TRAFFIC ACCIDENT ANALYSIS AND PREVENTION FROM THE PSYCHOLOGICAL STANDPOINT

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Abstract: By road traffic accident prevention generally we understand a set of measures that either directly or indirectly influence road users so as to reduce their conflict behavior in road traffic, which mostly results in harm to health or damage to objects. This preventive activity takes many forms including: the creation of safe traffic environments through traffic engineering measures; education and training of individual road users, including training in driving schools and testing the applicants for licenses; good quality legislation regulating and monitoring the technical condition of vehicles and roads. Punitive enforcement, too, can be considered prevention. The basic general rule for work in the field of road traffic safety accident prevention is the "3 E" rule: Education, Enforcement, Engineering. Sometimes this is extended to "4 E" by including Evaluation. These 3 or 4 rules express the necessity for a complex approach to the problem. The analysis of the reliability of individual accident prevention systems should refer to the tripartite basis: the person, the means of transport, and the environment; and it is made possible by theoretical models based on the analysis and evaluation of errors. Within the framework of analyzing preventive measures, the research was focused on selecting workers, education of road users, training programs and working conditions.

Key words: accident analysis, accident prevention, human errors

People are generally not able to specify exactly why the accident and injury happened. The etiology of many accidents and work injuries is relatively unknown. Psychological approaches have been asserting themselves in research, classification of sources and factors that precede these events. System models were focused on a man (dangerous action) and hazardous work conditions or sources of injuries. Accident analysis with an emphasis on its causes and effects was an aim of interest to Rotter (2005).

Attention was rightfully paid to problems of human action reliability. In connection with technical development and analysis of technical systems reliability, a range of approaches and evaluation of errors that happen in the course of human activity was evolved. Human error problems are becoming one of the sharply developing branches of theoretical and applied psychology. Questions such as which mistakes people make, why they make them and how we can prevent them are asked.

Since the beginning of the 20th century, injuries have belonged to the main problems of public health. Because many injuries are mostly an effect of modifiable human behavior, it is logical that behavior modification should be precisely what psychologists press for.

The work accuracy of a man operating a machine or some technical equipment (operator) is an indicator of how his actions correspond to a set program. In Engineering Psychology, the feature of accuracy has another function. It is used as a mean of research on the psychical activity of an operator. Accuracy of work can be an indicator of individual differences among operators, an indicator of their mental and physical states and an indicator of the influence of various external factors on their activity.

If the inaccuracy of an operator's work exceeds set limits, the normal activity of the system is disturbed and this is classified as operator error. If the inaccuracies of an operator's work reach the level where that operator cannot fulfill his functions or if his activity indicator exceeds the limit necessary to achieving an aim, we speak about operator failure.

Correct fulfillment of an activity depends on a range of tasks, states and facts. The particular elements of which every critical activity consists can be designated as critical activity elements.

Psychological study of an increasing operator reliability problem demands research into his activity in situations with higher or even extreme demands. For these situations, in which one or more parameters of system and surrounding in interaction with a man are approaching the limits of human possibility or even exceeding it, we generally use the terms demanding or extreme situation. It is necessary to place especial emphasis on detection of differences in how a man acts and even of his character and abilities in demanding situa-

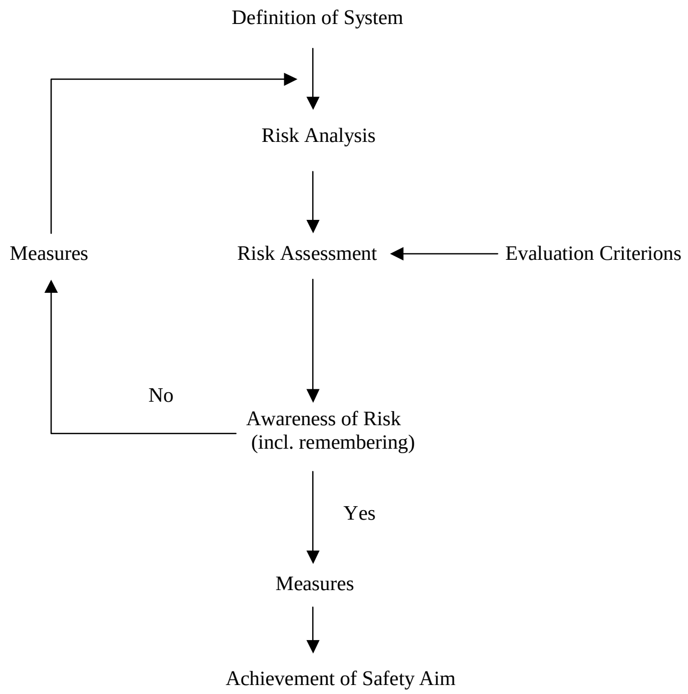

Figure 1. Process of risk evaluation

tions compared with normal or optimal situations. Study of human activities in demanding situations is a basic approach to problems of reliability of actions at work.

Evaluation of risk generally proceeds in four steps, which are worked up in series (see Figure 1).

In order to achieve all the conditions, a research system must, as a first step, be defined. During a risk analysis in the second step, possible scenarios of events, their relevancy or, as the case may be, their probability of appearance, together with their consequences, are analyzed. The third step is very important, assessment of identified risks takes place there (Hohn, 2007; Kaasboll, Rundmo, 2007). It can on the basis of this evaluation be decided in the last step whether existing risks will be realized and remembered, whether technical and organizational measures will lead to a decline in potential danger, to a prevention of threat or getting events under control.

In a road transport system, two opposing forces act. One is oriented to safety and the second one to mobility. If mobility overrides safety, the number of injury accidents increases. If mobility decreases and more safety measures (restriction of speed limit, use of safety belts) are imposed, then the number of injury accidents declines.

Progress in traffic safety is based on a process of collective learning by society as a whole. Safety is improving in many countries, but not to an equal extent. The rate of improvement is specific for every country and stays constant for some time.

The next step in developing the conceptual approach, which is intended for clearing the findings of various traffic safety studies, is to propose a typology of basic risk factors as a cause of accidents and injuries that can be affected. This typology can stand us in good stead as a basis for modeling engineering measures. Risk factors can be reduced to the following types: 1) Kinetic Energy; 2) Adhesion; 3) Visibility; 4) Compatibility; 5) Complexity; 6) Predictability; 7) Individual Rationality; 8) Individual Vulnerability and 9) System of Safety Warning.

Movement of people and vehicles produces kinetic energy. The amount of kinetic energy is a function of body weight and speed. This basic physical principle identifies speed and vehicle weight as basic risk factors in frequency of accidents . However much kinetic energy may be a risk factor, it does not lead to undesirable effects if it is under control. If control over a body in motion is lost, the possibility of stopping is critical for the avoidance of an accident or the reduction of serious injury if an accident does happen.

Adhesion between vehicle and surface of road is said to be a basic risk factor of accidents.

Another basic factor is visibility. Visibility is the possibility of seeing an object at a specific distance. The greater the distance at which an object can be identified, the better the visibility is.

If different vehicles or road users collide, their compatibility in terms of weight and speed influences accident consequences markedly. Compatibility corresponds to differences between categories of road users in terms of the kinetic energy caused by movement. The smaller the differences are, the greater the participants' compatibility is. One of the ways to reduce incompatibility is to separate groups of participants that are distinctly incompatible in time or place. Speed, weight of vehicle, adhesion, visibility and compatibility are risk factors that are closely connected to physical principles of bodies moving on a surface.

It is often argued that human factors present the greatest risks for traffic safety. The stated approach proposes a reduction of the human factors that are conductive to accidents to these basic categories: complexity, predictability, rationality and vulnerability.

Complexity relates to both traffic system and traffic in general. It is the amount of information that road users have to process and behave in accordance with in a unit of time. In dense city traffic, complexity is high, because participants must pay attention to a quickly changing traffic situation while performing perception-movement tasks as they walk or drive a vehicle.

Predictability means the reliability with which we can anticipate the appearance of a risk factor. The behavior of road users can be predicted for a specific situation. Driving in a traffic lane can be an example of easily predictable behavior. When driving on an unzoned double - lane road - most drivers do not expect any driver traveling the opposite way to drive unexpectedly into their lane. For most of the time, this prediction is right.

Individual rationality concerns a range of ways to act by which a road user satisfies his preferences (maximize utility). Accidents are often explained as a failure of rationality or reliability, such as risk-taking or human error. Nobody can use a traffic system without being exposed to the risk of a road traffic accident. On the other hand, it is reasonable to suppose that almost nobody wishes to be exposed to accidents. That is why the range within which road users are able to act rationally guarantees that they can avoid accidents to a large extent. Factors that can stifle rationality involve both elements of roads and vehicles (wrong signing or vehicle defects increase the probability of error occurrence) and human status. Alcohol or drug consumption, lack of sleep, illness or other more or less stable individual traits can stifle rationality.

When an accident of a certain gravity happens, some people are more vulnerable than others. We talk about individual vulnerability. People are more vulnerable as they get older. From a biomechanical point of view, an accident that would not lead to the fatal injury of an eighteen year old can kill an eighty year old.

Hazardous behavior is defined either as a socially unacceptable voluntary activity with possible negative consequences, if inattentiveness rises (e.g., excessive speed, intoxication, etc.) or a socially accepted behavior when the danger is known (such as it is at motor races). It has been proved that hazardous behavior by even one man in a population leads to accidents and injuries (Galovski, Malta, Blanchard, 2006).

The importance of risk evaluation at either individual or group level results from the high number of risk situations we are involved in every day. Risk evaluation is difficult, because there is an extreme variety of risk situations and different approaches to their evaluation (Štikar, Hoskovec, Šmolíková, 2006).

It is very difficult to envisage how road users can be modified to a precautionary approach to traffic. Engineering measures on their own do not completely guarantee an increase in traffic safety. Traffic safety increases only if no abnormal behavioral adaptation occurs. Is it possible to explain a behavioral adaptation of road users in general terms? *Wilde's theory* of a risk homeostasis can be interpreted as an attempt to form a general theory of adaptation of road traffic participant behavior. It was developed originally for an area of drivers' behavior. The rate of accidents is not determined by the level of real risk but by a risk level acceptable to an individual in a given situation. The theory indicates that people adjust their behavior so that they keep a constant level of perceived risk. If improved safety measures (e.g., better protection) are established, then people will behave in a more risky way to keep their habitual risk level.

The characteristics of changes of a structural-safety range resulting from the engineering effects of traffic-safety measures influence the probability of a participants' behavioral adaptation to them.

Figure 2 shows a relation between an engineering effect and the effect of behavior in relation to safety measures.

The result of a behavioral adaptation is expressed in terms of a range of safety behavior. This term has regard to how road users evaluate their safety while traveling. In contrast to the structural-safety range, it is not possible to express it in physical terms. Exact measurement of forms and levels of accommodation in some cases, such as measurement of vigilance and

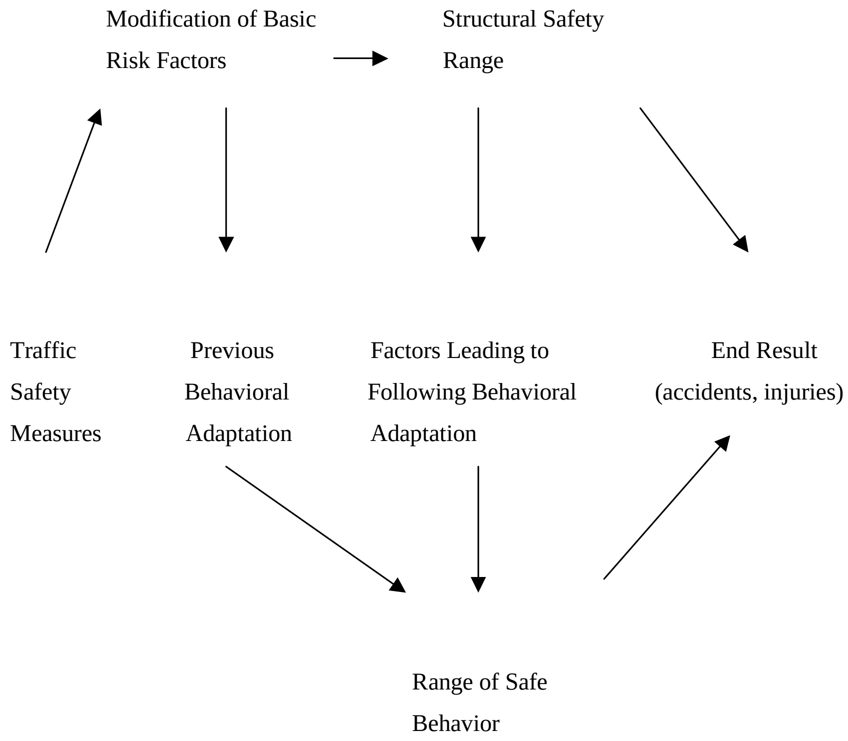

Figure 2. Modified model of cause string that expresses an effect of traffic safety measures

attention of traffic participants, is difficult. Maladapted behavior of road users is easily measured, e.g. in terms of increased speed.

Traffic-safety measures realized in a structural range do not usually lead unambiguously to a decrease in the number of accidents. For example, if a lighting is improved markedly, it can lead to an increase of speed and a decrease of attention, which can sometimes have a negative effect.

A number of experts have asked which errors people make, why they make them, and how we can prevent them. The theoretical approach to human mistakes has contained psychoanalytic, cybernetic and social-theoretical conceptions, field theory, decision-making theory and S-R, activating grades, stress, human enforcement and skills concepts.

Reason (2003) brought out a historical review of important psychologists' contributions to the study of human errors. Starting with Jamese Sully (1881) and Sigmund Freud (1904, 1922), he goes on to William James (1880) whom he takes for an author of an almost compact error theory. He continues with Joseph Jastrow (1905), Gestaltists Max Wertheimer, Wolfgang Köhler and Kurt Koffka (1912) and their follower Kurt Lewin in the inter-war period. He brings up a contribution of the neurologists Karl Lashley (1917, 1951), and Henry Head (1920), who introduced the term "scheme" as an explaining principle for some psycho-physiological phenomena. After the Second World War information theory (e.g., Miller, 1956) was especially beneficial. Focus on cognitive processes led to a range of important findings, especially to the rise of a main memory concept (Baddeley, Hitch, 1974) and to a basis for a decision-making theory, which was elaborated by Tversky and Kahneman (1974), who used the term "restricted rationality".

Reliability is determined by 1) the character of a man who has a natural tendency to make operational errors; 2) the surroundings in which the activity takes place. The surroundings do not consist only of physical, chemical and biological settings but also of a social one. The effects of these surrounding are designated as PIFs (Performance Influencing Factors). Some authors use the term PSFs (Performance Shaping Factors), which is actually the same. In error analysis, near-accident and accident analyses, these four categories are discerned: 1) exciting cause - which led directly to the result; 2) contributing causes, i.e. the PIFs that contributed to an accident event, such as reduced visibility, unsuitable ergonomic construction of communicators, etc.; 3) root causes, which are hidden behind a range of contributing causes. These lie mainly in a range of social conditions, e.g. behavior and attitudes of company management towards people and safety problems. The neglect of safety problems leads to the result that only the employee actually involved in an accident is blamed for the error, but all the PIFs stay hidden and remain latent.

It is necessary to distinguish between different types of errors; these can be designated as "slip", lapse, mistake and willful, i.e. intentional breaking of a rule.

A "slip" happens if a man tries to perform some correct action but does it wrong. Such as when a doctor or a nurse puts a wrong dose into an infusion, even though he/she knows the correct one. Errors refer to visible activity and are usually connected to errors in attention or perception. A serviceman's attention can be disturbed and then he undoes another hydraulic tube than the one he was supposed to. He knew what he wanted to do, nevertheless he makes a simple error.

Lapses are internal events, usually memory failures. It is an omission of some action, in Czech we call them "opomenutí", in English "lapses". Such as when a surgeon forgets some instrument in an open body and sews up the patient.

A mistake is an error that happens when a person does the wrong thing. The action can be done perfectly but it is not the action that was supposed to be done. Such as when a doctor prescribes what the patient is allergic to. Mistakes happen on a higher level than perception - it is a matter of mental processes contained in evaluation of information that is available to planning, formulation of intention and evaluation of probable results of planned actions. If a serviceman forgets an operating sequence or he has never understood it completely, then he can make a wrong decision, especially in a case where he has to manipulate some new thing. It is the choice of a wrong action.

Willful breaking of rules are actions done intentionally but which are not correct. People intend only to break a rule but not to suffer from the possible results. Employees sometimes cut corners because they want to increase their productivity or finish a task. Breaking of rules is permitted and sometimes even demanded by management. This kind of mistake is the most difficult to inhibit.

According to Reason (2003) this leads to an analysis of the way people recognize that they have made an error. Processes of error detection are part of multilevel instruments that coordinate and take control of human activity. Their efficiency is given inversely to their place in a controlling hierarchy. For example, low-level corrections of body position work with a high rate of reliability. At the other extreme, cognitive processes at a higher level (aim setting and choosing means of achieving them) are much less sensitive to possible departure from the optimal way to a desired state. The relative efficiency of these detecting instruments depends on the immediacy and validity of feed-back information. On a low level, this is automatically provided simply by neutral instruments. At higher levels it tends to be absent or at least be open to many interpretations.

Basically, there are three ways to discover an error. Primarily it is a self-monitoring process, which is the most efficient when bringing about changes on the level of physiology and skills. It can be signaled by some environmental signs, the most evident being the enforcement function that restrains the continuation of the activity. It can be also revealed by another person, which is the only way of finding specific mistakes in complex, dangerous and stressful situations. Analyses indicate that about three out of four errors are disclosed by their causers. The chance of their correction is best at the skill level and lowest at the level of knowledge.

Rasmussen (1983) contributed to a creation of an error taxonomy by distinguishing three effect levels corresponding to a decreasing range of knowledge or experience in surroundings or task:

Based on a skill: A man carries on routine, highly mastered tasks that can be characterized as automated. Except for the occasional check, this behavior is connected to a low effort of will. Errors on this level are concerned with internal variability of power, place or time coordination.

Based on a rule: Means a situation solution, which arises if the situation changes a little and modifies our programmed behavior though we know the situation and are trained in it. It is based on rules, because we apply known principles. Errors are connected with a wrong situation classification that leads to the use of a wrong rule or an incorrect recollection of the procedures.

Based on knowledge: This kind of activity happens in new situations when we have no applicable rules. We have incomplete or incorrect knowledge. It can have a form of a problem solution, in which analytic thinking and retained knowledge are used.

"Slips" and lapses relate mainly to tasks based on skills without a lot of cognitive effort. Small differences in a situation can be missed (attention failure). It is possible not to remember one step in the procedure.

Mistakes occur particularly at tasks based on rules and knowledge, such as there being no rule for the given situation or the correct solution's not being found for the problem.

A given classification allows a system analysis in terms of cognitive processes. It offers guidance on the cognitive characteristics, abilities and limitations of people. That has both implications for which kind of errors can be made and specific indications how to construct systems to prevent errors.

As we go on to show, in the beginning of the 90's this taxonomy admitted of material alterations which relieve some theoretical deficiencies and introduce new concepts into thinking about human errors that more realistically reflect human activity, mainly in the area of activities based on knowledge.

We think it appropriate for both theoretical and practical purposes to classify these human differences into three groups: permanent individual characteristics, development factors and temporary variable factors (see Figure 3).

Permanent characteristics mean the structure and nature of behavior, constitutional type, intellectual capacity, sensory and psychomotor capacity and personality structure that are innate or acquired in childhood. These factors remain constant with respect to work accidents, without respect to work age. Their variability is not important. Every person has his/her relatively constant level. Preventive measures with regard to permanent factors concern employee selection for a job that demands special abilities or a job with a high risk. To this end psychological and medical methods are used.

Development factors are mostly connected to the age of a person. Age has an influence on physiological and psychological changes and, through them, even on accident probability. The different accident frequency and characteristics of people of

Accident Causes		*Preventive Measures*
Permanent Characteristics	-------------	People Selection (Psychological and Medical)
Development Factors	------------	Training and Education, Age Limits
Temporary Variable Factors	-----	Activity Mode

Figure 3. Accident causes and preventive measures

different ages is quite well known. Next to these age-dependent facts, there are many variable and suggestible factors that belong to this group. The most important are education, training and experience. The influence of knowledge, work habits and attitudes to accident frequency is at least basically clear.

Prevention measures for time-dependent factors include time-limit settings (e.g., for driving licenses, for different jobs, etc.), requirements for minimal training and safety experience and education focused on increasing knowledge and improving attitudes.

Temporary variable factors are irregularly and quickly changing characteristics, such as short-term illness and tiredness, effect of alcohol and drugs and temporary stages of depression and excitement. These factors can increase the probability of an accident in certain circumstances, though the person belongs to the "safe" category in both the previous groups.

One of the central aims of traffic psychological research is to identify sub-groups with a higher accident risk or characterized by certain mobility problems in a heterogeneous total group of road users. Acquired information makes it possible to develop the measures, that have to be focused on sub-groups. These kinds of measures have greater influence than broadly oriented campaigns. To the most important groups belong: children, teenagers, older people and, according to kind of vehicle and job: motorcyclists, truck drivers (Krems, Baumann, 2005; Kroj, Holte, 2006), professional versus non-professional drivers (Öz, Özkan, Lajunen, 2007) and according to mental shortcomings, such as alcoholism and agressivity (Galovski, Malta, Blanchard, 2006).

The preventive measures that a state provides for permanent factors are not possible to the same extent for other factors. Immediate control of temporarily variable factors depends on the individual. Regulation of working hours, restriction of alcohol percentage in blood while using the road, etc. are partly preventive but it is not possible to control them in entirety in practice. Continuing analysis leading to preventive measures is necessary.

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ANALÝZA A PREVENCE NEHOD Z PSYCHOLOGICKÉHO HLEDISKA

J. Š t i k a r, J. H o s k o v e c, J. Š m o l í k o v á

Souhrn: Prevencí nehod v silničním provozu se obecně rozumí soubor takových opatření, která přímo či nepřímo působí na účastníky silničního provozu s cílem předejít jejich konfliktnímu chování v silničním provozu, které má ve většině případů za následek poškození zdraví nebo věcí. Preventivní působení má mnoho forem, mimo jiné: vytvoření kvalitní právní úpravy chování jednotlivých účastníků silničního provozu; vytváření bezpečného dopravního prostředí formou dopravně inženýrských opatření; výchovu a výcvik jednotlivých účastníků silničního provozu, včetně výcviku v autoškolách a zkoušek žadatelů o řidičská oprávnění; kvalitní legislativa, upravující technický stav vozidel a pozemních komunikací a kontrola jejího dodržování. Také represi je možno chápat preventivně. Základním obecným pravidlem práce v oblasti bezpečnosti silničního provozu a prevence nehod je pravidlo "3E" (Education, Enforcement, Engineering, t.j. výchova, tvorba a prosazování práva a dopravní inženýrství). Někdy se toto pravidlo rozšiřuje na "4E" o Evaluation (zhodnocení). Toto pravidlo vyjadřuje nutnost komplexního přístupu k danému problému. Přístup k analýze spolehlivosti systému člověk - dopravní prostředek - prostředí, z něhož by měla vycházet prevence nehod, umožňují teoretické modely zakládající se na analýza chyb a jejich hodnocení. V rámci analýzy preventivních opatření byl výzkum zaměřen na výběr pracovníků, výchovu účastníků silničního provozu, výcvikové programy a pracovní podmínky.