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The selected elements of threat to road safety. Presentation of international research results¹

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Abstract: The safety of road users is one of the most important elements of the functioning of every society. The data published by the European Commission shows that on roads in the EU in 2017 was 25.3 thousand deaths occurred in road accidents. To reduce the number of road accident victims, threats in this area should be identified and appropriate solutions implemented. The article presents factors in traffic accidents, elements of human mentality which have a significant impact on driving a vehicle, factors influencing a driver's action in traffic and correlation of the system of safety management including the procedure of risk management. The article presents partial results of international scientific research carried out in Poland, Czech Republic and Slovak Republic. In the survey participated respondents from ten cities. Opinions were obtained from 642 people on the subject of individual personality factors determine the behaviour of vehicle drivers. Furthermore were presented respondents' answers regarding legal changes relating to the proposal penalties for drivers participating in road traffic under the influence of alcohol and drugs. The article has been prepared within the frames of realizing a research project called „Simulator supporting police officers' training in the implementation of activities during a road accident” no. DOB-BIO9/06/01/2018, which has received funding from the Polish National Centre for Research and Development.

Keywords: road safety, transport engineering, traffic accidents, human behavior

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2nd International Conference on SOCIAL SCIENCE, HUMANITIES & EDUCATION

21 - 23 JUNE 2019

VIENNA, AUSTRIA

1. Introduction

The study shows that in most countries of Organization for Economic Cooperation and Development (OECD) cost of car accidents represents 2 % of a country's gross domestic product. In developing countries loss is much bigger than received loans or international assistance. In etiological research of road incidents the following elements are distinguished as causal factors:

- Human – as a traffic user – U;
- Vehicle (V);
- Road (Surrounding – S).

While interpreting the concept of “traffic user” it should be understood as all users of roads (drivers, motorcyclists, cyclists, traffic participants – pedestrians). The above – mentioned elements occur in the greatest part of carried out analysis which is related to the issue of traffic safety.

Data published by the European Commission indicate that on roads in the European Union in 2017 in accidents was dead 25.3 thousand people. Over 135 thousand people have been wounded. In 2017 the average fatality rate on European roads was 49 person per million inhabitants against 174 deaths per million globally.

Swedish roads were the safest (25 person was die on road per million citizens of this country), and the most fatalities was in Romania (98 person death). Looking at the longer-term developments since 2010, the number of road deaths has decreased in all EU countries. The strongest decreases were observed in Lithuania (-37% between 2010 and 2016), Portugal (-37% up to 2015), Greece (-36% up to 2016), Norway (-35% up to 2016), Switzerland (-34% up to 2016) and Spain (-32% up to 2015). Overall in 2017, the European Union recorded a 2% reduction in the number of fatalities on European roads. Was estimated that material costs of road accidents amounted to over 150 billion euro. Losses resulting from the loss of life or suffering severe damage to the health of EU citizens are unmeasurable.

The document by the European Union *4th road safety action programme 2010–2020*, contains many sectoral solutions aimed at reducing the number of fatalities in road accidents over the next decade. Guidelines for the implementation of the abovementioned *4th road safety action programme*, describe 7 strategic goals for 2010-2020, the achievement of which is to help in a significant (50%) reduction in the number of fatalities in road accidents in the EU. The document includes the following directions of the necessary activities:

- Objective 1: Improve education and training of road users;
- Objective 2: Improve the enforcement of traffic rules;
- Objective 3: Improve the condition of road infrastructure and creating the so-called safe environment of roads;
- Objective 4: Safer vehicles;
- Objective 5: Promoting new technological and system solutions to improve road safety;
- Objective 6: Improve of the quality and effectiveness of rescue and assistance activities undertaken in emergency situations and after a road incident;
- Objective 7: Special protection of road users particularly exposed to participation in incidents (accidents, collisions).

2nd International Conference on SOCIAL SCIENCE, HUMANITIES & EDUCATION

21 - 23 JUNE 2019

VIENNA, AUSTRIA

The article presents factors in traffic accidents, elements of human mentality which have a significant impact on driving a vehicle, factors influencing a driver's action in traffic and correlation of the system of safety management including the procedure of risk management. In the article been used the results of the international research made in Poland, the Czech Republic and Slovak Republic. The research concerned the elements of human mentality which have a significant impact on driving a vehicle. The research material presented in the article has been supplemented with factors in traffic accidents and considerations about the correlation of the system of safety management including the procedure of risk management. This is a pioneering research in these three countries. In the available literature of the subject was not found information about similar research. The research was attended by representatives from Police Academy in Szczytno, Academy of Police Force in Bratislava and Police Academy of the Czech Republic in Prague. The article has been prepared within the frames of realizing a research project called „Simulator supporting police officers' training in the implementation of activities during a road accident” no. DOB-BIO9/06/01/2018, which has received funding from the Polish National Centre for Research and Development.

2. Factors in traffic accidents

In the area referred to traffic safety there are two essential concepts: collision and road accident. Collision is determined as traffic incident which results in damage that a vehicle was subject to and in which persons neither were killed nor suffered any injuries. However, traffic accident is an incident in which one or more participants of traffic take part in an event in which a person is injured or killed². In such circumstances police, ambulance and, when needed fire service (in a situation in which a victim is trapped in a vehicle) must be called immediately³. In each collision there can be three interlinked phases distinguished: initial, culmination and final. In the initial phase there is a traffic situation in which traffic participants have no possibility to prevent an accident⁴. The effect of a culmination phase which lasts several seconds and occurs on the short passage of road, are the most serious consequences (injuries, traffic participants' death, damage or destruction of a car and material damage in environment). There is an exception of a traffic incident with the participation of many vehicles on roads with high traffic intensity (over 700 vehicles per hour), where the time of culmination phase and collision zone (so-called domino effect) will be extended. The final phase is a continuation of a culmination phase and may end after all vehicles participating in a traffic collision will stop or last (e.g. in case of fire).

A man constitutes a central element of a system human-vehicle-road. Therefore, solving problems of traffic involves knowledge of road users such as drivers, cyclists and pedestrians.

² *Criminal liability for serious traffic offences : essays on causing death, injury and danger in traffic*, in. Dijk, A. A., Wolswijk, H. D. (ed.), Hague 2015, pub. Eleven International Publishing, p. 62.

³ Weston, P. G. 1997. *The Police Traffic Control Function. 5th Edition*, Illinois: Charles C Thomas Pub Ltd., p. 19.

⁴ Dukkipati, R. V. 2014. *Road vehicle accident reconstruction*, Kent: Tunbridge Wells, p. 332-336.

2nd International Conference on SOCIAL SCIENCE, HUMANITIES & EDUCATION

21 - 23 JUNE 2019

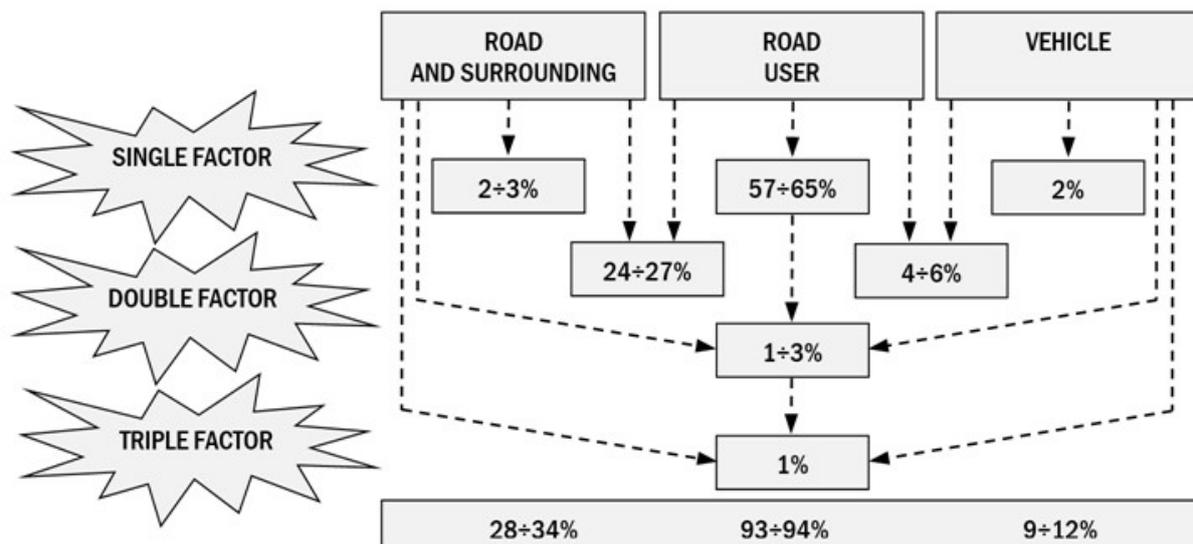
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Human failure plays a decisive role in most cases of road incidents (accidents, collision)⁵. The failure consists in:

- Failing to comply speed with traffic conditions and prevailing speed limits;
- Non-compliance with prevailing on a road;
- Performing inappropriate maneuver;
- Non-compliance with traffic rules by pedestrians.

Research carried out in the United States of America and Great Britain in 70s of the 20th century indicate that the main reason of 57-65 % of all accidents was improper behavior of a traffic user, and the next 30 % ones - the behavior was one of two or three reasons.

Figure 1: The percent of particular factors in traffic accidents.



Source: Rumar Kare. *The role of human behaviour. Psychological aspects*, [In:] *Road Safety, first and foremost a matter of responsibility*. ECMT International Seminar 1998.

The most common reasons of traffic accidents are:

- *Speeding and non-compliance with driving conditions* (e.g. road condition, weather conditions) as the main cause for accidents. Its offenders are mainly young people driving

⁵ *Human factors in traffic safety*, in A. Smiley. (ed.) pub. Lawyers & Judges Publishing Company, Inc. Tucson 2015, p. 46-51.

2nd International Conference on SOCIAL SCIENCE, HUMANITIES & EDUCATION

21 - 23 JUNE 2019

VIENNA, AUSTRIA

high level cars. These vehicles “are not able to” drive on our roads which have holes and minor unevenness. Badly placed road signs limiting speed contribute to even a bigger problem. Moreover, speeding cars “do not involve” weather conditions. Slippery roads that reduces wheel grip and limited visibility while high rainfall or fog as well as strong winds – are the reasons for not only collision but fatal accident;

- *Forcing right of way.* Rapid pace of life, rush, increased traffic in rush hours, traffic jams, a lot of delivery cars and heavy good vehicles on working days but also so-called Sunday drivers who drive slower (cautiously) – force those who more efficiently carry out maneuvers to overtake. It doesn't always happen in a safe way (lack of adjustment of time and place). In the most tragic circumstances frontal impact occurs;
- *Driving a vehicle under the influence of alcohol, drugs or other psychoactive substances.* Drunken drivers are a real nightmare. They are not aware of the fact that when they feel confident after drinking alcohol, they become threat to both themselves and the others. Alcohol makes driver's reaction longer. It results in fast and uncontrollable driving without paying attention to road signs and other traffic users. A new and dangerous group is constituted by drug users;
- *Inappropriate behavior of unprotected road users (pedestrians).* Pedestrians are the most common fatal victims of traffic accidents. The reasons for this are two-fold. The former are with regard to the fault of a pedestrian, for instance crossing on a red light, crossing at unspecified area, intrusion into a street, leaving the vehicle and at the same time preventing good visibility, presence of children on the street with no guardian. Pedestrians are not always aware of being losers and that they have no chances in a potential collision with a vehicle. The latter reasons are with regard to the fault of incautious people who do not comply with traffic rules or drunken drivers⁶;
- *Damage to a vehicle, failures.* Each make of a car, even coming from the most renowned company may break down. Currently, kit vehicles after repairs and with hidden factory defects pose a threat for potential accidents. Failure may occur in each moment of driving on the road and life of a driver, passengers and other persons being in the proximity of the incident is dependent on the driver's reaction.
- *Psychophysical state of a driver.* Research and everyday observation of vehicle users classify these people as:
 - ✓ safe drivers;
 - ✓ unreasonable drivers;
 - ✓ active drivers with limited attention;
 - ✓ passive drivers with reduced attention.

Psychophysical factors determine safe driving. They include temperament, age, eyesight, general health condition, fatigue, current professional or family situation, stress, fast decision making⁷.

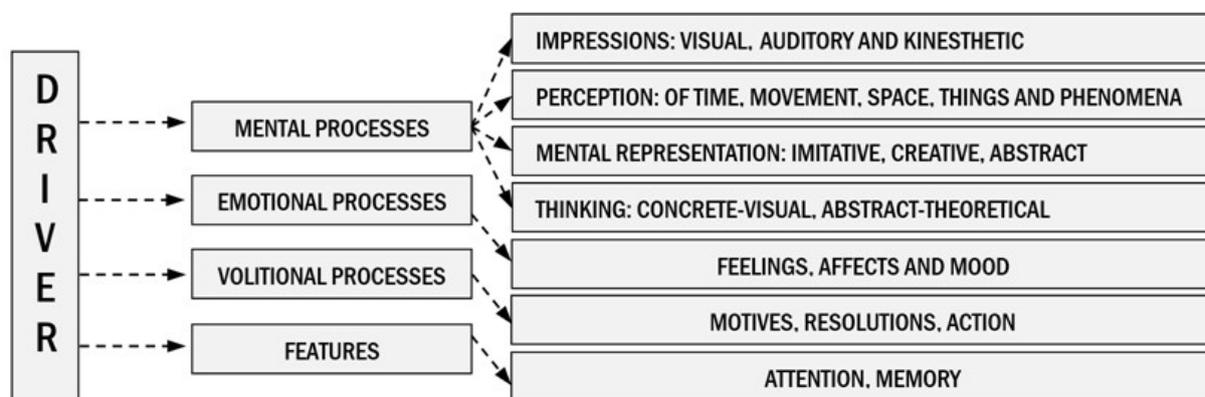
⁶ *Auto motives: understanding car use behaviours*, in K. Lucas, E. Blumenberg, R. Weinberger. (ed.) pub. Emerald Group Publishing, Bingley 2011, p. 26-31.

⁷ Dworzecki J. 2011. *Traffic in Poland. Diagnosis of safety components*, in Suja M. (ed.) Metodológia a metodika analýzy zdrojov ohrozenia vnútornej bezpečnosti SR, Bratislava: Academy of Police Force, p. 22.

3. Factors influencing a driver's action in traffic. The results of research

Safe participation in traffic depends on a degree of mental and physical development⁸. The elements of psychological provenance which have a significant influence on driver's decisions directly referring to the activities in order to increase traffic safety are cognitive processes (impression, perception, mental representation, thinking), emotional, volitional and other characteristics such as the influence of alcohol or drugs on a driver's organism).

Figure 2: Elements of human mentality which have a significant impact on driving a vehicle.



Source: Own elaboration.

3.1. Research group and results of international research. Selected aspects

The group participating in the survey was from Poland, the Czech Republic and the Slovak Republic. The survey was conducted between 10 January – 2 March 2019 in cities: Wrocław, Słupsk, Kielce, Szczytno, Katowice, Warszawa (477 respondents from Poland), Bratislava, Kosice (98 respondents from Slovakia), Prague and Zlin (67 respondents from Czech Republic). 642 respondents (61% men and 39% women) participated in the survey at the age of 19-71. The largest group was represented in respondents at the age of 25-35, which accounted for 33% of all surveyed. The survey was anonymous.

Table 1: Age comparison of respondents.

| Age of respondents | The number of respondents | % |
|--------------------|---------------------------|----|
| 19-24 | 180 | 28 |
| 25-35 | 212 | 33 |
| 36-45 | 64 | 10 |
| 46-55 | 103 | 16 |
| 56 and more | 83 | 13 |

⁸ Nepelski, M., 2014, *Gwarancje zarządzania kryzysowego : wybrane zagadnienia (Crisis management guarantess: selected issues)*, Szczytno: WSPol, p. 64-67.

2nd International Conference on SOCIAL SCIENCE, HUMANITIES & EDUCATION

21 - 23 JUNE 2019

VIENNA, AUSTRIA

Source: Own study.

Respondents were also asked about having a driving license.

Table 2: Experience respondents in driving cars.

| Experience in driving cars | The number of respondents | % |
|----------------------------|---------------------------|----|
| No experience | 39 | 6 |
| Less than 5 years | 83 | 13 |
| 6-15 years | 180 | 28 |
| 16-25 years | 205 | 32 |
| 25 years and more | 135 | 21 |

Source: Own study.

In an anonymous questionnaire the respondents were asked to indicate solutions in the field of law, organization and technical aspects and the individual characteristics of drivers which affect the level of road safety. Among the individual characteristics of drivers, respondents could select elements of personality such as: temperament, thinking, memory, perception, attention, driver's personality, eyesight and time of reaction. Respondents could mark only two from eight proposed.

Table 3: The most important individual characteristics of drivers – respondents' answers.

| Experience in driving cars | The number of respondents | % |
|----------------------------|---------------------------|-----|
| Temperament | 83 | 13% |
| Thinking | 148 | 23% |
| Memory | 19 | 3% |
| Perception | 26 | 4% |
| Attention | 161 | 25% |
| Driver's personality | 90 | 14% |
| Eyesight | 51 | 8% |
| Time of reaction | 64 | 10% |

Source: Own study.

According to respondents the most vital elements of personality (psychological and physiological features, driver's personality) which play a crucial role in safe driving consistent with traffic regulations and road as well as weather conditions are:

- *Attention.* Lack of attention is one of the main psychological factors leading to making mistakes by drivers and consequently to the occurrence of traffic incidents. This ability occurs dually as active or passive attention. Active attention is a conscious focus on any object at a certain time and with a defined aim. It involves psychosomatic engagement resulting in tiredness. Passive attention appears without conscious human intention and does

2nd International Conference on SOCIAL SCIENCE, HUMANITIES & EDUCATION

21 - 23 JUNE 2019

VIENNA, AUSTRIA

not require any effort⁹. Passive attention can make changing attention easier or difficult into active e.g. proper horizontal and vertical marking of streets should result in an immediate reaction in the form of activating active attention (raising awareness, enhancing concentration) waiting for a situation which is indicated by a sign. Characteristics of attention are decisive in making mistakes (severability, mobility, permanence, range and switch) – 25% of respondents' answers;

- *Thinking*. It is a higher degree of a cognitive process. It enables to reflect not only external features of perceived objects but also relations between them. In addition, it might be a cognitive activity aiming to solve a problem (theoretically or in action). While driving a car there are tasks which are new, a driver doesn't have a ready-made algorithm to deal with. A person must possess the ability to draw proper and adequate conclusions on the basis of a current analysis of the information available, e.g. a driver defines efficiency of device basing on knowledge of how it should normally operate – 23% of respondents' answers;
- *Driver's personality*. Taking selected, constant elements of psychological profile of each person into consideration, three categories in driver's behavior should be pointed out:
 - ✓ logical behavior;
 - ✓ illogical behavior;
 - ✓ irrational behavior.

In the category of logical behavior, a driver's actions can be predictable contrary to the other categories which result in doing unforced maneuver that in no way determines a situation on a road. Aggressive drivers are characterized by action inconsistent with logic which might be caused by restlessness, surprise or uncertainty. The author indicates greater, impulsive and irrational form of action e.g. when a driver performs maneuver inadequate to the present situation on the road without any reason or when a person behaves aggressively towards other participants of traffic¹⁰. The probability of a collision is rising. On the other hand, intelligent drivers can fully use their knowledge and skills and properly react for new tasks and situations. Appropriate analysis of thinking and interpretation of current information about traffic as well as making – based on experience – decision as to what maneuver to perform.

A separate category of behaviour of car drivers is the so-called Road rage. Road rage is aggressive or angry behavior exhibited by a driver of a road vehicle. These behaviors include rude and offensive gestures, verbal insults, physical threats or dangerous driving methods targeted toward another driver or a pedestrian in an effort to intimidate or release frustration. Road rage can lead to altercations, assaults and collisions that result in serious physical injuries or even death. Strategies include long horn honks, swerving, tailgating and attempting to fight the other driver¹¹ – 14% of respondents' answers;

⁹ *Human factors in traffic safety*, in A. Smiley. (ed.) pub. Lawyers & Judges Publishing Company, Inc. Tucson 2015, p. 122-127.

¹⁰ Hauer, E. 2015. *The Art of Regression Modeling in Road Safety*, Cham-Bazylea: Springer International Publishing, p. 93.

¹¹ Szlemko, W. J., Benfield, J. A., Bell, P. A., Deffenbacher, J. L., Troup, L., *Territorial Markings as a Predictor of Driver Aggression and Road Rage*, "Journal of Applied Social Psychology", pub. Blackwell, 2008, no -Wiley .1688-p. 1664 ,38

2nd International Conference on SOCIAL SCIENCE, HUMANITIES & EDUCATION

21 - 23 JUNE 2019

VIENNA, AUSTRIA

- *Temperament*. Personality traits of traffic participants often contribute to the reason of traffic accidents. In modern traffic, a driver should have a good health condition and proper features of intellect and character. Undoubtedly, they can be recognized at least in some way by means of specialized examinations. By doing this, persons who might cause dangerous situations could be excluded from traffic. In order to exemplify, psychopaths or people who are inclined to panic or aggression might be indicated. Claiming the specified characteristics represents lack of qualifications which are useful to participate in traffic. The above-mentioned conclusion refers also to persons who are temporarily in a condition which limits safe taking part in traffic. Here, such conditions can be distinguished as severe anxiety, anxiety disorders, state of significant weakening, tiredness, fatigue, psychometric disturbances as a result of drinking alcohol or taking medicines, limited physical ability because of dislocation or fracture of upper and lower limbs which has consequences in the reduction of physical performance of a driver – 13% of respondents' answers;
- *Time of reaction* comprises time needed to stop a car. It can be measured over time from the moment of stimuli appearance to the moment of doing the action which is a result of a stimuli. In order to assess a certain driver, average time of reaction is significant (average time of reaction appointed pursuant to series of measurements of the time of reactions for a particular stimuli) but also stability of reaction measured by a difference between the longest and the shortest time of reaction. The driver with a significant dispersion of the time of reaction may introduce more dangers in traffic – 10% of respondents' answers;
- *Eyesight* lets receive visual stimuli. It is related to the concept of seeing comprehended as the ability of spatial (stereo metric, stereomicroscope) perception of objects and distinguishing size, shapes, colours and movement. It enables to assess the distance and speed of vehicles being in field of vision well – 8% of respondents' answers;
- *Perception*. Is another significant element in information processing. This is a cognitive process connected with impressions and comprehension of the sense of objects and phenomena. A person who drives a vehicle receives a great number of visual, audible and other less important (e.g. thermal) stimuli. They form the uniform view with the necessity to draw attention depending on traffic situation – 4% of respondents' answers;
- *Memory*. This ability consists in the skill of reflecting experience in the past, being at the same time an important factor which enables a driver to behave in a right way especially in difficult traffic situations. Insufficient occurrence of the above-mentioned feature results in doubts in making decisions what consequently leads to making a mistake or slowing the beginning of an appropriate action and as a result of a dangerous situation while participating in traffic – 3% of respondents' answers.

Respondents from Poland and Slovakia was agreed about the most important factors affecting the behavior of drivers (attention: Polish respondents – 24%, Slovak respondents – 26%; thinking: Polish respondents – 23%, Slovak respondents – 23%; driver's personality: Polish respondents – 15%, Slovak respondents – 13%). In contrast, respondents from Czech Republic pointed within elements of personality which play a crucial role in safe driving: thinking 29%, temperament 24% and attention 21%. At this point it should be noted that in the countries from which the respondents came, there are differences in the number of hours of courses entitling to the acquisition of driving licences (category B – cars).

2nd International Conference on SOCIAL SCIENCE, HUMANITIES & EDUCATION

21 - 23 JUNE 2019

VIENNA, AUSTRIA

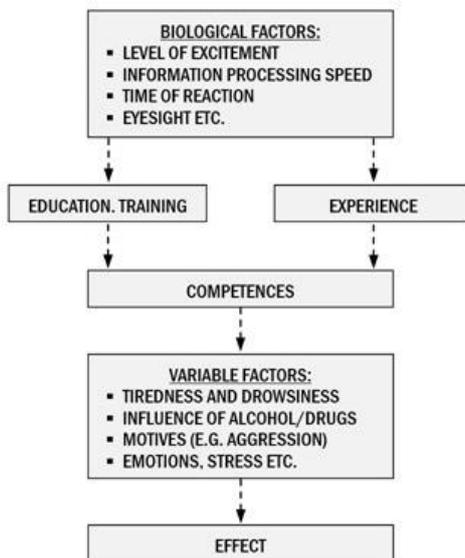
Table 4: Number of hours on driving licences in Poland, Czech Republic and Slovak Republic (category B – cars).

| Stage of the driving course | | Poland | Czech Republic | Slovak Republic |
|------------------------------|--|--------|----------------|-----------------|
| Theoretical classes | | 30 hrs | 36 hrs | 32 hrs |
| Practical classes including: | Classes on the simulator | - | 7 hrs | 6 hrs |
| | Classes on closed maneuvering square (parking test, U-turn, park in a parking lot) | 14 hrs | | 8 hrs |
| | Basic technic service by car | 2 hrs | 2 hrs | - |
| | First aid (practical classes) | - | 4 hrs | - |
| | Driving in urban traffic | 14 hrs | 21 hrs | 24 hrs |
| Total hours on the course | | 60 hrs | 70 hrs | 70 hrs |

Source: Own elaboration.

Many factors influence the behaviours of car drivers and therefore is an important issue the number of hours of practical classes in the frame of driving licences course. Increased number of practical classes it allows instructors to better know the candidates for drivers. This allows to exclude a unsustainable person which as drivers may pose a direct threat to other road users.

Figure 3: Factors influencing a driver's action in traffic.



Source: Own elaboration on the basis of: Carsten, O. Multiple perspective, in Human factors for highway engineers. Fuller, R., Santos, J.A. (ed.), pub. Emerald Group Publishing Limited, Oxford 2002, p. 78-91.

The respondents were also asked about proposed penalties for drivers under the influence of alcohol. Alcohol is one of the main reasons for traffic accidents. As a result of using, the driver records less number of optical impressions, has worse concentration span and less ease to draw attention to other point in space. Moreover, visual acuity is reduced, the field of vision is limited, susceptibility of glare is increased and the time of repetitive sight adaptation is prolonged to the conditions of visibility.

2nd International Conference on SOCIAL SCIENCE, HUMANITIES & EDUCATION

21 - 23 JUNE 2019

VIENNA, AUSTRIA

Furthermore, very dangerous is also impact in mental processes represented by excessive activity and talking as well as neglecting dangers, confidence coming from misjudgment. Courage is increased and it is accompanied by stem to motor discharge in the form of speeding. Additionally, in such situation sense of responsibility for actions is diminished and recklessness and carelessness are much higher. Research results show that at concentrations 0,2-0,3 per mille there is decrease in psychophysical capacity of a driver who in specific conditions may appear to be a contributing factor in case of an accident (e.g. sleet, fog or a sudden stepping on the street by a pedestrian).

With a total alcoholic strength within the limits 0,3-0,5 per mille there are criminal's psychomotor difficulties which can be checked. With 0,3 per mille causes impairment or intellectual function of brain disorder, impairment of attention, reaction time delay for new visual stimuli, disorders in muscular system.

Along with the occurrence of psychomotor disorders the probability of traffic accident is more likely. It is proved that the risk of causing a fatal accident in traffic occurs in case of alcohol level in blood 0,5 per mille doubled compared to driving a vehicle by a driver while sober. In addition, pedestrians in a state of alcoholic intoxication are threat for traffic creating significant reason for traffic accident. Accidents caused by intoxicated pedestrians take place:

- in built-up areas, cities with heavy traffic, where pedestrians do not comply with traffic rules and commonly made mistake is recklessly encroaching onto the roadway in front of a speeding automobile;
- at night, dawn and dusk, during the autumn-winter and winter-spring periods, when there is a limited visibility of pedestrians by other participants of traffic;
- at weekends, the biggest participation of drunken pedestrians takes place on Saturdays and Sundays;
- in late afternoons, between 6 p.m. and 10 p.m. whereas during night time between 10 p.m. and 4 a.m. the participation of intoxicated pedestrians is the highest.

In 2018, drivers under the influence of alcohol were responsible for 5.86% all accidents in Poland. In Slovakia this indicator in 2017 amounted to 3.9% and in the Czech Republic 4.3%. Respondents participating in the survey from among the four proposed legal solutions have chosen lifetime ban on driving vehicles for drivers being under the influence of alcohol.

Table 5: Proposals penalties for drivers under the influence of alcohol – respondents' answers.

| Proposals penalties | Poland | Czech Republic | Slovak Republic |
|--|--------|----------------|-----------------|
| <p>The high penalty payment (minimum 2000 euros)</p> <p>Currently, this penalty is maximally 1250 euros in Poland, 1300 euros in Slovakia, 1950 euros in Czech Republic</p> | 5% | 37% | 22% |
| <p>Penalty 5 years in prison</p> <p>Currently, the drivers being under the influence of alcohol may be sentenced in Poland for 2 years, in Slovakia for 3 years and in Czech Republic for 3 years. The execution of the penalty may be suspended.</p> | 12% | 9% | 7% |
| <p>Material punishment – confiscation of the vehicle</p> | 26% | 13% | 25% |

2nd International Conference on SOCIAL SCIENCE, HUMANITIES & EDUCATION

21 - 23 JUNE 2019

VIENNA, AUSTRIA

| | | | |
|---|-----|-----|-----|
| Lifetime ban on driving vehicles for drivers being under the influence of alcohol | | | |
| Currently, driving ban in Poland it's average 3 years, in Slovakia average 3 years and in Czech Republic average 4 years. | 57% | 41% | 46% |

Source: Own study.

Participants of the survey marked in the largest dimension total ban of driving vehicles, regardless of the cost this kind of solution, which may have significant economic consequences. Considering that the countries whose citizens participated in the survey undertaken all activities aimed at achieving a balanced budget, the introduction of this type of penalisation seems impossible in the coming years.

Citing the road as an element of safety system in traffic, it should be indicated that in the light of statistic data it is placed as the second (after a driver) "causal factor" responsible for number of traffic incidents. Constructive features of the road as well as its closest surrounding have decisive meaning in terms of ensuring safety for the traffic participants. This consists in road and thoroughfares construction which will be characterized by simplicity, regularity as well as homogeneousness of applied solutions what further on improves readability and comprehension by drivers and other traffic participants.

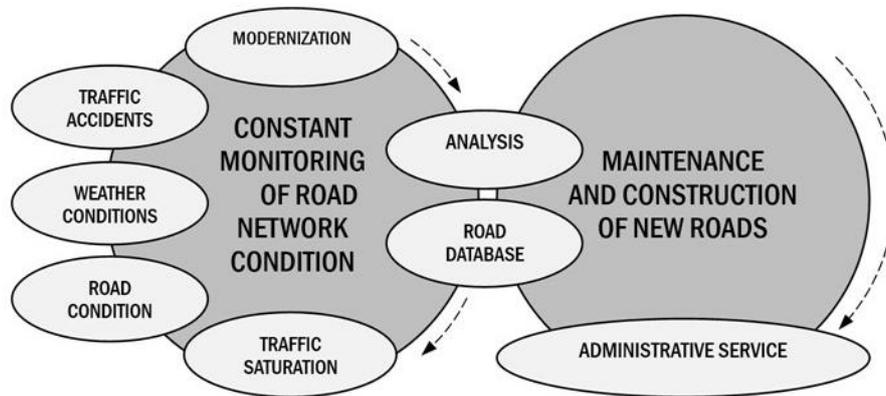
Respondents answering by one question in survey, indicated the best technical and engineering solutions that can improve road safety. In terms of the proposed solutions were included:

- Designing, building and modernizing road infrastructure with no collision intersections;
- Integrating and modernization information and technical systems used by the Police;
- The creation of road infrastructure for mobility autonomous vehicles;
- Full implementation (also in used vehicles) of the eCall system;
- Measurements of the vehicles speed on the road with using drones.

According to the respondents, currently the best technical and engineering solution will be designing, building and modernizing road infrastructure with no collision intersections. This solution was most often indicated (Polish respondents – 37%, Slovak respondents – 44%; Czech respondents – 31%). In contrast, the least indicated was the creation of road infrastructure for mobility autonomous vehicles (Polish respondents – 4%, Slovak respondents – 9%; Czech respondents – 7%). As follows from responses, efforts should be concentrated on modernization and development of currently road infrastructure, while the construction of a road network for autonomous vehicles is considered by the respondents a challenge for the future.

Constant monitoring of existing road networks, modernization of a system and development representing contrasting actions with systematic saturation of traffic will contribute to the limitation of the present risk for traffic.

Figure 4: Permanent elements which influence the process of traffic safety management.



Source: Own elaboration.

4. The correlation of the system of safety management including the procedure of risk management

Modern system of safety management (e.g. in land traffic) should perform at the level of organization management or in the area dealt with. Thanks to this, despite particular correlations it will be more general from the procedure of risk management.

The procedure of risk management should be, however, part of a modern and properly developed system of safety management. The situation lets considering formed conglomerate as one-way and repeated periodically procedure being a part of safety system management including risk procedure management.

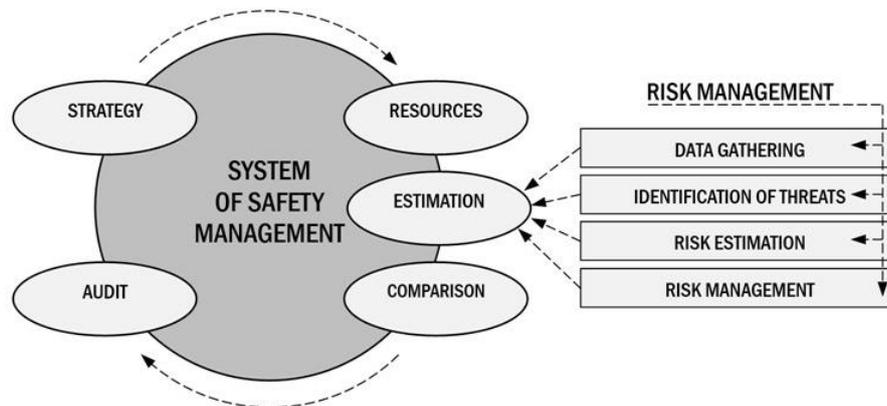
Another significant element of the road that directly has an impact on safety of traffic participants (drivers) is channel capacity. It is defined as the biggest number of units (vehicles or pedestrians) which in particular road and operational conditions can pass width of the road (street, enter to junction, pedestrian crossing, cycle path etc.) in units of time (1 hour). Channel capacity of the width of road or other element of road infrastructure depends not only on physical features but also on weather conditions and behavior of drivers.

Figure 5: The correlation of the system of safety management including the procedure of risk management.

2nd International Conference on SOCIAL SCIENCE, HUMANITIES & EDUCATION

21 - 23 JUNE 2019

VIENNA, AUSTRIA



Source: Own elaboration.

Another significant element of the road that directly has an impact on safety of traffic participants (drivers) is channel capacity. It is defined as the biggest number of units (vehicles or pedestrians) which in particular road and operational conditions can pass width of the road (street, enter to junction, pedestrian crossing, cycle path etc.) in units of time (1 hour). Channel capacity of the width of road or other element of road infrastructure depends not only on physical features but also on weather conditions and behaviour of drivers.

Road devices are also responsible for (active and passive) safety.¹² They should:

- minimize possible traffic fluidity;
- correct (at least partly – so-called forgiving road) mistakes made by traffic participants;
- minimize the effects of traffic accidents.

Another major factor of traffic incidents is bad working condition of vehicles. A vehicle is a crucial element of traffic and it is related to a certain risk of damage as far as its use is concerned. While defining risk in terms of traffic safety, it should be indicated that it is represented by the form of the quantity of frequency of undesirable incidents and consequences (results) which the incidents might result in.

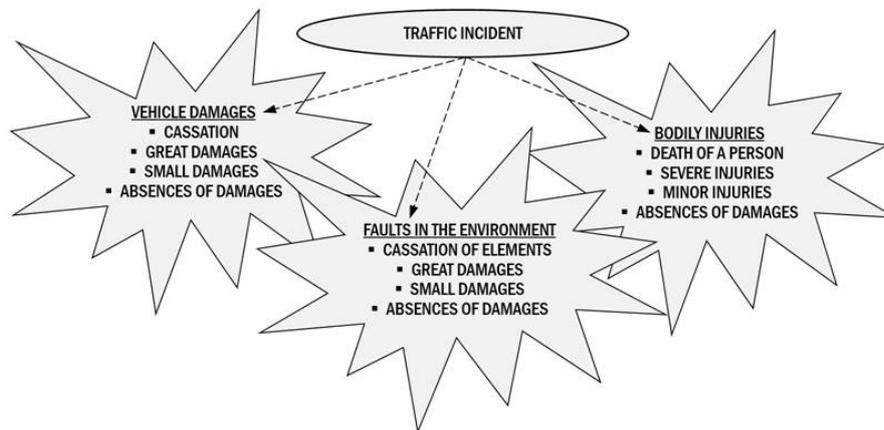
Figure 6: Classification of risk of damage resulting in the use of a vehicle in traffic.

¹² In road engineering the elements of *active* safety are devices which channel the stream of vehicles within, improve traffic flow and order of vehicles. Typical devices of active safety are road safety barriers, road barriers on bridges. As far as passive safety of road is concerned, any devices that allow for a decrease of probability of accidents matter significantly (light signal system, anti-glare shields, distracting screens, acoustic screens), or reduction of its effects (e.g. light posts, traffic lights which absorb energy of the vehicle crash in such a way that they are destroyed and deformed).

2nd International Conference on SOCIAL SCIENCE, HUMANITIES & EDUCATION

21 - 23 JUNE 2019

VIENNA, AUSTRIA



Source: Own elaboration.

In order to fix the risk of break-up in a certain category¹³ with reference to particular types of roads, the following formula is proposed:

$$R(k)_{i,j} = \frac{n_{i,j}}{N} \cdot 100\%$$

where:

$R(k)_{i,j}$ – risk of break-up of a vehicle in a certain category and on a particular type of the road;

$n_{i,j}$ – number of damaged vehicles in a certain category and on a particular type of the road;

N – general number of vehicles participating in traffic incidents;

$i = 1$ – refers to a national road;

$i = 2$ – refers to a provincial road;

$i = 3$ – refers to a municipal road;

$j = 1$ – refers to a damage of A category;

$j = 2$ – refers to a damage of B category;

¹³ For assessing the degree of damages, following categories for adoption are proposed: A category – *catastrophic* – fatalities, permanent disability, loss of system, environmental deterioration, estate devastation: vehicles after rollover or total destruction, damages of over 60 %, fatality – a person who died on the place of accident or within 30 days after the accident because of bodily injuries; B category – *serious* - a lot of injured persons, staff sickness, a serious destruction of a system as well as environmental deterioration: vehicles damaged to a large extent, damages within the limits of 31-60 %, seriously injured person – who suffered severe damage, incurable illness or chronic illness endangering life, permanent mental illness, inability to work (total or partial), important and persisting disfigurement or body deformity as well as injuries in the form of fracture, organ damage, serious cuts and lacerations; C category – *marginal* – few of injured persons and some cases of personnel illnesses, slight damages of the system and marginal environmental damages, vehicles with damage of a minor degree, damages to 30 %, a person slightly injured - i.e. with a detriment to the health other than defined in B category, damages of action of body organs or health impairment for a period lasting not longer than 7 days issued by a doctor; D category – *negligible* – healthcare personnel is not engaged, damages of the system and environment such small that they may be tolerated: the absence of damages to vehicles or the absence of bodily injuries. Source: Own elaboration.

2nd International Conference on SOCIAL SCIENCE, HUMANITIES & EDUCATION

21 - 23 JUNE 2019

VIENNA, AUSTRIA

$j = 3$ – refers to a damage of C category;

$j = 4$ – refers to a damage of D category;

However, undertaking action aiming to determine the risk of bodily injuries of traffic incidents (including the category of an incident and type of a road) proposed formula is as follows:

$$R(c)_{i,j} = \frac{m_{i,j}}{N} \cdot 100\%$$

where:

$R(c)_{i,j}$ – the risk of occurrence of bodily injuries in a certain category and on a particular type of the road;

$m_{i,j}$ – the number of injured persons in a certain category and on a particular type of the road;

M – general number of persons participating in an incident;

$i = 1$ – refers to the national road;

$i = 2$ – refers to the provincial road;

$i = 3$ – refers to the municipal road;

$j = 1$ – refers to a damage of A category;

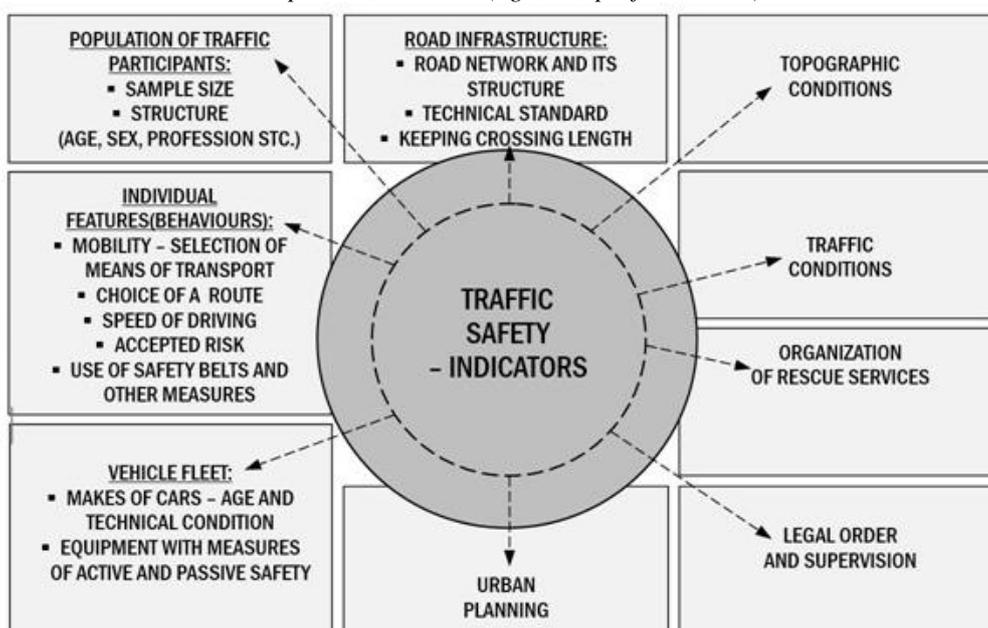
$j = 2$ – refers to a damage of B category;

$j = 3$ – refers to a damage of C category;

$j = 4$ – refers to a damage of D category.

Accident rate and traffic safety are phenomena of which description involves inclusion of the entire complex of reasons and circumstances of the accidental event. The most significant groups of factors influencing traffic safety are presented below.

Figure 7: The most significant groups of factors influencing traffic safety. Population of traffic participants: sample size; structure (age, sex, profession etc.).



Source: Own elaboration.

2nd International Conference on SOCIAL SCIENCE, HUMANITIES & EDUCATION

21 - 23 JUNE 2019

VIENNA, AUSTRIA

5. Conclusions

The aim of the program of the improvement of road safety on European roads which was adopted by the European Commission for the years of 2011 – 2020 is halving the proportion of fatalities¹⁴. The programme takes on a genuine dimension inter alia aiming to improve safety of vehicles, infrastructure and change in traffic participants' behavior.

In the document there are seven strategic aims (without indicated time frames for the realization of particular actions):

- improvement of security systems in vehicles;
- construction of safer road infrastructure;
- speeding up Intelligent Transport Systems;
- improving training system for traffic participants;
- better enforcement of current legislation;
- reducing the number of road injuries;
- a new attitude to motorcyclists.

According to the results of researches surveyed by the Barometer (international public opinion survey), the improvement of infrastructure should be top priority (52% of respondents expressed such opinion), more effective enforcement of current rules of Traffic code (42%) and introduction of identical regulations for both national and foreign drivers (36%). Such a point of view partly supports the results of the research project called „Simulator supporting police officers' training in the implementation of activities during a road accident” no. DOB-BIO9/06/01/2018, which has received funding from the Polish National Centre for Research and Development. The results of the survey conducted as a part of this project in three European countries also indicate the expectations of citizens who see the need for modernization and development road infrastructure, tightening penalties especially for drivers being under the influence of alcohol (or drugs and other psychoactive substances) and introducing organizational changes in the training of candidates for drivers.

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¹⁴ Valletta Declaration on Road Safety, 29 March 2017 Valletta.

2nd International Conference on SOCIAL SCIENCE, HUMANITIES & EDUCATION

21 - 23 JUNE 2019

VIENNA, AUSTRIA

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