

road, safety, risk, accident, risk indicators, risk criteria

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SAFETY AND RISK IN ROAD TRAFFIC: SELECTED PROBLEMS

Summary. In the field of road safety, the concept of "risk" is used to define a measurable level of road safety dependent on numerical accident exposure value. This is an approach different (even contradictory) to calculate the level of security, measured by the number of accidents or injuries. So, whether otherwise - risk assessment is needed to improve the safety of road transport and define priorities in the field of public health. The article presents the concept of risk and selected problems of risk analysis in road traffic.

BEZPIECZEŃSTWO I RYZYKO W RUCHU DROGOWYM: WYBRANE PROBLEMY

Streszczenie. W dziedzinie bezpieczeństwa drogowego pojęcie „ryzyka” jest używane na określenie mierzalnego poziomu bezpieczeństwa drogowego zależnego od liczbowej wartości „ekspozycji ryzyka”. Jest to podejście różniące się (a nawet przeciwstawne) do obliczania poziomu bezpieczeństwa mierzonego przez liczbę wypadków lub obrażeń ciała. Tak, czy inaczej - ocena ryzyka jest potrzebna do poprawy bezpieczeństwa transportu drogowego i zdefiniowania priorytetów w obszarze zdrowia publicznego. W artykule przedstawiono koncept oraz wybrane problemy analizy ryzyka w ruchu drogowym.

1. INTRODUCTION

The proper functioning of transport systems depends to a large degree on efficient management. It should make the transport system highly functional, pro-ecologic, economically optimal and, above all, safe. Effective management of safety is management by objectives, i.e. the kind of management system, which basic principle is: "we manage safety" by "risk management".

There are worked out a variety of organizational, technological and transport systems management standards; mainly air and rail. Meanwhile, the road transport generates the greatest social costs, including the costs of road accidents, the costs of environmental degradation and the congestion costs. One of the four main objectives of the management of road transport is the desire to minimize the number of road accidents, in particular limiting the number of heavy accidents. And this is the issue of road safety management. A reminder of the central place of road transport on the "map of transport safety researches"- was second motivation to write this paper.

In the field of road safety, the concept of "risk" is used to define a measurable level of road safety dependent on numerical accident exposure value. This is an approach different (even contradictory) to calculate the level of security, measured by the number of accidents or injuries. So, whether otherwise

– risk assessment is needed to improve the safety of road transport and define priorities in the field of public health [1].

2. ROAD TRANSPORT AS A SYSTEM WITH HIGH POTENTIAL OF RISK REDUCTION

A good measure of the effectiveness of risk management in transport is external costs of transport. This system, which generates higher costs, has a greater potential of their reduction. Road transport generates the greatest costs and, therefore, it is the system through the effective risk management can be obtained relatively larger reductions to all identified risks. Hence the thesis: road transport as a system of relatively high risk reduction potential. Perhaps paradoxical is that it is this type of transport - in contrast to the other – there was not so far a coherent methodology for risk management. This is one of the reasons for which this chapter of the book was written. And here are some arguments proving the primacy of road transport for the generation of risks to the safety of humans.

1. Road safety is a major problem for public health; every year about 1-1.2 million people are killed on the roads, which is about 2% of all deaths; more than 50 million per year are injured in road accidents, which represents 22.8% of injuries [2]; even before the 2000 year global costs of road accidents was estimated approximately 1% of the gross national product (GNP) in low-income countries, 1.5% in middle-income countries and 2% in high-income countries.
2. The total external costs of road transport in the European Union in 2001 were around 260 billion euros. In this amount are costs of accidents, congestion, air pollution and noise. The most important component of costs are the costs of road accidents (58%); the congestion costs (19%); the emission costs (15%); the noise costs due to road traffic will have a share of 8%. Costs of congestion are estimated for approximately 0,5% of GDP, that is 30 billion euro a year; forecasts for 2010 year provided to the increase of up to 80 billion euro [3].
3. Indicators of freight road transport, which in the European Union remained (the years 1995-2009) from about 1300 to 1900 billion tonne-km and was higher than the rate for maritime transport, and much higher than the rate of other modes of transport; for example this indicator for railways was at around 390 – 460 billion tonne-km [4].

Of course, there are many other arguments that road transport is the most dangerous and “dirty”. This is a known issue - therefore it is illustrated by few statistical indicators.

Table 1

Indicators of accidents in passenger and freight transport, Poland, 2007 [5]

Transport mode	passenger transport				freight transport	
	Number of casualties 10 ⁶ passengers		Number of casualties 10 ⁹ person-km		Number accidents per 1x10 ⁶ tonne	Number accidents per 1x10 ⁶ tonne-km
	fatality	injured	fatality	injured		
road	0,32	3,62	18,02	204,93	44,83	0,41
rail	1,15	1,04	16,45	14,82	1,59	0,01
water	-	-			0,22	0,0
air	3,54	7,48	1,98	4,19	2225,0	0,97

In the table below the simple risk index values of accident fatality [6].

Table 2

The probability of fatal accident

Probability of accident fatality in year			
road	water	rail	air
$2 \cdot 10^{-4} - 2,5 \cdot 10^{-4}$	$2 \cdot 10^{-5} - 8 \cdot 10^{-5}$	$1 \cdot 10^{-5} - 5 \cdot 10^{-6}$	$7 \cdot 10^{-7} - 2,5 \cdot 10^{-5}$

Table 3

Deaths per billion kilometers [7]

air	bus	rail	van	water	car	bicycle	foot	motorcycle
0,05	0,4	0,6	1,2	2,6	3,1	44,6	54,2	108,9

The prism of road transport in the area of generating of external accident costs confirmed various indicators; in particular this applies to average accident costs, table 4. Accident cost is a function of accident rate and accident severity, which in turn depends on the efficiency of the management of the road accidents risk; it must be here a reminder about relationship "risk - costs". In the analysis of costs of transport accidents is known "risk approach" - a technique for valuing external accident costs, where lower costs are like "premium" for the avoidance of risk factors and vice versa. With this approach is bound the index Value of Statistical Life (VSL).

Table 4

Average accident costs (2000) [8]

road	rail	aviation	Over all	road	rail	aviation	waterborne	
Passenger transport [Euro/10 ³ pkm/a]				Freight transport [Euro/10 ³ tkm/a]				
32,4	0,8	0,4	22,3	7,6	0,0	0,0	0,0	6,5

Economic costs of road crashes, as a% of GDP created at 1.59% level (Australia, Victoria; method: human capital approach) to 4.9% (Canada; method: willingness to pay, based on costs of one province). In EU leaders countries in terms of road safety – costs are as follows: 1.7% (Great Britain, 2004; method: willingness to pay and economic loss for direct costs); 2.54% (the Netherlands, 2003; method: the total costs traffic crashes); 2.0% (Sweden, 2001; method: cost of illness, willingness to pay). For comparison in the United States in 2000, these costs amounted to 2.3% of GDP, used mixed approach [9].

3. THE SPECIFICITY OF ROAD SAFETY RESEARCH

Road traffic is a very difficult object of study. It is a process: 1. spatially and temporarily nonstationary, 2. has a nature of self-organization process, 3. carry out in it difficult decision- tasks situations and there are often small safety margins.

On the other hand, there are certain regularity, which may facilitate the analysis and traffic management: 1.demand for traffic has often repetitive character, hence observed cyclicity; 2.traffic on the road network has in the long term trend to stabilize the structure of the motion, as a result, participants in traffic set their preferences of road choice for traffic needs.

Road traffic can be interpreted as a phenomenon of great complexity which is not subject to the simple laws, and often you can observe the paradoxes negative of intuition or common health. Examples that illustrate the opinion are many. For illustration, several special problems showing multi-aspects of road safety issues. (1) Methodology for limiting transport congestions, particularly bottlenecks requires opposite strategies of than tells intuition; for example, turning off some lanes of traffic. The effectiveness of this strategy is confirmation of Braess' paradox, who in 1968 has calculated that increasing the throughput of the network of roads not only increases its productivity, but it restricts, [10, 11]. (2) Another interesting problem is associated with systems of forecasting the traffic intensification on roads. Prognostic information about impediments in traffic on a particular chunk of road goes to road users, and those responding, looking for detours; the same forecast proves to be false. This recalls the negative feedback in cybernetic set. (3) The Phenomenon observed in dense road traffic is the "butterfly effect" which is described in chaos theory. In traffic this effect is achieved as a result of the shock wave, (shock front), which source can be a single disturbance of traffic, for example a sudden braking or changing lanes. This phenomenon is trying to be used for prediction of congestion on roads [12]. (4) In the analysis road traffic in urban networks more

willingly goes back to the fundamental relationship between supply and demand, known in economics. This approach is used to design of electronic systems for charging for entry into the most jammed streets during peak hours, so that the demand is highest. (5) The concept of shared space concept borrowed inter alia by Hans Monderman to enforce safe behavior of road users [13]. It appears that, for example, the complete removal of conventional means of regulating and controlling traffic in the city (road signs, traffic lights) and replace them with one simple principle "give way from the right side", results in an increase in road safety. Seemingly irrational strategy has yielded good results. Explanation is simple: drivers and pedestrians began (because they had to) be careful. And simple conclusion on the issue of modeling and testing of such complex phenomena as road traffic: sometimes the simplest solutions are most effective. Future road risk management methodology must increasingly take into account all known aspects of road traffic, namely: physical, psycho-social and economic. May also discard strategy seemingly paradox.

4. POLICIES FOR ROAD TRAFFIC SAFETY

Technical progress and changes in lifestyle, including travel, cause inter alia changes in human mobility model. This was the cause of the increase in motorization and an increase in the average number of kilometers driven per year. One of the many different effects of the intensification of traffic was the increase in the number of road accidents. A response to those phenomena was, inter alia, planning of the various road safety strategies. In Europe from a long time the best achievement in this regard are in the Netherlands, Sweden and United Kingdom. In the following figure are shown next approaches and strategies for road safety, used from the 1950s of the 20th century in the Netherlands. Similar strategies are applied in Sweden and the UK [14, 15]. Interesting comment, which explains a historical sequence and context of the road safety strategy in these three countries, gives Meng Lu in his work: „The need for such successive sets of measures can be partly explained from the economic law of diminishing marginal returns, which implies decreasing marginal effects of additional investments in a certain measure for improving road traffic safety beyond a certain level of implementation”. Another explaining factor is technological development it-self, which creates an evolution of requirements for traffic safety measures and of possible solutions”, [16, 15]. Let us add that the European Union established the basis for its road safety policy in the year 2001 [17].

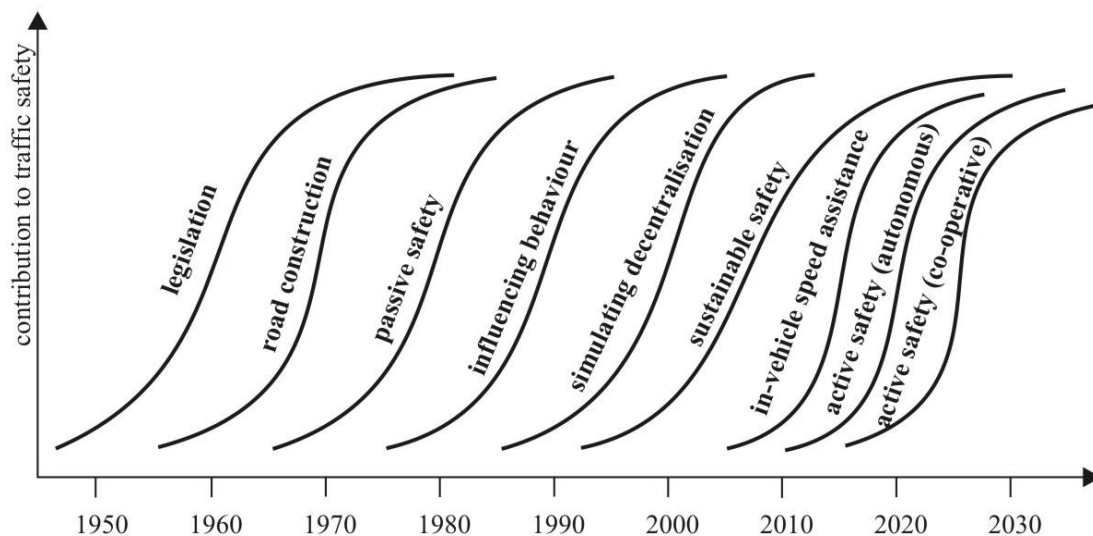


Fig. 1. Conceptual view on traffic safety policy development in The Netherlands

Rys. 1. Przegląd koncepcji rozwoju polityki bezpieczeństwa ruchu [drogowego] w Holandii

5. SAFETY AND RISK IN ROAD TRAFFIC: BASIC CONCEPTS, DEFINITIONS, MODELS

There are not known the definition of the term "road safety" expressed explicit. However, there are several "specifiers" of this concept. Often is used the terms "traffic safety", which, however, is a general term and can refer to the safety of all types of traffic: air, rail, road [18]. Similarly, as another general definition: "safety of transport is the most important principle of each operating transport system; it is a basic component of all metrics of success " [19].

And here is another interpretation of „traffic safety”: *“Term that is related to the negative performance of the traffic system to generate traffic accidents that involve injury or fatality. At the individual level, traffic safety is related to the absence of danger and experience of security”*. The same author gives a definition of the concept “traffic system”: *“Systems theory view used to describe the processes of the traffic system as dynamic and complex interactions between and among elements at various levels. The three main elements are usually identified as: the roadway infrastructure, the road-user, and the vehicle”* [20]. And another conception – “safety continuum”: theoretical concept inferred in relation to the use of proximal safety indicators whereby all interactions are placed on the same scale with safe passages at one extreme and (fatal) accidents at the other [20]. It appears that "information noise" does not cover only the definition of „road traffic safety”. For example, the definitions of such key concepts as „road accident”, collision, crash, incident, near-accident, fatal accident, safety critical event, injury accident, accident severity, traffic violation and many others – are different depending on the source, [20 - 23].

Traffic "produces" different states of threats and adverse events, and some of them may be recorded. In particular it relates to near misses are the best available proactive predictor of safety [3]. The first classification of events preceding the incidents concerned industry and was presented in the form of a model of the triangle, from the name of the author called later as Heinrich’s Triangle, [24]. Below the modern "road" version of Heinrich’s triangle [3]. Hypothetical frequencies of "road events" comes from the many empirical studies, but they should be interpreted cautiously: driver error without hazard (1.000.000) = driver error with hazard (100.000) = near misses (10.000) = minor injury (1.000) = serious injury (100) = disabling injury (10) = fatal (1).

Basic dimensions of traffic safety. The easiest way road safety problem can be written in the following formula: the traffic safety problem = exposure x risk x consequences.

This record was the first time used in a simple descriptive model [25]. There were introduced the concept of "three basic dimensions of traffic safety":

1. (risk = accidents/exposure) or risk = (injures/exposure);
2. consequences = (injures/accidents) or consequences = (fatalities/injures);
3. exposure (exposure of risk), defined by the measurement of exposure to accidents.

These three dimensions can be described on the Cartesian axes and unbind a cuboid, which will symbolized a quantitative picture of the road traffic safety [26, 25].

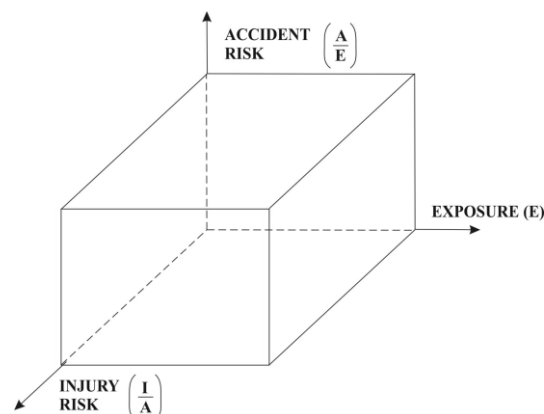


Fig. 2. Idea “three basic dimensions” of road traffic safety

Rys. 2. Idea “trzech podstawowych wymiarów” bezpieczeństwa ruchu drogowego

6. THE CONCEPT OF RISK IN ROAD TRAFFIC

One of the earlier definition of risk in road traffic, which has proposed Hauer as the likelihood of an accident, [27]. Later F.A. Haight has added to the definition of the risk another element, i.e. "the effects of road event" [28]. Still later was adopted in researches road safety, used in other fields definition of risk as "a combination of the likelihood or frequency of the threat and magnitude of the consequences of the threat" [29]. In the activities of the European Road Safety Observers (ERSO) adopted the general definition of risk discussed in the working [1], which comes from practical approaches: „a risk is the expected road safety outcome, given a certain exposure. The outcome is usually the number of accidents or victims of a certain type, but fundamentally need not be. For instance it could also be monetary loss due to the socioeconomic consequences of road accidents” [30]. Interpretations of risk on the road are many; for example, several other definitions:

- risk: an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives [31];
- risk: quantified the expression of uncertainty and the harmful effects of danger [32];
- risk: the possibility of an unwanted event occurring [33];
- accident risk: risk for accident involvement (for different road-user classes). Objective risk reflects accident frequency in relation to a measure of exposure or population [20];
- accident risk: probability of an accident to occur per unit of exposure [15].

7. ROAD SAFETY RISK INDICATORS

Measurable effects of risk in road traffic can be a variety of size, and the general definition of road safety risk indicator is as follows:

$$\text{risk} = \frac{RSO}{E} \quad (1)$$

Where: RSO - road safety outcome; E - amount of exposure (risk exposure). By such interpretation - risk indicator shows how many adverse events (for example road accidents) fall on unit of exposure (exposing themselves to risks in road traffic). Which means that in the same exposure E, the risk is increasing function of RSO. Which is of course not revealing, but you should understand the regularity.

Because road accidents are "product" (final outcomes) of a road traffic system - therefore RSO is typically the number of accidents or casualties (fatal accidents, accidents with hospitalised or fatally injured victims, fatalities, persons injured). However, interpretations of risks exposure E are based on different sizes; the selection must be dictated by such features as: availability, comparability and usability of risk and exposure data. Due to the fact that to estimation of road risk, you can use different size of RSO and E, the number of road safety risk indicators is big, [20, 34, 30, 35, 36]. Let us take, for example, the accident rate: "*Accident rate (collision rate) — The number of accidents (collisions) per unit of exposure. For an intersection this is typically the number of accidents divided by the total entering Annual Average Daily Traffic (AADT). For road sections this is typically the number of accidents per million vehicles per kilometers or miles traveled on a section*" [37]. Very similarly defines Safety Performance Function (SPF). This function expresses the relationship between the sizes of the AADT and the safety of the road; it is defined as the number of accidents per unit of time and the length of road, [38, 39].

There is not a general rule of selection the best measure of exposure E. And may not be one measure of exposure E. Let's give one example: when you apply to calculate the risk population data as a measure E, then the calculated risk indicator provides unduly a higher rating position to countries with low indicators of motorization, [40]. You must therefore make such calculations with another risk factor. Most common - somewhat arbitrarily - exposure measures are divided into two groups:

- traffic estimates: road length, vehicle kilometers, fuel consumption, vehicle fleet;

- persons at risk estimates: person kilometers, population, number of trips, time in traffic, the driver population.

In Europe apply are exposure measure based on the following specifications of traffic system: (1) population, (2) vehicle fleet, (3) road length, (4) fuel consumption, (5) driver kilometers and (6) vehicle kilometers. Calculated on the basis risk indicators are compatible with CARE (Community Road Accidents Database) and are usable for EU road safety risk comparisons, [36]. There are many classifications, lists, bills of road safety indicators. Attempting to develop standards in this area are undertaken for a long time, an example is table 5, where (abbreviated) are shown risk indicators most frequently chosen for analysis of road safety.

Table 5

Risk indicators in international data files [30]

Risk indicator /general/	International data file (IDF)				
	EUROSTA T	ECMT	UNECE	IRTAD	IRF
Accidents per inhabitant				x	
Accident per vehicle-km				x	x
Fatalities per inhabitants	x	x	X	x	
Fatalities per licensed drivers					
Fatalities per vehicles		x		x	
Fatalities per vehicle-km				x	x
Injured per inhabitants	x				
Injures per licensed drivers					
Injures per vehicles				x	
Injures per vehicle-km				x	

(ECMT): The European Conference of the Ministers of Transport (ECMT); (UNECE): The United Nations publishes since 1955, through its Economic Commission for Europe (UNECE); (IRTAD): The International Road Traffic and Accident Database; (IRF): The International Road Federation (IRF).

Of course, a list of road risk indicators is much wider; you can also add to it the following indicators [41].

The primary issue in the analysis of risks in road traffic is to establish a coherent list of "dimensions" and "road safety" indicators, i.e. size, preferably characterizing level and possibilities of controlling the risk in road traffic, which already belongs to the problems of road risk management. One of the most interesting results is an integrated benchmarking model called Road Safety Development Index (RSDI) [18].

Three-dimensional theory of road safety description: exposure – consequences – the risk may be presented in the form of a chain of factors (safety measurements), where the numerator is always the last factor which relates to described safety situation. Such a quantitative record of safety in road traffic can be called ratio chain expansion. This tautology was presented in work [42]. According to this idea - the number of fatal road accidents per number of inhabitants can be expressed as a chain of products containing: the approximate value of the average threat per inhabitant, road accident indicator and number of fatalities in the accident [34]:

$$F/I = (E/I) \cdot (A/C) \cdot (F/A) \quad (2)$$

where:

F – number of fatalities; I – number of inhabitants of the area

E – risk road exposure (a measure of exposure to road threats); A – number of road accidents in the area.

The above assessments of risks in road traffic are the introduction to the evaluation of risk - an important stage of risk management process. The main question here is: what is the acceptable level of risk? The unambiguous answer is impossible. Each level of risk, other than zero is arbitrary and

questionable. In addition: speaking about acceptable level of risk you should distinguish between the different types of risks; personal, social, voluntary, etc. What level of risk is acceptable for an individual user of transport who is traveling to a certain destination by specific means of transport? What is the acceptable risk for society as a whole, in other words, how many accidents or injured persons per year - the public is able to accept in transport systems? These are fundamental questions. There are more.

8. SAFETY PERFORMANCE INDICATORS (SPI)

Monitoring the various characteristics of road traffic, in particular the behaviour of road users helps explain how does the risk change in road traffic. Here is the definition of the SPI, to explain how does the risk in road traffic. Here is the definition of SPI: *“Safety performance indicators (SPIs) are measures (indicators), reflecting those operational conditions of the road traffic system, which influence the system’s safety performance. Basic features of SPIs are their ability to measure unsafe operational conditions of the road traffic system and their independence from specific safety interventions. SPIs are aimed to serve as assisting tools in assessing the current safety conditions of a road traffic system, monitoring the progress, measuring impacts of various safety interventions, making comparisons, and for other purposes”* [43]. The methodology of the SPI is developing in countries of the European Union in seven problem areas in road safety: 1. alcohol and drugs; 2. speed; 3. protective systems; 4. daytime running light; 5. vehicles; 6. roads; 7. trauma management.

Indicators of risk in road traffic can be also found in the group of indicators for sustainable transportation planning. These indicators are its role in creating policies of planning sustainable transport. A lot of information about this type of indicators yields, for example, publications, [37, 44].

9. EVALUATION PROBLEMS OF RISK IN ROAD TRAFFIC

At the stage of assessing risk is essential to choice of criteria for the evaluation of risk. Such criteria always refer to the difficult problem of social acceptability of risk. There is no developed methodology and standards for valuation risk in the field of transport. Specific applications find known general criteria. The process of risk evaluation must have some points of reference - basic of them are: experience and provisions of laws and standards. Keep in mind, however, what is written for a long time - that new transport risks affect on change the rights and standards so far in force [45]. There are known many practical principles for evaluation and acceptance of risk; some of them can be applied in the field of road transport:

1. in the case of a risk of serious accidents, seeks to maintain the level of safety not worse than in other countries;
2. “daily risks” should not increase significantly as a result of human participation in road traffic;
3. when planning road transport investments are required tests whether there are alternatives, so you get the same transport effect with lower risk;
4. means to improve road safety (or wider transport) should be invested where they bring the best results (economic);
5. for the evaluation of risk in repetitive situations it is necessary to use professional experience;
6. professional standards - their weight is considered in each procedure of risk acceptance;
7. in-depth principle: the principle according to which no safety mean is perfect and therefore requires the application of several protective measures (barriers, layers);
8. Risk Cost Benefit Analysis, (RCBA) - the principle of recognizing "risk" for economic category.

10. CRITERIA FOR EVALUATION AND ACCEPTANCE OF RISK. IMPLEMENTATIONS FOR ROAD TRANSPORT

In the risk assessment are used two basic methods: 1. reference method, 2. substitution method. In more commonly used reference method is compared the calculated risk with a known and accepted individual and group risk or level of risk of natural hazards. Most risk area is divided into three levels:

1. acceptable risk: "a risk, which for the purposes of life or work, everyone who might be impacted is prepared to accept assuming no changes in risk control mechanisms" [46];
2. tolerable risk: is defined by [47] and adapted from [48] as "a risk within a range that society can live with (1) so as to secure certain net benefits. It is (2) a range of risk that we do not regard as negligible or as something we might ignore, but rather as something we need to (3) keep under review and (4) reduce it still further if and as we can.";
3. Unacceptable Region (risk cannot be justified except in extraordinary circumstances).

Risk selection shall be made between widely accepted risk and unacceptably risk. Between these two limits risks there is "tolerable area of risk" to which are used criteria for acceptance of risk.

ALARP (As Low As Reasonably Practicable) was introduced by the Health and Safety Executive [49]. According to this principle - the best is choice so "low-risk as it is practically reasonable". In the ALARP model "area" of risk increase is divided into three areas/regions [50]:

1. Broadly Acceptable Region (Risk is tolerable without reduction. But it is necessary to maintain assurance that it remains at this level);
2. ALARP or Tolerability Region (Risk is tolerable only if its reduction is impracticable or if the cost of reduction is grossly disproportionate to the improvement gained);
3. Unacceptable Region (Risk cannot be justified except in extraordinary circumstances).

Areas 1 and 2 are divided into broadly acceptable threshold, while areas 2 and 3 divides limit of tolerability threshold. In transport interpretation ALARP rule would be as follows: technical condition of means of transport, transport infrastructure elements, working processes (for example road traffic) – are so safe, as far as the estimated risks for them - separately and all together - "as low as it is practically reasonable". Risk control is then keeping residual acceptable at level of acceptable risk, such as a specific indicator ERSMR, calculated for the data from a specific year (period of time).

Generally the level of residual risk is determined by different methods, for example: methods of preferences studies for applying the expert techniques by Risk Cost-Benefit Analysis. In most European countries maximum accepted individual risk is 10^{-6} per year, while group risk is 10^{-5} per year. The ALARP criterion was applied, inter alia, in rail transport in Great Britain and the car and rail transport in Switzerland [51].

French rule GAMAB - Globalement Au Moins Aussi Bon, or in english Globally As Good As Exciting: safety is comparable to the equivalent system. According to this criterion, a new or modernized transport system cannot give greater risk than technical-exploitation risk of functioning equivalent transport systems. The above rule is sometimes presented in a version of GAME-Globalement Au Moins Equivalent, where it is required that any change in the system would not lower its safety. So this principle formally introduces the current level of safety as a point of reference and makes it an absolute criterion. At least three countries of the European Union apply this criterion to risk estimation and determining aims in transport safety programmes [52].

According to German criterion MEM - Minimum Endogenous Mortality new technical or organizational solutions in a system (for example road transport) cannot "significantly" increase the mortality of any social group because of functioning or of this system. It means that risk cannot be increased, which results in mortality higher than "reference mortality", i.e. the lowest mortality rate in the 13 age group of boys. MEM criterion means that individual acceptable risk of death should be less than a set limit. In case when risk is increased as a result of the creation of a new technical installations (e.g. new transport investment) acceptable individual risk of death can be inversely proportional decreased to the number of endangered people. It seems that this risk indicator can be used especially in risk transport analysis of particularly dangerous goods.

ALARP, GAMAB, MEM criteria are recorded in many standards of safety, for example in functional safety standard CENELEC, where risk evaluation commit by Safety Integrity Levels (SIL)

concept divides safety requirements into classes ranging from 0 (no safety requirements) to 4 (highest safety requirements). The MEM criterion tried to use for evaluating of individual risk of death in road traffic. The calculated rate of 10^{-4} [person/year] was based on the following data: 1. the total number of accidents per year; 2. the total number of vehicles in motion; 3. average annual mobility, i.e. the average annual number of driven kilometers [53]. In comparison with MEM criteria, which is 2×10^{-4} [person/year], this is a similar level of risk. Risk determined by MEM as acceptable at 10^{-6} level [person/year], i.e. 10^{-10} [person/hour]. If refer this rate to single vehicle in road traffic, this would be 10^{-7} [per vehicle/year]. GAMAB ALARP and MEM principles were used in creating methodologies for evaluation of the safety systems used to avoid collisions in traffic, i.e. AVCSS systems (Advanced Vehicle Control and Safety Systems) [54].

11. CONCLUSION

Yet, several tools have been developed to safety modeling and safety assessment. It can be conventionally classified using the following criteria [55]: (1) format, specifies whether the method is a database, data analysis tool or data mining tool (D), generic term (G), mathematical model (M), integrated method of more than one technique (I), specific technique (T); (2) purpose, specifies the primary purpose of the method, i.e. whether it is a risk assessment technique (R), human performance analysis technique (H), hazard mitigating technique (M), organization technique (O), training technique (T), hardware dependability technique (Dh), software dependability technique (Ds), design technique (D), which is aimed at design rather than analysis; (3) safety assessment stage, which lists the stages of a generic safety assessment process, during which the method can be of use. These stages are: 1. scope the assessment; 2. learning the nominal operation; 3. identify hazards; 4. combine hazards into risk framework; 5. evaluate risk; 6. identify potential mitigating measure to reduce risk; 7. safety monitoring and verification; 8. learning from safety feedback; (4) application, i.e. is the method applicable to hardware (Hw), software (Sw), human (Hu), procedures (Pr), organization (Or).

Many of these tools were and are used in the safety of transport (the most in aviation, aircraft, rail); a lot of methods relates to computer processes, which of course is related to transport. But few of these tools were used in studies of road safety.

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