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TRANSPORT

ISSN 1648-4142 print / ISSN 1648-3480 online

2012 Volume 27(4): 351–356

doi:10.3846/16484142.2012.750625

ANALYSIS OF THE INFLUENCE OF FATIGUE ON PASSENGER TRANSPORT DRIVERS' PERFORMANCE CAPACITY

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Submitted 14 March 2012; accepted 4 October 2012

Abstract. The article deals with the influence of professional drivers' fatigue on the occurrence of traffic events. The study of various scientific works on the causes of traffic events related to human psychophysiological qualities has revealed that all of these works highlight the complex work process of a driver as an operator of a certain mechanism. It is governed by the regulatory documents reviewed in this article. Driver's fatigue is a quite frequent accident-causing human factor. Building upon the results of the study on human idiosyncrasies, the authors suggest a methodology for professional selection of drivers. This methodology is based on practical data, i.e. on a comprehensive analysis of performance peculiarities of professional drivers employed at Joint-Stock Company 'Vilnius Public Transport' (in Lithuanian – UAB 'Vilniaus viešasis transportas'). Application of the suggested methodology enables to reduce the number of road accidents caused by city passenger transport drivers by up to 40÷50%. The article proposes a methodology for compilation of professional selection criteria for passenger transport drivers, also applicable to drivers working in other transportation areas, as well as to employees of field investigation services and other persons who constantly face nervous and emotional stress and experience a lack of information and time.

Keywords: road safety, driver fatigue, driver performance capacity, psychophysiology, road accident.

1. Introduction

When a human operates a machine, some uncertainties of the control system's behavior arise. The more complicated is a task to be solved by a person, the more abundant are the uncertainties during operation of a specific object. It is natural, because a more complicated task is affected by many interrelated factors, so their assessment and making an appropriate decision turn into an increasingly complex task for a person. Awareness of the potential, as well as of own strengths and weaknesses provides favorable conditions for choosing an operation mode which enables a person to properly assess the whole information obtained, to make the only correct decision and to timely implement it (Atchley, Dresel 2004; Guzek *et al.* 2009; Richard *et al.* 2002; May, Baldwin 2009).

Seeking creation of a common road safety area, since the year 2010 the European Commission proposes to continue the work towards cutting the number of road deaths in the European Union by half by 2020. As compared to the aim which has not been accomplished during implementation of the current European Road

Safety Action Programme, setting such common goal means that this issue is given a much greater importance (taking into account the progress already made by some member states over the previous decade) and this step demonstrates the commitment of Europe to ensuring road safety.

In Lithuania, like in many other countries, the road accident rate mostly depends on the driver performance – up to 75% of road accidents occur due to driver's fault (Zaranka *et al.* 2009; Zaranka, Pečeliūnas 2009).

2. The Survey on the Regulatory Documents Governing the Behavior of Road Users

The necessity for development of a common transport policy is set out in Article 70 of the Treaty of European Economic Community (hereinafter – EEC) dated 25 March 1957, whereas Article 71 confirms the intent to establish the following:

- the common rules applicable to international transport going to/from the territory of a Member State or through the territory of more than one Member State;

- the conditions for providing transportation services in a Member State by carriers that are not permanent residents of the state;
- the measures for improving road safety;
- other relevant measures.

As early as in the year 1969, legal norms of the European Union (hereinafter – the 'EU') started regulating the activities of professional drivers. The purposes of the Council Regulation (EEC) No. 543/69, as of 25 March 1969, included:

- limiting the daily and weekly driving time;
- the obligation of professional drivers to time their activities using a special recording unit (tachograph) or, alternatively, a special booklet.

On 1 July 1970, with a support from the United Nations (hereinafter – the 'UN'), EU signed a European Agreement concerning the work of crews of vehicles engaged in international road transport (hereinafter – 'AETR') that extended the use of recording equipment to other European territories outside the EU (former Soviet republics, Balkan States, east states and so on).

In the year 1985, striving to avoid distortions of the competitive conditions and to improve the road safety situation, the Council Regulation (EEC) No 543/69 was annulled; it was replaced by the Council Regulation (EEC) No 3820/85 and the Council Regulation (EEC) No 3821/85 approved on 20 December 1985.

The Council Regulation (EEC) No 2135/98, as of 24 September 1998, on a partial alteration of the Council Regulation (EEC) No 3821/85 in respect of tachographs usable in motor vehicles and the Council Directive No 88/599/EEC, as of 23 November 1988, on application of the Regulation (EEC) No 3820/85 and the Regulation (EEC) No 3821/85 introduced a mandatory recording unit for every professional driver (with few exceptions).

In September 2001, the White Book approved by the European Commission set the task of cutting the number of persons perished in road accidents before the year 2010 by half by means of equalizing the amounts of fines, taking additional measures for improvement of road safety and introducing advanced technologies. The abovementioned task was set again in Verona Declaration passed by European ministers of transport in October 2003.

Upon pursuing the objectives set out in the White Book approved by the European Commission, the Regulation of the European Parliament and the Council (EC) No 561/2006 'On the Harmonization of Certain Social Legislation Relating to Road Transport and Amending the Council Regulations (EEC) No 3821/85 and (EEC) No 2135/98 and Repealing the Regulation (EEC) No 3820/85' was passed on 15 March 2006.

The Law of the Republic of Lithuania on Road Traffic Safety, as of 12 October 2000, provides the legal basis for road safety in the Republic of Lithuania, establishes the duties of state and municipal institutions and organizations related to implementation of the safe traffic policy, describes the principles of training road users, defines the key rights and duties of road users, the persons responsible for road maintenance, police

and customs officers and other officers involved in traffic control, as well as the key requirements for technical condition of road vehicles and its inspection, for vehicle registration, also the road traffic safety requirements designed in order to protect life, health and property of road users and other persons and to improve traffic conditions for vehicles and pedestrians.

For professional drivers, the schedule of driving and rest was set by the Law of the Republic of Lithuania on Approval, Enactment and Implementation of the Labour Code, as of 4 June 2002, and the decision No 587 of the Government of Republic of Lithuania 'On Approval of the List of Jobs with the Working Time up to Twenty-four Hours a Day and the Peculiarities of the Schedule of Works and Rest Times in Various Sectors of Economic Activities', as of 14 May 2003.

The amenability for violations of the above-mentioned standard acts is set out in the Code of Administrative Offences of the Republic of Lithuania, as of 3 January 1985.

3. The Survey on Driver Fatigue-Related Studies

In the beginning of solving the problem of infallibility and occupational safety, the individual traits of a person, i. e. the influence of his psychophysiological peculiarities upon faultlessness and occupational safety should be considered. The said correlation was analyzed by M. M. fon Veber and I. I. Richter (Romanov 2002) while taking an interest in safe activities of railwaymen. In the early 20th century, it was found that professional psychologists started exploring the problem of occupational safety of drivers with analyzing the influence of a person's individual upon occupational safety.

On analyzing the road accident rate, American scientist U. Bingham (Vaisman 1992) singled out three typical groups of drivers (causers):

- those more frequently taking actions unacceptable to the society;
- those with more health problems;
- those who are less smart (according to test results).

Richard *et al.* (2002), May and Baldwin (2009) and McCarley *et al.* (2004) considered that errors within the working time are caused by emotional disturbance – in other words, emotions that disturb the working process. In their opinions, such emotions appear when the subject has doubts about the way of solving the problem he faces (does not fully perceive what has happened and what should be done) or fears to be incapable of solving the problem.

Richard *et al.* (2002) developed special methods for assessing the traits required for the driver's activities. While developing the said methods, the scientists considered that the key traits of a driver include: an ability to distribute attention, a quick orientation in the traffic situation and an ability to foresee its development.

In further research, Atchley and Dressel (2004) concluded that both the traits specified in the studies carried out by Richard *et al.* (2002) and a set of other

properties are required for drivers of trams to ensure their occupational safety. They proposed to supplement the list of traits required for their professional selection with the following traits: good vision, good hearing, an ability to overcome weariness, an ability to operate equipment and so on. While tram drivers were chosen for employment according to all above-listed criteria, the accident rate caused by trams was cut by more than half within two years (Atchley, Dressel 2004).

While analyzing issues of labour hygiene in respect of drivers, Vaisman (1992) developed the theoretical basis of the methodology for professional psychophysiological selection of drivers. This methodology enables to establish: the time and accuracy of simple differentiated reactions, the ability to assess the space/time ratio, the ability to predict probabilities, the emotional stability, the ability to learn proper conduct in problematic situations, the scope, concentration and distribution of attention, the ability of reorientation and many other indicators.

In addition, Vaisman (1992) proposed to assess a driver in the system 'Driver–Vehicle–Road–Environment' not only in the physiological aspect, but also as a personality with abundant psychological traits that ensure his usefulness. Road safety largely depends on a need for successful accomplishment of a task, on thoughtfulness in activities, on taking an interest in vehicle control process, striving for success, constancy of will and other factors. Reliability of a driver may be impaired due to his strong risk proneness, emotional instability, aggressiveness, improper perception of the scale of values, or imaginable advantage.

McCarley *et al.* (2004) carried out an assessment of individual peculiarities of vehicle drivers as well as the psychophysiological and psychological traits relevant for this profession according to the developed methodology and pointed out that the key property of the nervous system is its strength. The dynamics of the professional behavior of a driver depends strongly on the level of the strength of his nervous system, and it is an important trait of a driver.

The authors point out that important professional traits of every driver include a capability of the body to change its functional state when a person's emotional stability and resistance to obstacles and monotony, as well as the ability to visually assess the changes of distance with a sufficient accuracy are tested. In addition, important traits of bus drivers include emotional stability, resistance to obstacles and monotony, the ability to predict possible situations, attentiveness and good memory; important traits of taxi drivers include emotional stability, resistance to obstacles, attentiveness and good memory; important traits of drivers of cargo-carrying vehicles include resistance to monotony, the ability to predict possible situations and the reaction time.

Exploring psychophysiological data on the example of taxi drivers, Konoplyanko (1987), found out that driver performance strongly depends on the complex reaction time, attentiveness and the data processing speed.

After generalization and analysis of drivers' driving errors, a scheme of psychological preconditions for erroneous actions of drivers in dangerous situations was developed (Fig. 1).

After introduction of psychological selection of drivers by a transport company in Paris, the number of vehicles increased by 30% and the number of traffic accident victims due to drivers' fault decreased by 30% within 10 years (Romanov 2002).

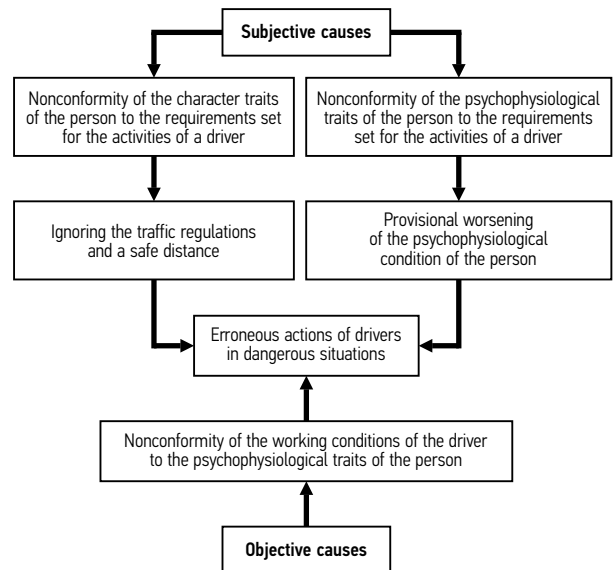


Fig. 1. The scheme of psychological preconditions for erroneous actions of drivers in dangerous situations

Upon summarizing the opinions of various scientists on psychological causes of traffic accidents, it should be concluded that some of them emphasize unsuitable individual traits, whereas others give attention to the increasingly more complex vehicle operators' work process. It should be noted that the influence of the human factor on road safety remains insufficiently researched. In a majority of studies this problem is analyzed in theory only and the results of the said works were not applied to practical activities; however, a majority of researchers make a unanimous conclusion: the professional selection based on the results of testing individual professional traits should be widely introduced. A methodology for such a selection may be developed only after a detailed analysis of the peculiarities of drivers' activities.

4. The Methodology of Studies on Concentration of Drivers' Attention

The process of methodology development includes: collection of general information on road accidents, caused by drivers of Joint-Stock Company 'Vilnius Public Transport' (in Lithuanian – UAB 'Vilniaus viešasis transportas'), analysis of the causes of road accident and preparation of corresponding recommendations for avoiding traffic accidents caused by similar reasons.

Upon completion of the required primary data collection, the processing and assessment of test data takes place.

The study has been subject to a validity test, i.e. a comparison with the data obtained by other authors. Receiving confirmation of validity is followed by practical testing of the methodology and preparation of recommendations for use.

While developing the methodology, the following assumptions were made:

- the tested individual peculiarities remain stable during professional activities of a driver – this assumption is made in reference to constant medical supervision of drivers;
- the gender and the age of a driver does not affect the individual peculiarities of the driver – this assumption is made in reference to the fact, that at the time of analysis 95% of professional drivers who took part in the research were men, age ranging between 29 and 67 years, thus eliminating the most 'risky' group of drivers (18÷25 years old) according to Romanov (2002);
- the experience of a driver does not affect a probability of the driver's involvement in a traffic accident – this assumption is made in reference to effective laws of the Republic of Lithuania, stipulating that a person working as a bus driver can not be younger than 23 years old;
- if the working conditions of drivers are the same, the probability of involvement in a dangerous situation will be the same for all the test subjects – this assumption is made in reference to the fact that work conditions are regulated by the Regulations of the European Parliament and the Council and the laws of the Republic of Lithuania, also taking into account the constant rotation of drivers;
- the technical conditions of the vehicles, as well as the road and the road-climatic conditions are not taken into consideration – this assumption is made in reference to the fact that technical condition of vehicles is controlled more strictly than is prescribed by the laws of the Republic of Lithuania, the vehicles operate in a setting where roads are constantly supervised;
- the quality of information means and traffic organization is not taken into consideration – this assumption is made in reference to the fact that drivers work on actually fixed routes.

The number of traffic accidents is chosen as the main indicator of work efficiency of professional drivers since it has a direct influence on health and life of traffic participants; losses of a transport company incurred due to a traffic accident; and is the determinative factor in company image formation. The ergonomics of drivers' workplace was not valued since the vehicle park is 5÷14 years old.

The number of working days factor was chosen in accordance with the Regulation of the European Parliament and the Council (EC) No 561/2006 and the Labour

Code of the Republic of Lithuania, as of 4 June 2002. These acts strictly regulate alternation of working days and rest days.

By choosing the number of work hours factor an assumption was made that individual human groups for variety of objective and subjective reasons have increased amount of work during the off-duty time.

The shift work factor was chosen in accordance with continuous rotation between the first and the second shift in the company.

5. The Results and Their Analysis

The key factor ensuring road safety is preservation of drivers' performance capacity. The degree of fatigue depends on duration of work. A longer working day of a driver causes a stronger expression of fatigue and increases probability of errors. The research on driver fatigue analyzed herein was conducted in Vilnius city, based on the data obtained from Joint-Stock Company 'Vilnius Public Transport'. After examination of over 250 traffic events the company's drivers were involved in, the following trend was observed: the majority of traffic events occurred during the first working day of a driver after the rest days (Fig. 2).

It may be explained by a lack of attentiveness of drivers which occurs after rest days and is mostly expressed within the first working hours (Fig. 3); by the way, this fact does not contradict the notes of Elbaz (1992),

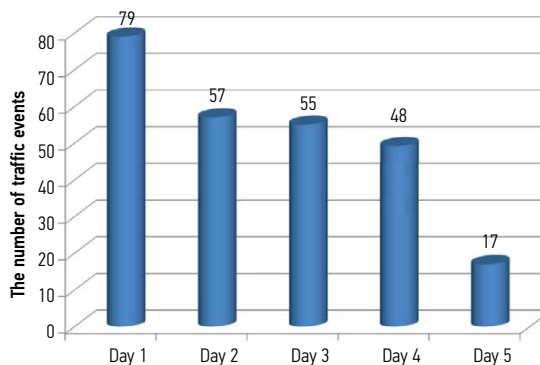


Fig. 2. The dependence of the number of traffic events on the number of the driver's working days (after the rest days)

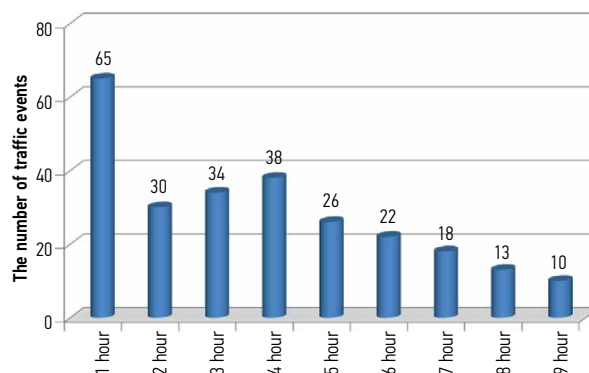


Fig. 3. The dependence of the number of traffic events on the number of the driver's working hours

related to the examination of disturbances of attentiveness of schoolchildren in the beginning of the learning process after vacation. In the opinion of the scientist, they were influenced by a relaxation period, so he proposed to introduce an additional concept of a period of reinvolved in the activities, when schoolchildren gradually concentrate their attention on the learning process. A monotony of work could also contribute to the above-mentioned disturbances – this insight was proposed by Benford and Meech (1992) involved in examination of operators' attention disturbances during the process of flotation. The routine work with the same breaks for rest caused worsening of their attentiveness after rest days; however, after a certain time, attentiveness of the operators improved. The authors proposed providing low-importance tasks to operators on the first day after rest days, thus enabling them to gradually involve in the activities. In this aspect, drivers of vehicles employed in Joint-Stock Company 'Vilnius Public Transport' may be attributed to the category of operators involved in routine activities.

In the course of the analysis of dependence of the number of traffic events on the number of the driver's working days, the following trend was observed: if the number of interrupted working days increases, the traffic accident rate falls; however, this statement is in conflict with the theory formulated by May and Baldwin (2009): according to which, more driver's working days causes increased driver fatigue and increased road accident rate. Romanov (2002) also claims that the number of traffic events caused by drivers having driven from 3 to 8 hours, is 2 times larger, and the number of traffic events caused by drivers having driven for over 8 hours is 9 times larger, as compared to the number of traffic events caused by drivers having driven for up to 3 hours.

According to this author, drivers having driven for over 7 hours cause 30% of the total number of traffic events. And the consequences of such events caused by the errors of drivers due to prolonged driving are usually more serious.

The contradiction of the obtained results to the ones published in references may be explained by the results of the survey of drivers of vehicles employed at Joint-Stock Company 'Vilnius Public Transport': it has revealed that instead of taking a rest, the majority of drivers work at home or are involved in supplementary activities during their rest days, so they return to their workplace tired. This fact coincides with the arguments expressed by Billiard *et al.* (1997) – they were involved in investigating the impact of neurosurgical diseases upon the sleep quality. One of the aspects of the investigation was sleep disorders after hard and monotonous work of the patients.

In addition, it was found that the drivers who start working in the morning, i. e. working in the first shift (from 04:00 am to 02:00 pm with an up to 1 hour lunch break), cause 25% (on the average) larger number of traffic events, as compared to the drivers working in the second shift (from 02:00 pm to the midnight with a lunch break up to 1 hour) (Fig. 4). This may be related

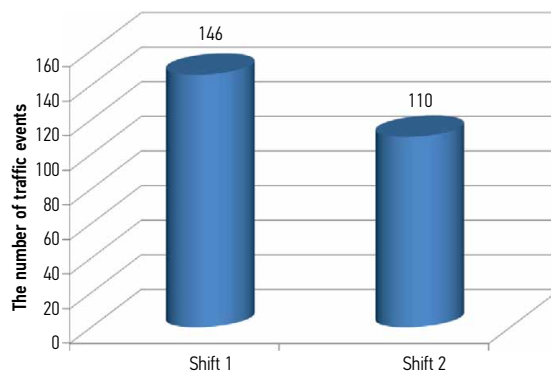


Fig. 4. The dependence of the number of traffic events on a driver's shift

to the above-mentioned trends in the drivers' activities. Although the physical rest time after the second shift is shorter, as compared to the rest time after the first shift, vehicle drivers have a rest after the second shift according to a regimen that conforms to the human physiological rhythm. These problems may be solved by professional selection of drivers: only highly-responsible drivers ready for such a work cycle should be selected.

It is advised to examine psychophysiological traits of a person during the training period and particularly during the period of formation of the professional skills, as well as in the course of the professional activities. Firstly, examination of psychological traits of a driver should be carried out during his work, in order to choose a work pattern that suits a particular driver (working in a city with intense traffic or on international routes), the type of a vehicle, the duration of the shift, the level of importance of tasks and the time of the day. Such an examination with assessment of psychophysiological traits of drivers is typical for professional selection.

Negative psychological traits of a driver may be counterbalanced by other traits and express themselves only in complicated traffic situations. It is advisable to carry out driver testing on a regular basis using special exercises simulating various emergency situations. The key criterion of driver's excellence should be an ability to work in complex road conditions. It would be purposeful to carry out driver examination after a long break in the activities (a disease, a leave, etc.) when the professional driving skills lose their automatic character. Such an examination is needed if a driver starts working on special vehicles.

When a driver is tired, only the simplest skills having achieved the 'automated' level remain and they enable the driver to take proper actions in well-known standard situations. First of all, disturbances of complex mental activities appear and they worsen the level of readiness for actions upon sudden and unusual changes of the traffic situation. This circumstance causes decrease of the driver work quality and gives rise to accident-causing errors.

The problems identified in this article need to be solved, since they have a direct influence on the number of traffic events. Positive changes have been observed

after toughening the driver selection process at Joint-Stock Company 'Vilnius Public Transport' according to physical peculiarities of a professional driver (overall physical fitness, vision disorders during the darkness hours, identification of professional drivers as 'morning larks' and 'night owls' and their further appointment to work in corresponding shifts) and upon application of other preventive measures (interviews to discuss the rest a driver had before his duty hours, taken during the daily pre-departure compulsory medical check, without any penalties to professional drivers in case of rest absence (a driver is relegated to the reserve)). Comparing 2010–2011 accident statistics to the first five months of the year 2012, the accident rate has decreased by 19.36%. These results suggest that continuing similar preventive measures could ensure significant decrease in traffic events, which were proved to be caused by the company's drivers. It should also be noted that this problem is highly topical and that there is a need for further studies to examine the peculiarities of applying these preventive measures and their impact on a professional driver's psychophysiological qualities, as well as on the traffic events caused by such qualities.

6. Conclusions

1. By rating the factors, the influence of individual traits on the degree of driver suitability for public municipal passenger transport was clarified.
2. For the purposes of comparing the influence of different driving styles and safety guidelines on driving, an opportunity of a prior separation of cautious and risk prone drivers before an assessment of certain peculiarities of their behavior (such as vehicle operation, velocity, etc.), both in laboratory and real traffic experiments, should be considered.
3. Research works on behavior should analyze the influence of experience and skills on the required distribution of attention, taking into account different age groups and genders.
4. Application of the proposed methodology will enable to reduce the number of traffic accidents caused by a fault of public municipal passenger transport drivers by up to 40÷50% by Romanov (2002), however in this study, when comparing the data of the years 2010–2011 to the data of the year 2012, the occurrence of traffic events at Joint-Stock Company 'Vilnius Public Transport' has decreased by 19.36%.
5. The methods proposed in this paper are also applicable to drivers of other vehicle types, as well as locomotive drivers and employees of various operative services where the nature of activities determines particularly high standards for personal psychophysiological traits.

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