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Analysis of Factors Determining Ergonomic Conditions of Driver's Workplace and Safety in Transport of Dangerous Goods

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Abstract

The article concerns issues connected with the safety of the carriage of dangerous goods. Raising a subject was justified with the rising number of cartages of these goods and the same height of the probability of the appearance of the environmental risk and remaining road users. A specificity of the arrangement was analyzed driver-vehicle-environment, paying special attention to ergonomic determinants of working conditions of the driver. In the article data of the National Police Headquarters concerning causes of accident involving dangerous goods in the road transport was also described. Exceeding the permissible speed, the non-observance of traffic regulations, as well as the tiredness which resulted in reducing the psychophysical efficiency for the driver were regarded as the root cause of accidents. Conducted analyses allowed to effect the preliminary selection of factors, which accepting the wrong level can constitute the cause of accidents.

1. Introduction

Road transportation of dangerous goods in Poland is estimated to an output of approximately 3.5 ton kilometers per annum. This is equivalent to some 5 per cent of total European transport performance and ranks Poland on the sixth position after Germany, Spain, Italy, France and UK. In Poland, similar to the other EU states, at least half of the cargo stuffs consist of flammable liquids handled at short distances in domestic traffic.

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Road transport is in Poland the most popular method of handling these materials which covers 81 per cent of general road transport performance and is particularly connected with urban agglomerations. However growing during recent years was popularity of the rail transport, its share in total carriage of dangerous goods would not exceed 18 per cent.

Hazards of the accidents occurring in transportation of dangerous goods are considered in Poland as a crucial problem for the public safety and environment protection. Consequently, the issues of suppression or at least reduction of the door to door transport hazards become extremely complicated and closely related to quality of ergonomic features of the tanker driver work position. One of the transportation safety components is provision of proper work conditions. Their configuration is relevant to several factors resulting from particular elements of the Driver-Vehicle-Environment System as well as from the work organization pattern. It is thus indispensable to have a method of ergonomic evaluation of the said system with due attention paid to: specific features of the driver workplace, reasons of the accidents and procedures applicable to dangerous goods transport operations. Such a method should provide for estimation of ergonomic quality of the workplace and for suggestion of improvements resulting in direct upgrade of the safety in handling this type of goods. The relevant problems are represented by the subject of this paper which is devoted to a review of the factors which determine the work ergonomic conditions and ensure safety in the road transportation of dangerous goods.

Specified here is a primary group of the quality appraisal aspects, which shall, in the second phase of this research work, be consequently submitted to the expert poll verification. Then, the obtained results shall make the base for the specifically designed procedure of evaluation of the DVE (Driver-Vehicle- Environment) System safe operation and of the relevant risk analysis with use of heuristic methods. The term – vehicle- relates to a truck for transportation of dangerous goods.

2. Specific Features of the DVE System

(Driver-Vehicle-Environment)

The human operator specific type of work is where a man performs functions of indirect control of the process [3]. This kind of work is related to operators which are directly controlling the movements of self-propelled traveling machines such as: railway engine drivers, truck drivers, street car drivers et c. Interdisciplinary knowledge covering engineering and human body sciences are indispensable to build proper configuration of the DVE System in the aspects of ergonomics and safety. This should provide for true description of the relations developing between particular parts of the system and their performance in the control process.

2.1. Driver Sub-system

Major task of operators of the above mentioned category is to monitor progress of the events and positions of the objects under control [3]. In the operator's performance there are always realized processes of orientation, decision making, and performing controlling activities. The former ones are connected with mental functions such as observation, attention, reception of stimuli. In association with these there are acting (either positively or negatively) emotional stimuli, motivations and tolerance to changes in the surroundings. Orientation process supplies the operator with information on the events occurring in the surroundings and how the system under his control performs. Another of the essential processes is decision making. It is directly connected with the function of thinking and memory. Sometimes it is referred to as the data processing function. An important role is played in the decision making process by the instant and the long-term or operating memory. The first one exhibits capacity to catch information however without ability to store it for longer period, while the latter involves the knowledge and experience of the operator. It is nature of the job currently performed by the operator that determines the applicable work requirements in the aspects of effective functioning of the vision and audition analyzers and motor activity. The operator is expected not only to accept the applicable warning signal, but also to properly interpret it, make adequate decision and carry out the required operation by intentional movement. Performance of the tasks connected with vehicle driving requires from the driver to have specific skills and predispositions. The occupational usefulness tests (or the negative selection tests) are to responsibility of special national institutions [1]. Suitably prepared standard methods are used in these selection tests. Final professional qualification decision is made with all the required documents, certificates, medical and psychological examination reports and the test stage work period comments taken into consideration. Psychological examinations are applicable first of all to the applicants for the functions related to safety of the traffic. It has been so far agreed, that a desirable personal profile of the dangerous goods transport vehicle driver should cover [4]:

1. Sensorimotor efficiency:
   a) *critical*: visual acuity, color sensitivity, stereoscopic vision, nocturnal vision, smell, coordination of sight and movements, fast motor reflexes, perceptiveness, dexterity;
   b) *desirable*: good hearing, good body balance, good sense of touch.
2. Talents
   a) *critical*: attention, divisibility of mind, imagination and creative approach tendency, technical skills;
   b) *desirable*: good memory, sound reasoning.
3. Personality
   a) *critical*: endurance to prolonged efforts, self-observation, ability to work under condition of social seclusion, ability to work under monotonous conditions, courage, work accuracy;

b) *desirable*: emotional endurance, good ability to subordinate, willingness to undertake work under unpleasant environment conditions, courage, persistence, patience.

The monotonous work conditions are recognized as a particularly arduous psychical burden in the truck driver job process. Extensive monotony will reduce alert readiness, which might rise the safety risk level to the state of life hazard for the driver and other road users [5]. Also adverse in the aspect of alertness is driving a truck during night hours involving particular eye strain. Designers of modern cabs make efforts to continuously improve driver work conditions. Improving comfort of the driver work results in reduction of the physical effort required to drive a vehicle. However, it would not be possible to entirely secure the driver from the truck vibration and noise as it moves. The impact of these factors will increase with higher speeds and numbers of the other road users. Their action would then result in comparatively rapid increasing fatigue with longer physical reaction times, disturbances in memory process, lower concentration, decline in visual acuity. The fatigue sensation will also disturb efficiency of movements and deteriorate the feet and hands coordination function, with the field of vision growing narrow – all these adding to drowsiness and apathy.

Also undesirable for good alertness of the driver are: sitting work position, limited number of movements in work performance and high temperature in the cab. Moreover, the work during night hours would disturb the normal human day/night activity cycle.

Bringing the mental and physical effort outputs of the dangerous cargo transportation driver to a reasonable balance, which is critical for optimum configuration of the whole D-V-E System, becomes a priority task in the search of ergonomic issues providing for good comfort of work for various population groups of operators driving their trucks under different climatic conditions.

Contemplating over the above reflections would lead one way or another to a conclusion that there are basically no means by which the operator of a motor vehicle could be protected against temporary information overloads, or emotional stress or any unpredictable real circumstances. We can counteract such situations by adequate selection of the applicants in the aspect of their psychological and professional characteristics. However, even the most elaborate selection would not ensure a reliable performance of the operator unless the „engineering device" was suitably adjusted to human capacities.

2.2. Vehicle Sub-system

The cab, as a workplace of the driver, is a separated part of the truck body. It should offer convenient work environment in consideration of the long hours truck driving efforts, providing for optimum reduction of physical and mental fatigue. Thus, the cab should satisfy several requirements related to ergonomics [3] with respect to:

- space arrangement of the workplace;
- layout of the indicator and control elements within the work space;
- good vision of the outside signals and traffic lights.

Space arrangement of the truck driver workplace is determined by [5]:

- user body size and basic position, which in this case is sitting position;
- scope of the movements, field of vision, required changes in body position et c.;
- equipment utilities, which should include additional control elements for optimum comfort, safety and functional reliability.

Space arrangement of the driver's cab is mainly defined by the layout of the dashboard, control elements and the seat. Their mutual disposition depends on the anthropometrics and field of vision of the driver.

Fast and accurate collection of the incoming information, which ensures safe and smooth drive would depend on both disposition of the indicator lights, their types and shapes and on the best road visibility. Disposition of the indicator lights and control elements should be suitably adjusted to the driver's field of vision.

Of material importance for reception of the signals and effect of the operator on control elements (which is of particular importance within limited space of the cab) is both position and the very structure of the driver's seat. Body position of the driver during work is mainly dependent on mutual disposition of the steering wheel and the seat and in particular on the back-rest shape, height of the seat over floor and steering wheel inclination angle.

Cab structure and windows: the windshield and other windows on the cab sides and in the doors should ensure proper visibility. This requirement is of particular importance for driving safety. Since the driver's seat is situated at a considerable height over the road surface, the area of the road surface immediately in front of the truck remains off the field of vision of the driver. The regulations [5] require, that extension of the dead field of vision in front of the most fore point of truck must not exceed 3 meters. To meet this requirement an extra mirror is installed over the windshield in addition to a system of suitably arranged mirrors which are normally mounted to driver's cab.

Good lighting of cab interior space, and in particular that of the dashboard, is conductive for proper receipt of information by the driver.

Easy climbing in and leaving the cab are also of material importance in the aspect of ergonomics.

2.3. Environment Sub-system

A review of traffic safety proves that human operator is the weakest link in the „Driver–Vehicle–Environment" System. The man at a steering wheel is not a passive addressee of the incoming information but an active element which function is to collect, select and interpret the data with due consideration given to the knowledge and experience stored, its memory, and to match these data with the actually prevailing road conditions. Efficient operation of the driver, considered as

the weakest link of the system, depends to much extend on the workplace material environment or the surroundings conditions. A review of these conditions should provide for evaluation of the workplace whether compatible with the applicable hygiene standard requirements [2]. The most important factors in case of the driver's cab seem to be: vibrations, noise, microclimate, lighting and air pollution resulting from both engine operation and from the outer environment [5]. Microclimate parameters in the truck cab is relevant to efficiency of the space heating and ventilation systems. Optimum temperature inside the truck cab is considered when remaining within the limits of 20-22°C. With a too low temperature, the driver tends to use thicker clothes with negative effect on his control performance. Moreover, low temperatures reduce driver's concentration and motor efficiency. But too high a temperature and inadequate ventilation will lead to oxygen deficiency and mental discomfort.

Noise in the driver's cab is usually caused by different factors, such as engine generated noise, operation of the drive unit, wear and tear of different mechanical parts of the truck or poor pavement condition. The noise is affecting central nervous system, which leads to rapidly growing sense of fatigue, loosing temper, delays in mental reactions and poor attention.

The most severe pathogenic hazard is presented by mechanical vibrations, which are generated by the vehicle and transferred to the driver through the seat structure. They may affect condition of digestive system, muscular/skeletal system with the pains concentrating in particular in lumbosacral or neck section of spinal column, osteoarticular system and labyrinth. All these symptoms can lead to deterioration of locomotor efficiency, clear vision, effective communication, memory storage process and to psychophysical efficiency of the driver. Low air pollution level within the cab is first of all relevant to correct performance of the ventilation system and leak free windows.

Deteriorating effects of these factors on human organism are also affecting health condition and psychophysical efficiency of drivers. Moreover, the drivers are also subject to the effect of so called remote factors such as other road users, traffic intensity, weather, visibility or pavement condition.

3. Causes of Accidents – Analysis of Work Conditions

The notion of the road accident is commonly accepted in colloquial meaning. First suggestion of formal definition of the road accident was proposed in Poland in the last century sixties. W. Rychter and E. Rzeszkowski were the precursors. They suggested, that "an accident is an event involving collision with another vehicle, or a man, or a stationary obstacle, or overturning of the vehicle, or its going out of the way, or falling of a man out from vehicle, or a disturbance occurring within the vehicle (such as fire or displacement of cargo). In such a case, the event must start and complete within the area of a public road designated for public traffic"[1].

In many European countries, as well as in Poland, more and more goods including dangerous goods are transported. In consequence of this rapidly growing road transport activity, more and more trucks and tankers exceeding 20 ton load capacity, appear on the roads. Accordingly increasing is the share of such trucks and tankers in the road accidents. Road accidents are inevitable consequence of development of the automotive industry and are closely related with general situation in the road traffic. The most outstanding among the factors having an impact on the traffic safety is human operator [1]. Human operator is considered the weakest link of the road traffic system which also includes vehicles, road and traffic organization arrangements. The road accident statistics in Poland indicate, that majority of these events, ie. about 79% of the total number, are caused by the driver's errors [6]. See Fig. 1 for the data supplied by the Police Headquarters, showing that the most frequently the accidents involving dangerous cargo were caused by excessive vehicle travel speed. Other accidents have been occurring because of inadequate, reverse, overtaking, violation of the right of way, fatigue, bypassing, lane changing.

Generally speaking, it can be said that cardinal causes of the road accidents are the drivers not observing traffic code, inadequate caution and disrespect of the custom of anticipating potential accident situations. Erroneous behavior of the drivers and disregard of traffic code, could be caused by numerous factors including fatigue.

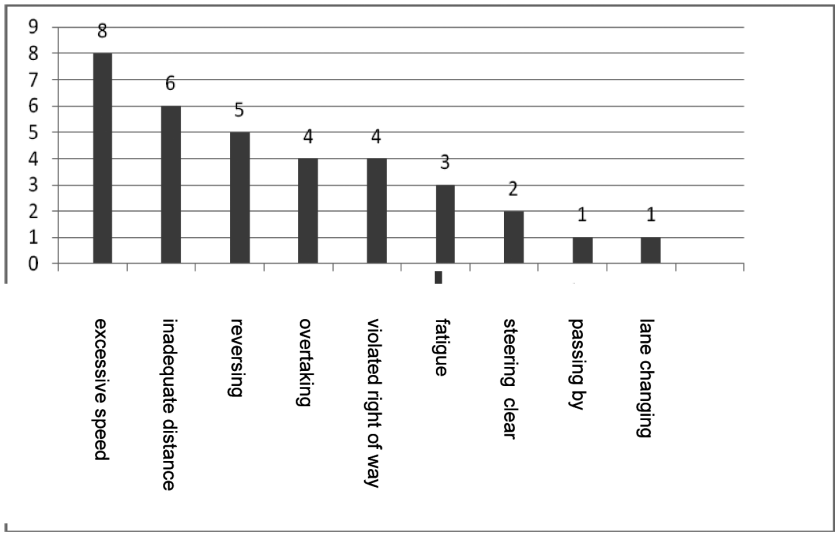

Fig. 1. Causes of road accident involving transport of dangerous goods in 2008

According to the obtained data „fatigue" is function of the work specific conditions as well as organization arrangements. It has been found by Australian research workers, that fatigue can reach a level to make the driver to create as dangerous situation on the road as he was drunk. Continuous activity for 18 hours without

a nap would reduce psychophysical efficiency of the driver to a level comparable with 0.08% alcohol concentration in blood, which is usually considered as intoxication. The factors stimulating fatigue sensation of the drivers should be split into those related with the outside conditions and these of personal nature. Outside conditions would cover for example cab interior microclimate, vibrations, incorrect work organization with too long drive trips, frequency of jobs performed during night hours, work shifts, traffic intensity and inadequate road lighting [6]. Personal fatigue relevant factors include age, physical fitness and health condition, driving time period, number of sleep hours preceding the drive, psychophysical efficiency, drinking alcohol and taking medicine. Accident risk has been associated with driver's fatigue as well as with prolonged driving hours and especially night hours. Accidents involving driver's fatigue are very often of a serious nature, since the driver, when tired, is unable to efficiently steer or brake the truck to avoid collision.

4. Preliminary Selection of the Factors Enhancing Good Ergonomics and Safe Work Conditions

The operations performed when driving or servicing heavy vehicles expose the driver to action of the factors creating potential hazards of accidents at work and particularly require safety and work hygiene rules to be observed. An accident is considered as, among others, a consequence of erroneous conduct of the driver, which might be caused either by some independent reasons or by his personal character features. No doubt, that the most difficult element to appraise is human being. In any analytical review of human functioning in complex circumstances with consideration given to the relations between the user, the machine and the environment, it is imperative that due attention should be paid to naturally random character of the human perception processes [3] and their strong association with different factors. Vital role in analysis of these problems is played by mathematic models used for simulation processes, which supply important information both in the phase of development of the Man-Machine-Environment System and in the service process. The processes of simulation and model applying methods, when extending outside typically geometric and mechanical limits, are bound to present considerable problems. A technique to overcome these problems uses of fuzzy modeling (basing on theory of fuzzy sets). These models can be used to represent conduct of a human operator by means of verbal description suggested by an expert (sometimes fuzzy models are referred to as „linguistic models") which in a „natural way" give consideration to lack of "precision" in human behavior. Applicable for the method to be developed are the following requirements:

- the method shall be applied for evaluation of the DVE System irrespective of the kind of the dangerous goods,

- consideration shall be given to all the elements of the system, viz: human, machine and material work environment,
- evaluation results shall be based on the essential factors as generated in the course of analytical review of the specific system performance, in the procedures applicable for this type of transport and in the analysis of the accident causes,
- preliminarily selected group of factors shall be subjected to verification procedure by the expert – based surveys (experts should be selected from a group of drivers experienced in this kind of transports),
- ultimate group of essential factors would be used for development of the required evaluation procedure using both conventional methods as well as simulation of the Driver-Vehicle-Environment System basing on the fuzzy set technique.

The information obtained in result of assessment of ergonomic quality of the system shall be considered as the basis for implementation of modifications for improvement of the system operating safety.

Analytical review of the driver work process as well as the causes of the accidents has made it possible to identify structure of the elements potentially enhancing occurrence of accidents. For diagram of this structure see Fig. 2. an accident should rather be seen as a coincidence of many factors, which should rather not necessarily be related to the DVE System.

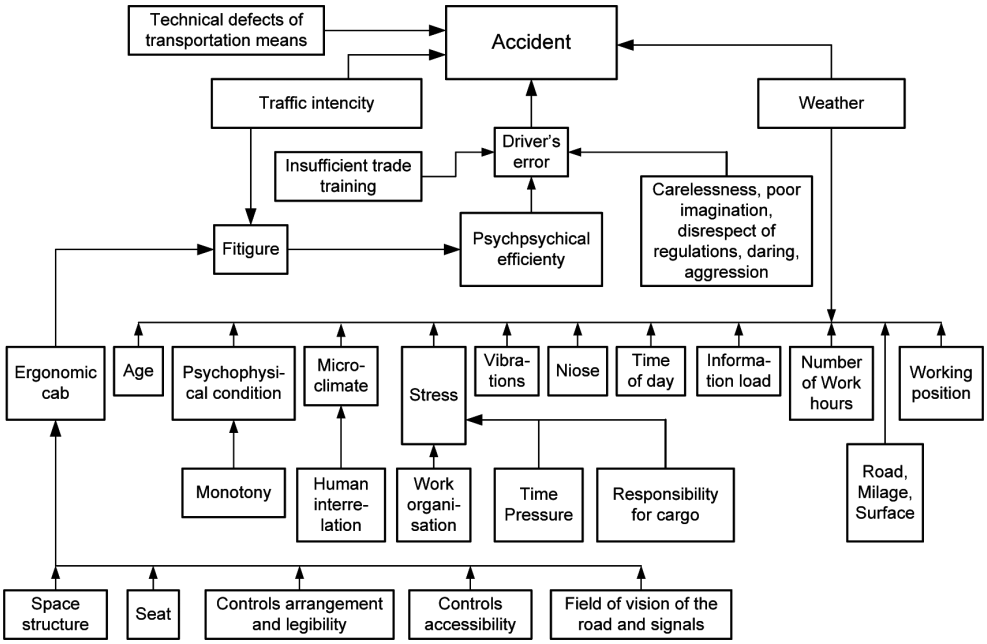

Fig. 2. Structure of the accident enhancing factors

The set of factors representing potential causes of accidents shall be submitted to estimate of the drivers experienced in transportation of dangerous goods

with thus obtained results used, when duly analyzed, for further research aiming in improvement of ergonomic quality of the Driver-Vehicle-Environment System and consequently in improvement of the dangerous goods transportation safety. Since there exists a significant correlation between ergonomic quality and safety standards of the work stations, it is intended to have a suitable method developed during subsequent research phases, which might be effective for evaluation of the Driver-Vehicle-Environment System safety and risk analysis based on heuristic techniques.

5. Conclusions

Ergonomic rules and requirements are observed in Polish, European and Worldwide standardization systems, enhancing reduction or, if possible, total elimination of the risk elements from immediate surroundings of the drivers workplaces. It should be practicable to reduce effects of many of these elements by ensuring proper work organization, efficient selection of the drivers and good ergonomic standards of the workplace. Before adequate corrective means inevitably leading to improvement of the driver work safety could be offered, proper methods of identification of crucial risk generating factors and of their impact on driver operating efficiency must be developed. These problems shall be dealt with in further research work.

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