

Research and analysis of work ergonomics of selected transport means operators

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Abstract. Ergonomics of transport means along with safety, availability, efficiency or eco-friendliness is one of the main assessment criteria for transport means functioning. Assessment of the considered transport systems operation depends on their operators' behaviour, functioning of vehicles and environmental factors. Having this in mind, it needs to be noted that the issue of transport systems ergonomics is, on the one hand closely related to the transport means, and on the other hand it directly affects peoples' actions and improves the possibilities to adapt to the environment, taking into consideration external factors. The aim of this study is to provide assessment and analysis of the influence of the operator's work place ergonomics of given transport means on the quality of transport services. The research object are delivery trucks, and motor cars, different in terms of the total capacity. In the first part of the study the problems connected with an operator's work place ergonomics is discussed and the concept of transport means ergonomics is defined. The role of ergonomics in a professional driver's work is specified. The factors and threats affecting safety of operators' behaviour are identified. A survey was developed and carried out among professional drivers to identify factors affecting the transport process as well as factors improving the driver's work comfort. On this basis, an analysis of the obtained results was made and negative ergonomic aspects involved in a vehicle driver's work place have been presented. The impact of selected elements of the driver's cabin equipment on safety and work comfort is evaluated. Problems and their causes are identified. Solutions to these problems are proposed in order to improve ergonomics of the vehicle driver's work place, thus affecting the quality of a system operation according to the sociotechnical approach.

1. Introduction

Ergonomics of machine operators' work post became an important research issue when after the Second World War constructors started to build new machines which were exposed to frequent damage as the human factor was not taken into account at the stage of design. At the same time, the psychological aspects of human behaviour were more and more appreciated and explored to help designers adjust a machine to the operator's needs [1].

The process of design of an ergonomic work post is carried out at two levels. First, it focuses on the operator's work post; second, it needs to take into account requirements of the cabin space. The criteria take into consideration such factors as: human body dimensions, body shape, muscle power, body



movements as well as the specificity of the operator's behaviour and the work he is supposed to perform. The design of a work post needs to take into consideration the tasks which must be performed by a man and a machine. It needs to be optimized to suit the physical and psychological capacity of the operator [2].

The major role of ergonomics is to improve work efficiency, provide safety and reduce to minimum, harmful factors affecting the operator's work quality, provide reliability of technical solutions, safety and comfort for humans [3].

Ergonomics is focused on elimination of negative emotions including: resignation, weariness, monotony, boredom or factors disruption of the work process [4].

2. Definition and division of ergonomics

Ergonomics is a science which should combine the needs and psycho-physical capacity of a human with a machine operation mode [5].

Ergonomics is referred to as an applied science. It is supposed to highlight the needs of humans in such a way that the design of transport means must be adjusted to the needs and the physical condition of a driver and a passenger [2].

Ergonomics aims at adjusting tools, machines and devices, as well as other objects, to physical and psychological capacities of a human. It focuses on the human rather than the output of his/her work [6].

The rules of ergonomics are supposed to provide each worker with appropriate conditions of work with simultaneous elimination of harmful and dangerous factors, though without negative effect on the work efficiency. According to these rules work should be performed efficiently and at the lowest possible biological cost. Also the work post should be adjusted to the needs of a human and comply with the existing conditions [3].

It aims at transforming the technical equipment, changing work organization or the environment in such a way that a human can efficiently do his/her job without difficulties and hazards [7].

At the same time ergonomics is focused on improvement of the society knowledge of implementation of rules and solutions into everyday work and actions involved in the process of work [8].

Applications of ergonomics can be divided into:

- correction ergonomics which applies to work posts which are not used any more, determines whether there are any abnormalities at the work post and makes sure that they are liquidated as soon as possible [3];
- conceptual ergonomics, which is supposed to optimize dependencies between the human, the machine and the environment as early as at the stage of design, thanks to which many mistakes and problems can be avoided [5].

According to specialization, ergonomics can be divided into [3]:

- -physical ergonomics which is directly connected with the shape of human body,
- -cognitive ergonomics which involves human psychology and relations between people,
- -ergonomics of work management and organization.

There are a few rules of ergonomics. The first rule involves ergonomics of four load levels affecting a working man. These include: organizational, physical, environmental and psychological loads. The second rule applies to identification of objects which cooperate with a human during operation, that is, the environment and the machines and tools [3].

The main assumptions of ergonomics involve using solutions which are most effective in terms of economy and ecology, aiming at raising efficiency, comfort and safety of work [5].

Ergonomics refers to such scientific disciplines as: anthropology (deals with measuring human body in order to create suitable work posts), work physiology (is responsible for phenomena occurring during work to prevent from tiredness or boredom), work hygiene (prevents from occurrence of factors which cause infections or diseases), psychology of work includes three aspects: adjustment of a human to work, work to human and human to human) [6].

3. Ergonomics for work posts of drivers

The employer should provide employees with a work posts where they are safe and nothing can threaten their health or life. The conditions of work should constantly be improved to make them optimal in terms of safety and comfort. Employers should minimize psychological loads and any other inconveniences adversely affecting the employee's health and life [9].

Work of a driver is connected with many aspects that have a negative impact on human health and directly affect the quality of transport processes. A driver has to cope with internal and external factors which have direct impact on his/her behaviour in the traffic, on a daily basis [10-14].

Having in mind the above mentioned facts, it should be emphasized that ergonomics of a driver work post is one of the issues which have a large impact on the quality of transport means operators.

3.1 Survey research

The survey was carried out for a group of professional drivers, different in terms of gender, age, driving license class, and the vehicle age. The respondents were employees of transport companies at the post of a driver. There were 50 respondents. The survey object was ergonomics of delivery trucks. The main goal of the survey was to identify the ergonomic conditions characteristic of the driver work post. The survey consisted of ten questions, including open and closed ones, and a metrics with the respondents data. Each questionnaire was numbered from 1-50.

There were 46 men and 4 women. Twenty respondents were aged 41- 50, fifteen (31-40), ten were over 50, whereas five were 21- 30; there was nobody under 21 - figure 1.

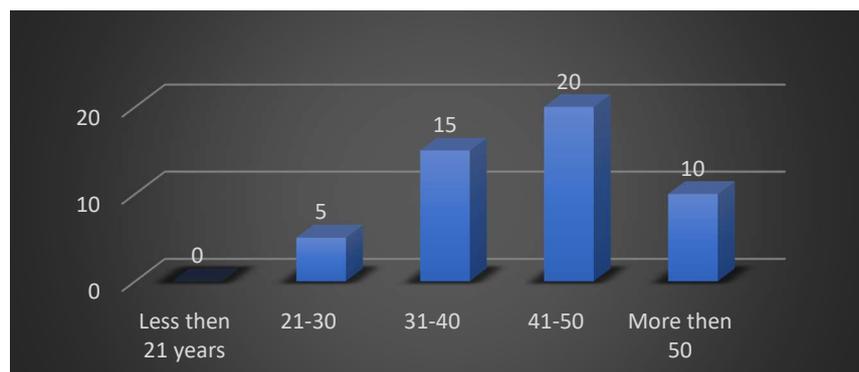


Figure 1. Chart depicting the respondents' age structure

In terms of the length of employment, the respondents were divided according to the time of employment at a given post. The most of respondents had been employed more than 5 years (33), 12 persons had worked at that work post for 3-5 years, four respondents 1-3 years, whereas, 1 person less than one year - figure 2.

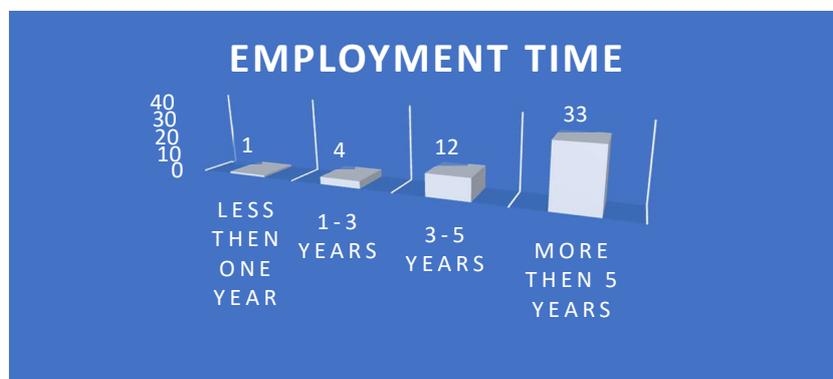


Figure 2. Chart showing the length of the respondents

The next aspect included in the metrics was the type of vehicle they were using. The vehicles were divided into four groups: up to 3.5 t, over 3.5 t without a trailer and over 3.5 t with a trailer. 21 respondents were in the first group, 23 were in the second group, whereas, the last group included 6 people. Age of the vehicles was the last division criterion. Five time intervals were provided. Most drivers used vehicles manufactured in (2006- 2010), 14 vehicles were produced after 2010, 11 between (2001-2005), 6 between (1995-2001), whereas one respondent was using a vehicle from before 1995 - figure 3.

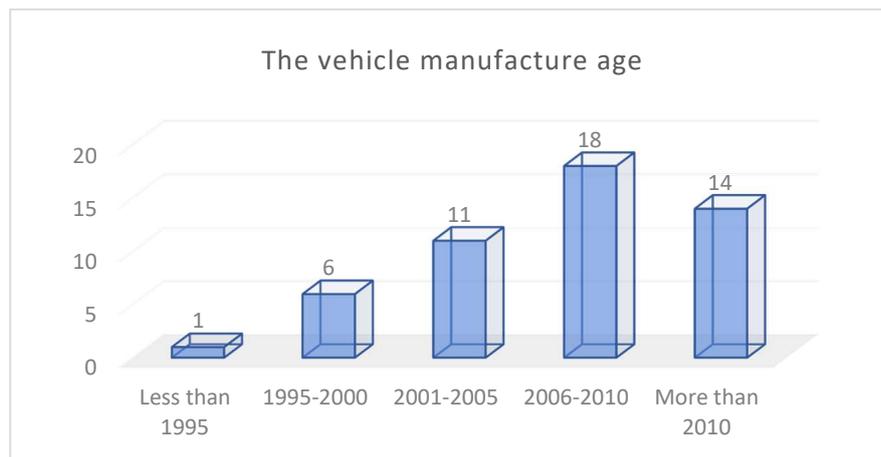


Figure 3. Chart of the analysed vehicles age structure

Ten questions were asked and the set of questions is presented in table 1.

Table 1. Set of the survey questions.

No.	Question
1.	What is your opinion about the comfort of driving according to scale from 1 (poor)-5 (excellent)?
2.	Which element of the cabin equipment needs to be changed, modernized (seat, steering wheel, power transmission system, mirrors, seat belts, windshield, arm rest, head rest, audio system or others)?
3.	Assess the difficulty level of operation of devices fixed in the driver's cabin 1 (low) -5 (high) and say which device is the most difficult to operate for you?
4.	Which external factor is the most annoying during driving and to what degree; 1 (the least) to 5 (the most) (noise, precipitation, slippery road surface, limited visibility, traffic congestion, temperature, other road users)?
5.	Which devices and to what degree, from 1 (the least) -5 (the most), have a positive influence on your work as a driver (fridge, television, sunroof, navigation, multifunctional steering wheel, air conditioning, webasto, gas cooker, others)?
6.	Is any maneuver particularly difficult for you due to the vehicle design or structure (parking, loading/unloading, mandatory stopover, driving)?
7.	Has your health condition deteriorated in result of your work as a professional driver?
8.	Does any factor have a negative influence on the job you do (work monotony, time pressure, responsibility for the cargo, long information circulation time)?
9.	Does any road structure obstacles affect the quality of your work (type and condition of the road surface, application of ITS, 'green wave', MOP-s availability and category, road marking)?
10.	Can your vehicle be effectively improved from the point of view of its operator, that is, the driver?

3.2 Results and analysis

On the basis of the survey research results carried out for a group of fifty supply van drivers, the basic statistical indexes were determined for the obtained scores, which are presented in table 2.

Table 2. Mean values of the survey scores

	Questions									
	1	2	3	4	5	6	7	8	9	10
Sum	177.5	209	182.5	187.28	59.66	188.75	150	152.5	98.3	205
Average	3.55	4.18	3.65	3.75	1.19	3.78	3.00	3.05	1.97	4.10
Median	3.75	4.50	3.75	4.29	1.06	3.75	5.00	3.75	1.67	5.00
Stand-dev	0.99	0.55	1.40	0.96	0.89	0.31	2.47	1.02	1.28	1.94
Coef-Var	0.01	0.003	0.01	0.01	0.01	0.002	0.02	0.01	0.01	0.01
Min	1.25	2.5	1.25	2.43	0.00	2.5	0	0	0.83	0
Max	5	5	5	4.57	3.89	5	5	3.75	5	5

The answers provided by the respondents to the first question, indicate that most of the drivers provided two highest scores, which proves that, generally, they are satisfied with the comfort of driving their vehicles.

Question number two was supposed to check which element of the cabin equipment requires change or modification. Almost half of the respondents indicated the seat as an element that needs to be modernized. They said it was uncomfortable, prone to damage, poorly adjustable, not fitting the body shape which has a harmful effect on the spine while long driving. Moreover, a hydraulic adjustment system should be used and the filling of the seat should be of better quality not to disintegrate or displace. Head rests need to be improved to fit better the body shape. According to the respondents, the elements which require modernization are mirrors because they: limit visibility, are not heated, generate the so called 'blind spot', should be larger, have too short perspective. The next system indicated by eight respondents to be not good enough, was the power transmission devices and post „A". As regards the gear box, the drivers proposed to replace the gear level with a joystick, introduce an automatic gearbox. They also indicated too short transmissions. However, the group of drivers who were not satisfied with 'A' post, had objections as to limited visibility which is of crucial importance and can lead to a collision or an accident. The next element, which was indicated was a steering wheel. Drivers said that a steering wheel should be multi-functional and made of leather. In relation to the comfort while driving in seat belts, it was found that: they should be more elastic, they should not get jammed, they are too tight and 'pull'. The arm rest was indicated as an element to be modernized as: it is too stiff and there should be two arm rests fixed on both sides. The wind shield is characterized by certain features which disturb a driver in his/her work. These include: poor visibility, frosting and evaporating and also insufficient range of the wipers operation, that is, they do not wipe the whole Surface of the wind shield. The audio system, however, is also an important element of the cabin equipment. due to the function it plays in reception of traffic information and prevention from monotony and boredom during driving. In the view of the respondents the following elements should be improved: the quality headphones and their poor configuration.

The third question consisted of two parts. The first was about the difficulty degree of operation of devices available in the cabin and it was discovered that the drivers did not find it difficult to operate the deck equipment. As far as the second part of the question is concerned, as many as forty two respondents answered that operation of no device was a problem for them. Eight persons, however, were of a different opinion and acknowledged that the most difficult for them was operation of the tachograph, use of navigation, reading deck computer messages, operation of the radio and operation of the temperature gauge.

Question number 4, offering a multiple choice, was connected with external factors which are considered to be the most annoying while driving. Most of the drivers indicated traffic jams and poor visibility. It is commonly known that traffic jams are reported in many towns, especially during rush hours. They are particularly annoying for drivers due to the pressure connected with the delivery time. Other factors include: noise, precipitation and slippery roads. Other road users were found to be the least annoying.

The fifth question was supposed to find out which device: a fridge, navigation, webasto, television multi-functional wheel, gas cooker, roof window, air conditioning or other appliances are the most important and have a positive influence on the driver's work. The most respondents considered navigation and air conditioning to be the most useful appliances. The fewest chose television. Navigation and air conditioning are, according to the drivers, indispensable systems as they make driving easier and more comfortable.

The sixth question was connected, with tasks they had to perform while providing transport services, that is, loading/ unloading or driving. The respondents were supposed to choose one activity and justify why they found it the most difficult or complicated. Most drivers chose loading and unloading to be the most problematic activity for them. However, driving was considered to be the easiest and the least complicated. They said that loading and unloading is time consuming, there are too few hooks within the loading space, there are no mechanical systems to be used for loading/unloading. Some companies consider drivers to be responsible for loading/unloading, besides, the period of waiting is too long and there are no side doors to facilitate loading or a proper platform to be used. Mandatory stopover is irritating because: a driver has to stay idly for a long time, there is too little space for resting, the vehicle often is not equipped with a bed, it is necessary to get familiar with the rules of a given country and additionally there is the pressure of delivery time. Parking was chosen to be problematic due to: lack of sensors, lack of cameras, possibility of hitting something or causing a collision because of the vehicle large size and length and little parking space. However, the driving itself was indicated by four drivers who mentioned the vehicle big size, constant noise, frequent failures and poor visibility.

The next question was connected with health deterioration in result of the performed occupation. 60% of the respondents did not complain about the health problems caused by the job they do and the remaining 40% complained about the problems with: spine, eyes, and spending too much time in a sitting position.

In the answers to question number 8, four factors which can have a negative impact on the driver's health were listed: work monotony, time pressure, responsibility for the cargo and long circulation of information. Most respondents chose the pressure of time as the most negative element of their work. It is known that punctuality of delivery is very important and financial penalties threaten for delays. However, an analysis of the answers shows that the least influence on the driver's work was attributed to information circulation.

The ninth question applied to the infrastructural factors. The respondents declared that the type and quality of road has the largest influence on the quality of their job. The least influence was identified for ITS installation in the road structure and availability and category of parking places.

Question number ten was about ergonomics improvement in the vehicle. The drivers could propose their own solutions to be used for improvement of their work quality and efficiency. 41 respondents said that it was not possible to improve ergonomics in their vehicles, whereas the remaining drivers proposed some solutions such as: modification of the steering system, increasing the engine power, improving visibility, installation of air conditioning, replacement of standard steering wheel with a multi-functional one, automatic gear box, modernization of the driver's seat, reduction of noise, additional adjustment of the steering wheel, and creation of additional closed compartments for storing items.

Summing up the survey results, particularly the answers to the first question, it can be observed that in almost 70% cases the respondents' assessment of their vehicle ergonomics level was good (20% very good), whereas it needs to be emphasized that none of the respondents provided the lowest score – figure 4.

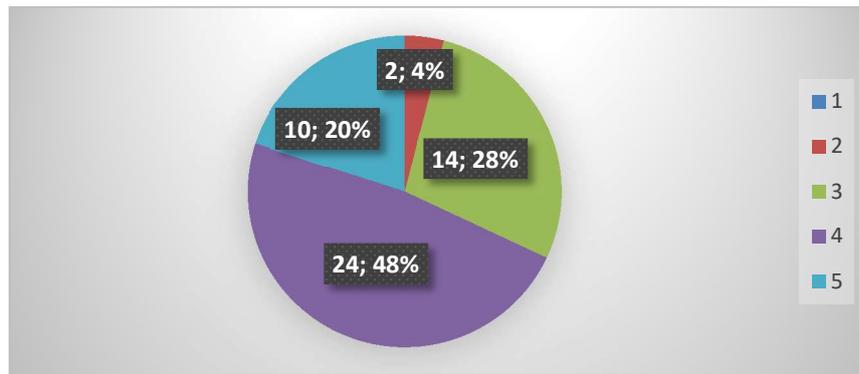


Figure 4. Chart showing ergonomics of the considered vehicles according to scale (1-5)

At the same time, considering the respondents' age (70% between 30-50) and the length of their employment (65% more than 5 years) figures 1 and 2, it can be said that they are experienced drivers whose answers were well considered and based on their job experience and a possibility to compare their current vehicles with those they have driven before.

It seems that this was the age of the vehicles that was the major criterion taken into consideration by the respondents. Most of them (64%) has been using the vehicles manufactured after 2006, including almost 30% of vehicles manufactured after 2010 (fig. 3), which can prove that the vehicles are equipped with new, innovative technologies and solutions that have a significant influence on the level of ergonomics of the transport means they use.

In connection with this, it can be said that the respondents are aware of the differences in the level of ergonomics of their vehicles and manufacturers take into consideration their requirements at the stage of transport means designing.

Additionally, in order to check the correlation between particular questions, a test of correlation coefficient significance was performed on the basis of the obtained results, whose implementation is shown in the form of a matrix, in table 3.

Table 3. Results of the correlation coefficient significance test.

Question	1	2	3	4	5	6	7	8	9	10
1	1									
2	0,207	1								
3	0,421	0,056	1							
4	0,201	0,005	-0,008	1						
5	-0,333	-0,261	-0,163	0,038	1					
6	0,121	0,198	0,227	0,021	-0,213	1				
7	-0,010	-0,142	-0,058	0,069	0,173	-0,100	1			
8	0,048	0,457	0,039	0,037	-0,301	-0,044	-0,010	1		
9	-0,035	-0,270	0,052	0,025	0,217	-0,180	0,031	-0,211	1	
10	0,170	0,202	0,247	0,210	-0,100	-0,174	0,042	0,062	0,076	1

According to the test results the sample number $n=50$, hence for variables of the continuous system it is sufficient and statistically significant. Only five pairs of variables have significant correlations in relations to each other, whereas the level of their significance is expressed by low values. Therefore, it provides the basis to consider this set as being oversized.

4. Summary

This study presents an analysis of the problems connected with work post ergonomics of an operator – a car driver. Factors which negatively affect the quality of the transport process have been identified by means of a survey research. An analysis of the obtained results has been performed and on its basis, negative aspects of operating a vehicle by its drivers have been identified. The impact of internal and external elements on the driver's quality of work has been assessed. Solutions and factors which could improve ergonomics of the respondents' vehicles have presented. Besides, a statistical analysis has been performed as well as a correlation coefficient significance test, on the basis of which, it can be said that the analysed set of questions provided in the survey was adequate and their number was not oversized because there is significance of correlation between them which means that particular questions are separable and do not reflect the information included in the remaining ones. There is a need to do more research and compare its results, e.g. for drivers of passenger cars or other transport means, in order to adjust machines and technical objects to psycho-physical characteristics of humans.

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