojazdach samochodowych, Kielce 2002, s. 225-228.
- [8] Rajchel K.: *Prawo drogowe, wypadki*. Politechnika Rzeszowska, Rzeszów 1998.
- [9] Reimpell J.: *Podwozia samochodów*, Warszawa 2004, WKŁ.
- [10] Szczuraszek T.: *Bezpieczeństwo ruchu drogowego*. WKŁ, Warszawa 2005.
- [11] Viano D.C.: *Role of the seat in rear crash safety*, 2002, SAE.
- [12] Wicher J.: *Bezpieczeństwo samochodów i ruchu drogowego*. WKŁ, Warszawa 2003.
- [13] Wrzeczona P. A., Mandosik J.: *Wybrane aspekty wiarygodności danych statystycznych wypadków drogowych*. Konferencja naukowo techniczna: Problemy bezpieczeństwa w pojazdach samochodowych, Kielce 1998, s. 211-214.
- [14] Zieliński A.: *Konstrukcja nadwozi samochodów osobowych i pochodnych*. WKŁ, Warszawa 2003.

---

**Prof. Jerzy KISIŁOWSKI , Ph.D., D.Sc.**

**Jarosław ZALEWSKI, M.Sc.**

Wyższa Szkoła Techniczno-Ekonomiczna w Warszawie

Politechnika Warszawska, Wydział Transportu

Zakład Teorii Konstrukcji Urządzeń Transportowych

04-703 Warszawa, ul. Hafciarska 11, Poland

tel. 0-22 5173450, fax. 0-22 8154694,

**e-mail: rektorat@wste.pl; jz@uste.pl**

---