Journal of Urban and Environmental Engineering, v.13, n.1, p.23-33

ISSN 1982-3932
doi: 10.4090/juee.2019.v13n1.023033

Journal of Urban and Environmental Engineering

www.journal-uee.org

IMPROVING OF URBAN PUBLIC TRANSPORTATION QUALITY VIA OPERATOR SCHEDULE OPTIMIZATION

Yurii Davidich, Yevhen Kush, Andrii Galkin *, Nataliia Davidich, Iryna Tkachenko

O. M. Beketov National University of Urban Economy in Kharkiv, Ukraine

Received 03 February 2019; received in revised form 27 March 2019; accepted 27 April March 2019

Abstract: The functioning of passenger transport systems should provide necessary quality of passenger service. The results of this research have shown possibility to increase the quality of urban public transport via influence on the driver's state due to the rational schedule planning. The state change patterns of drivers during the idle time on the final and intermediate bus stops were formalized, based on field observations. The following conclusion was made: decreasing of driver's body stress takes place during the idle time on the route stops. The intensity of decreasing of driver's body stress is inversely proportional to the meaning of activity index of driver's regulatory systems before the start of standing time. Consequently, the duration of idle time must be differentiated depending on the value of the indicator of activity of driver's regulatory systems before the start of standing time, which is influenced by the working conditions. ECG method was used for assessing driver's fatigue in elements of transportation process. Comparative analysis of driver's state changes during the different types of idle time shows the comparability of the results of the study. Transportation management experts can use the research results in urban transport schedule planning and monitoring.

Keywords: Passenger transport; transport process; driver's state; idle time

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* Correspondence to: Andrii Galkin. Tel.: +380 93 196 50 04. E-mail address: galkin.tsl@gmail.com. ORCID 0000-0003-3505-6170.

INTRODUCTION

The increasing of passenger's transportation quality in the system of municipal public transport is one of the most important needs in the transport sphere (Eboli, Mazzulla, 2007). The safety and security arrangements of passenger's transportation are also very important. They determine the quality of transport service (Eboli, Mazzulla, 2006). The traffic safety is one of the most relevant social and economic problems of our time. Its formation is very complicated and uninterrupted process which requires corresponding continuous monitoring and appropriate measures for improving driving conditions (Yannis & Georgia, 2008). The transport vehicle conditions, driver's behavior and surrounding conditions influence the quality of passengers' transportation.

The aim of the research is to improve the quality of public transport by optimizing the driver's schedule. Object of research is a pattern of influence of the technology of transportation on the driver's state. To achieve this goal, using the method of expert assessments, the significance for passengers of the safety of movement was determined as an indicator of the quality of urban public transport. Based on the systems analysis methods, the safety of the transportation process was found significantly affected by the driver's condition, which in turn is affected by the parameters of the elements of the passenger transport process. The use of the methods of probability theory and mathematical statistics made it possible to determine the patterns of change in the state of the driver of urban transportation with various types of idle time that can be used to optimize the driver's schedule.

ANALYSIS OF RECENT STUDIES AND PUBLICATIONS

Improving the quality of urban public transportation is one of the most important areas meeting the needs of society in the field of transport (Eboli, Mazzulla, 2007). Researchers divide the criteria for the quality of urban public transport functioning into socio-economic indicators of passenger service and performance indicators of transport enterprises (Eboli, Mazzulla, 2006). According to researchers, one of the most important criteria for assessing the quality of transport services for the population is the total expenditure of residents' time (from the starting point to the final) (Yannis & Georgia, 2008). Scientists note that the organization of passenger transportation should ensure the rational use of rolling stock, complete safety and a high culture of passenger service at the lowest cost (Gudkov, Velmozhin, Mirotin, 1998). An important characteristic of the quality of transport services, according to researchers, is the comfort of the trip (Eboli, Mazzulla, Pungillo, 2016). The quality of urban public transport by the passenger occupancy rate and use of time in the ride, speed, traffic intensity, the headway, regularity factor, service efficiency indicator, cost efficiency ratio, overall indicators of vehicle indicators (Daszczuk, Choromański, Mieścicki, Grabski, 2014). The paper (Yannis & Georgia, 2008) also takes into consideration the severity of road accidents, and in (Eboli, Mazzulla, 2008), scientists have determined that improving the quality of transport should have a positive effect not only on the quality of transport in the urban public transport system in general (overall goal), but also from the point of view of individual categories of transportation quality (Fig. 1).

In this case, researchers note that the assessment system includes indicators, distributed according to the classification criteria into organizational, socio-economic, technical, technological and environmental (Braniš, et. al., 2018; Frederix, Viti, Tampère, 2013). Thus, the quality of transport services for passengers is determined by many indicators. In general, urban public transportation should be convenient, safe, and the time spent on a trip should be minimal (Marcucci, Valeri, Stathopoulos, Gatta, 2011). As the researchers point out, when designing the process of transportation of passengers, it is necessary to take into account the parameters that affect the quality of transport services. The value of these parameters was formed when introducing various methods to improve the transport process. Designing optimal route schemes is central in the organization of the operation of urban public passenger transport (Pattnaik, Mohan, Tom, 1998). Construction of a rational route network of public transport in cities is an important task, the quality of which depends on the time and money spent by the urban residents on travel, the comfort and safety of transportation, environmental factors (Bifulco, Di Pace, Viti, 2014). The quality of urban passenger transport can be improved by developing a system of dispatch control and control of the operation of vehicles (Rossi, Gecchele, Gastaldi, Biondi, Mulatti, 2017). The quality of passenger service is also conditioned by the type of urban passenger transport used on the route (Grigorova, Davidich, Dolya, 2015a). The main criteria for choosing a vehicle are the conditions for the most complete satisfaction of the population's needs for transportation, the efficient operation of urban passenger transport and improving the quality of public service (Makarova, Khabibullin, Shubenkova, Boyko, 2016). Periodically rationing of the speed of movement is carried out in order to ensure the safety of transportation, reducing the time spent by passengers on a trip (Gudkov, Mirotin, Velmozhin, Shiryaev, 2006). The quality of passenger transportation is affected by the location of bus stops (Chumachenko et. al, 2017). The correct location of bus stops affects not only the distance of pedestrian movement to it, but also, the total cost of passenger time spent on the movements and the speed of vehicles (Grigorova, Davidich, Dolya, 2015b). Since, the ridership is unevenly distributed over the hours of the day, the length of the route, working days per week, it is important to design modes of urban public transport and their combinations in order to improve the quality (Horbachov, Naumov, Kolii, 2015). Schedule of traffic is the basic design document for organizing the operation of urban public transport. Development of convenience schedules determines the quality of service and the efficient vehicles' use (Drabicki, Kucharski, Szarata, 2017). The selected modes of drivers' operation determine the ability to adhere to schedules and traffic safety, which determines the level of quality of passenger transportation. Important circumstances of passengers' safeties are condition of the rolling stock, the driver state and quality level of road surface (Gudkov, Mirotin, Velmozhin, Shiryaev, 2006). Other research, points on the directions to improve the quality of the urban passenger transport as the part of urban transport system is ensuring environmental safety and reducing environmental pollution (Braniš, et. al., 2018).

In consequence, the analysis of the factors used to assess the quality of public transportation showed that traffic safety is one of the main factors. However, the level of significance of this indicator for passengers was not fully formalized by researchers. Improving traffic safety is possible at the stage of projecting the parameters of the technological process of passengers' transporting and planning driver's a schedule. Simultaneously, the available methods of scheduling the driver's work do not fully take into account the effect of technological indicators on the state of his body. The safety transportation characterizes the function ability of public transport at the given parameters that provide the transport task realization and minimize irregularities that can be potential or actual menace for life and health of passengers. The state of the driver influences the transportation safety essentially (Stojmenova, Sodnik, 2016). The drivers of public municipal transport have the biggest load on their nervous system among all the other transport drivers (Davidich *et al.*, 2018).

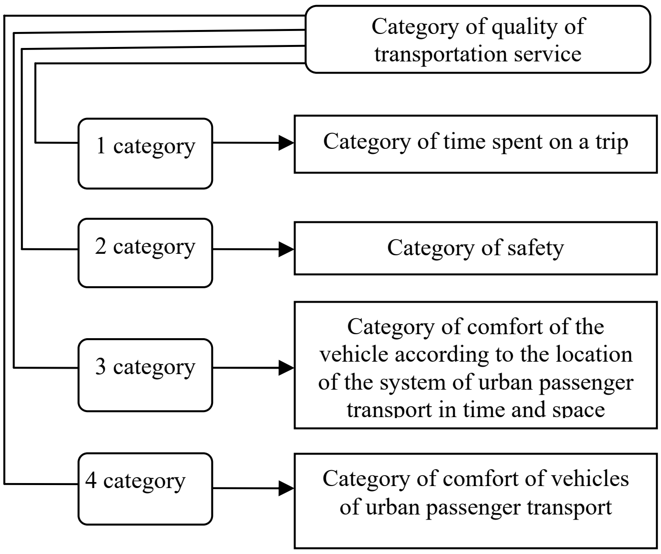

Fig. 1. Categories of quality of transportation in urban passenger transport

Motor transport technical process is the process with the difficult technological cycle. The driver is the main and direct participant who manages the transport process on the route. Researchers equate profession of the driver to the operator of dynamic objects (Kaplenko, 1997). The productivity level, carriage effectiveness and traffic safety depend on his organization of schedule. The working patterns are directly connected with preservation of health and continuation of worker's career longevity (Witt, et. al., 2018). Fatigue during the long period of driving decreases driver's working ability and becomes the main reason of making errors. These unfavorable conditions could complicate driver's behavior in extremely situation and be a reason of road accident happening (Duchowski, 2007). The estimation of fatigues appearance is one of the main tasks of working process management (Afanasieva, Galkin, 2018). Big psychological and physical overloads on the route cause driver's fatigue. Driver's working efficiency depends on the type of transportation process (Comi, Nuzzolo, Brinchi, Verghini, 2017).

Some researchers think, that the duration of driver's workability period starts from 0,5 till 1,5 hours of his work (Volper, 1979). Others note that the formation of high level of functioning efficiency happens during first 1,5-2 hours (Volkov & Mashkov, 1993). The gradual growth of psychological function charges starts in 4-5 hours. Decrease of work tension as usual takes place after 6-7 hours of work (Tharewal, et. al., 2014). Perceptible fatigue of drivers is observable in case of the longer then 8-hours working day. The same conclusion made there searchers (Davidich *et al.*, 2018), who defined that driver's working efficiency lasts during 7-8 hours and after that it decreases. Drivers who work more than 10-hours every day have overfatigue (Mishurin, Romanov, 1990). Working efficiency decreases after the 10-hours working day, and it is unacceptable for road safety (Volkov, Mashkov, 1993). After ten hours of work, there is a decrease in efficiency, which is unacceptable in terms of road safety (Zhang et al., 2018), and after twelve hours there is a significant reduction in professional and important physiological functions (Prasolenko, Burko, Halkin, 2017). The amount of drivers, who complain on fatigue, impaired concentration, sleepiness in case of 8-hours working day is lower on 22,7%, 9,0% and 3,5% than in cases with 12-hours working day and more (Galkin, et. al., 2018). However, sometimes at the end of shift some of driver's activity factors become better. Researchers think that it happens because of high stress level of adaptation and compensatory mechanisms that are aimed at preserving of the efficiency of work (Meng, Li, Cao, Li, Peng, Wang & Zhang, 2015). It was found that in case of 8-12 hours shift bus drivers have the activation state of some physiological functions at 8-10 hour of their work. It can be seen in improvement or in stabilization of some physiological parameters of the driver's functional state (concerning the level recorded previous time) (Lobanov, 1980). Also, as it is mentioned in (Roman-Liu, Grabarek, Bartuzi, Choromański, 2013), the necessity in relaxation is based on driver's energy cost. As we see from analyzed literature, researchers didn't consider the process of driver's state change during the rest period. In order to create correctly the time schedule and time duration of additional idle time, it is necessary to create and analyze regularities of change of the driver's state in case of idle time on the intermediate and final bus stops.

Researchers offered to use integral estimation test shows the activity of regulatory system for estimation of the human state (Lobanov, 1980). It shows the reaction of human body on the influence of environmental parameters. This parameter estimates the intensity of communication channels of human regulation and how they react on the influence of environmental parameters. This value is determined analyzing the human cardiograms.

The authors of work (Osipova, 1984) represent the index of regulatory systems activity (IRSA) in the form of sum of conditional marks. Depending on the meaning of this sum, the human body state can be defined, e.g.: less than 3 points – normal state, 3-6 points – state of stress, 6-8 points – state of over-stress, 8-10 points – state of exhaustion (asthenization). The amount of positive and negative marks that take part in the formation of total value also should be taken into account.

DATA AND RESULTS OF RESEARCH

Definition of significance for passengers of the criteria for assessing the quality of the work of urban passenger transport

To achieve the goal on the first stage of the research it was conducted a survey of passengers where they were asked to choose the criteria for estimating the quality of urban public passenger transportation. Also they were proposed to range them from the most important till the least important according to their opinion. Data processing of research was made on the next stage. The Kendall's coefficient of concordance was used for the estimation of the experts' opinion consistency:

$$W = \frac{12S}{m^2(n^3-n)}, \qquad (1)$$

where W – the Kendall's coefficient of concordance; m – the quantity of experts; n – the quantity of factors; S – the sum of deviation square, defined as follows:

$$S = \sum_{j=1}^{n}(X_j - X_{cp})^2, \qquad (2)$$

Where X_j – the sum of grades of j – factor; X_{cp} – average sum of grades, defined as follows.

$$X_{cp} = \frac{\sum_{j=1}^{n} X_j}{n}. \qquad (3)$$

Accounting results present in the **Table 1**. Analysis of Table 1 showed that the average sum of the ranks of all factors was 2177,8. Received coefficient of concordance value is equal to 0.62 and it points to experts' opinion consistency. The empirical value of Pearson criterion was used for checking the coefficient of concordance static weight:

$$\chi^2 = \frac{12S}{mn(n+1)}. \qquad (4)$$

The calculations showed that criteria target value is χ^2= 2310,77. We compared criteria target value χ^2 with the tabled one value to define the coefficient of concordance static weight.

In agreeing of experts' opinion, the target value is bigger than the tabled one (21.0) for the level of confidence 0,5 and the number of degrees of freedom m=13. As the result we can make a conclusion that received coefficient of concordance is significant and the experts meaning is nonrandom.

There were made the factors significance diagrams of passenger quality service during transportation (**Fig. 2**). Due to the fact that passengers assigned rank 1 to the most significant factor, and rank 13 to the least significant factor, the factors with the lowest values of the sum of marks are the most important.

The analysis of received results allowed us to make a conclusion that, the most important factor of quality service in urban public transportation is the time of trip. Passengers find this factor very important to come in time at their workplaces. The next significant factor is waiting time of vehicle. It is important to wait for the vehicle within the shortest possible time and decrease

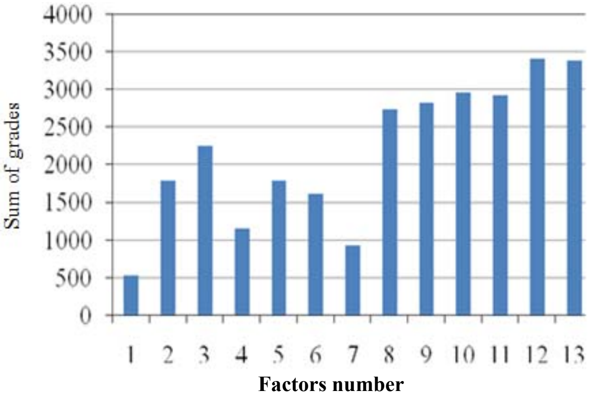

Fig. 2. The factor's significance diagram of passenger quality service during transportation

Table 1. The analysis of interviews with experts

Factor's number	Factor name	Grades sum by factors
1	Time period of trip	525
2	Filling the saloon of vehicle	1788
3	Service culture	2248
4	Safety transportation	1151
5	Period of approach and departure from the bus stop	1784
6	Number of transfer	1613
7	Time spent on waiting for the vehicle	930
8	The quality of roadway covering	2742
9	Outside appearance and cleanness of saloon	2831
10	Organization of bus stops	2964
11	Information support of the trip	2926
12	System of trip payment	3416
13	Structural features of vehicle	3390

the spending time on transportation. The transportation safety takes the third place in order of importance for the urban public transportation because to reach to destination with the minimal risk for life and health is one of the quality criteria of passenger service.

The considered quality indicators also influence the decision of passengers to choose a route. With this choice, passengers compare possible travel options based on travel experience, psycho-physiological status and personal behavioral. The studies conducted by the authors showed that the attraction of passengers choosing the *i*-th route for movement between the origin and destination can be formalized using the following quality indicators:

$$Ver_i = f(\sqrt{T_{mv}}, \sqrt{(S/D)}, \log(\gamma_{cp}), \sqrt{T_w}, \sqrt{T_a + T_d}, exp(T_{tr}), (K_s)^2), \quad (5)$$

where T_{mv} – time of movement along the route; *S/D* – the ratio of the cost of travel on the route to passenger's income; γ_{cp} – average passenger occupancy rate of vehicles operating on the route; T_w – waiting time at the bus stop, min; T_a ,T_d – consecutively, the time of arrival and departure of passengers to the bus stop; T_{tr} – transfer time between routes; K_s – traffic safety indicator on the routes.

The type of function in front of each model variable (5) determines the nature of its influence on the attraction of passengers choosing the *i*-th route. Thus, the increasing of traffic safety influences the quality of urban public transportation functioning.

Definition of significance for passengers of the criteria for assessing the quality of the work of urban passenger transport

On the next stage there were conducted field observations and the information about regularities of driver's state changes during different types of idle time was received.

Method of mathematical analysis of heart rate on the basis of electrocardiogram registration and finding the IRSA was chosen for the estimation of driver's functional state. To expand the research results of interrelation of driver's functional state and parameters of technological process on the general totality it is necessary to define the structure of selection.

The selection should be like a representative of overall set sample. The overall set sample viewed task is all bus drivers, who work at urban public transportation. In this task, we can use classification on the type of nervous system as the base of accordance of structure selection and overall set sample.

Data from works (Woodson, Tillman, Tillman, 1992) were used to select the proportion of observables in connection to any group of nervous system type. As the research results were received in work (Gyulyev, Lobashov, Prasolenko, Burko, 2018) in case of assessment the group of workers:
Sanguine – 26-30 %; Choleric – 28-31 %; Melancholic – 15-19 %; Apathetic – 25-27 %;

Given ratio was used for the survey. To define the type of nervous system the special typological checklist was used (Afanasieva, Galkin, 2018). The studies took place in the road transport vehicles with varied capacity. Electrocardiogram was registered by the portable cardiograph with self-contained power. The bus characteristics (model, mileage), information about driver (age, years of experience as driver) were noted on the special cards before its departure. In addition, the type of driver's nervous system was noted using the special typological test(Dorrian, Lamond, Kozuchowski & Dawson, 2008). Before the start of one record keeper seated near the driver and another one sat in passenger compartment. Time of departure and arrival at final stop and time at intermediate stops were fixed in the observation list. Besides, electrocardiogram of drive was registered at every stop and before starting movement.

Several characteristics were recorded during the movement on the route:

- Route characteristics (idle time at the bus stop, movement time between bus stops and their quantity);
- Traffic conditions (vision distance, road surface conditions, lanes quantity, cross roads quantity);
- Passenger flow characteristics (the ridership arrived and departure at the bus stop);

Monitoring of this characteristic was repeated at every trip. The working schedules on the routes were defined at the end of working day. In addition, the traffic conditions were defined for each route. IRSA of bus driver's body was identifying as the result of cardiograms analysis received as the result of the study of driver in the process of route traffic.

Processing of the results of the survey was done as the determination of the values of the IRSA of the driver before the idle time at the final bus stop $(P_{Д}^{ПК})$, before the idle time at the intermediate bus stop ($P_{Д}^{ПП}$), after the idle time at the final bus stop$(P_{П}^{ПК})$, after the idle time at the intermediate bus stop$(P_{П}^{ПП})$, period of idle time at the final bus stop $(T_{П}^{ПК})$, period of idle time at the intermediate bus $(T_{П}^{ПП})$ and driver's age $(B_{В})$. The example of the results of calculation processing data is shown in **Tables 2** and **3**. Consequently, data about factors that characterize parameters of technological of transportation process were received as the result of made observations and calculations.

The model of line type was chosen as task solution for development of regressive models of impact of technological process parameters on the IRSA. Selection size of samples during the development of regressive models was defined according to recommendations, where the number of observations should be 6-7 times higher than the quantity of factors included into the model (Frenkel, 1966). The least square method was used for calculation of regression coefficient (Goldstein, 2011). The characteristics of model parameters were defined with the help of known methods of statistic (Lawless, 2011). The Student criterion was used to calculate the relevance of the factors, which are included in the models. The informative model capacity was defined by the Fisher criterion (Lawless, 2011). Correlation ratio between attached variable and factors, which influence its value, was defined by the coefficient of multiple correlations (Goldstein, 2011). The results of the calculations of factors impact models on the IRSA value before and after idle time at the intermediate stops are shown in **Table 4.**

Table 2 The results of processing data for idle time at the final bus stops

$P_{Д}^{ПК}$, marks	$P_{П}^{ПК}$, marks	$(T_{П}^{ПК})$, sec	$B_{В}$, years
4	3	420	30
5	3	500	30
4	3	180	46
7	4,8	60	21
7	4,8	900	21
7	5,14	300	21
7	5	840	21
6,71	6,33	5	21
6,71	5,4	5	21
5	4	360	21
6,83	4,75	60	21
5	3,4	900	60

Table 3. The results of processing data for idle time at the intermediate bus stops

$P_{Д}^{ПП}$, marks	$P_{П}^{ПП}$,marks	$(T_{П}^{ПП})$, sec	$B_{В}$, age
4	3	180	46
7	4,8	60	21
6,71	5,4	5	21
6,83	4,75	60	21
5	5	35	35
7	4,33	30	21
6,8	4,33	30	21
4	4,5	60	39
5,7	3,75	240	21
1,1	3	30	66
8,5	6	240	35
1	2,3	180	66

Due to that fact, the possibility of using some of non-linear dependencies was analyzed:$y = \log(x)$, $y = e^x$,$y = 1/x$. It was found out that the biggest value of coefficient of multiple correlation is observed in the process of using the parameter that influences the IRSA during the idle time at the intermediate bus stop.

The excess of Fisher criterion target value over tabulated one indicates high enough information ability of developed one-factor model. In the dependency model ΔP on $B_{В}$ there is a high level of correlation and in the dependency model on $T_{П}^{ПО}$ – there is medium correlation. The determination coefficient value shows that excluded factors from obtained model can influence the observed parameter. The following conclusions were made on the base of analysis of received one-factor models.

The idle time duration at the intermediate bus stop decreases the stress of the driver. The longer driver stays at the bus stop, than more time he resting and becoming to a normal functional state. For elderly drivers, the regeneration process takes more time.

The IRSA change during the idle time at the bus stop happened in none-liner dependence regardless to the changes of driver's state irregularly during the whole transportation process. It is associated with the fact that at the beginning of idle time at the bus stop the driver's

Table 4. Model of impact of various factors on the IRSA value evolution before and after idle time at the intermediate stops on the route

Factors	Type of model	Coefficient of correlation	Coefficient of determination	Fishers criterion	
				Actual	Calculated
Idle time at the intermediate stop of the route ($T_П^{ПО}$), sec.	$\Delta P = -0{,}37 - 0{,}004T_П^{ПО}$	0,33	0,11	7,75	2,38
Driver's age ($B_В$), years	$\Delta P = -3{,}05 + 0{,}06B_В$	0,73	0,53	24,5	1,98

Table 5. Parameters of the model of changes in the IRSA rate of the driver during the idle time at the intermediate bus stop

Factors	Symbol, dimension	Measurement borders	Coefficient	Standard error	Student criterion	
					Actual	Calculated
IRSA before idle time at the intermediate bus stop	$P_Д^{ПО}$, marks	1-9	0,99	0,06	17,1	2
Logarithm of the period of idle time at the intermediate bus stop in the value degree of IRSA divided into 4	$\ln(T_П^{ПО})^{\frac{P_Д^{ПО}}{4}}$	2,01–7,13	–0,08	0,04	2,01	2
Driver's age	$B_В$, years	21-60	0,009	0,004	2,31	2

state of changes more intensive and then it decreases during the idle time period.

It means, the IRSA value after the idle time at the bus stop depends not only on the rest time but also on the state of driver at the beginning of idle time. Parameters estimation of the model's changes the IRSA during the idle time at the intermediate bus stop is shown in **Table 5.** The obtained model has described as:

$$P_П^{ПО} = 0{,}99P_Д^{ПО} - 0{,}08\ln(T_П^{ПО})^{\frac{P_Д^{ПО}}{4}} + 0{,}009B_В. \quad (6)$$

The target values of Student criterion exceed their table value, which indicates the importance of factors of the model. Statistical evaluation of the model of IRSA changes of the driver during the idle time at the intermediate stop are shown in **Table 6.** For both models between dependent and independent variables, medium level of correlation can be observed. As coefficient of determination value shows, the factors that were left out of consideration in this model influence observed parameter. The calculation results of changes of models parameters of IRSA during the idle time at the final bus stop are shown in **Table 8.** The changes of IRSA during the idle time at the final bus stops were analyzed also. The factor models that influence the difference of IRSA value change before and after idle time at the final bus stop are shown in **Table 7.**

Table 6. Statistical evaluation of the model of IRSA rate changes of the driver during the idle time at the intermediate stop

Indexes	Values
Fishers criterion: calculated	1,39
Actual	2023,52
Coefficient of multiple correlation	0,99
Approximation average error, %	6,8

The excess of the estimated value of the Fisher criterion shows a sufficiently high capacity of information developed by one-factor models. Analysis of received models allows making the conclusion that the character of influence of independent variable models is the same as their influence on the changes models of IRSA during the idle time at the intermediate bus stop. The model looks like this:

$$P_П^{ПК} = 0{,}9P_Д^{ПК} - 0{,}17\ln(T_П^{ПК})^{\frac{P_Д^{ПК}}{4}} + 0{,}009B_В. \quad (7)$$

The target values of Student criterion exceed their table value, which indicates the importance of factors of the model. Statistic values of model shown in **Table 9** are in accordance with the acceptable limit.

Given models describe observed phenomenon with decent accuracy taking into account acceptable coefficient of correlation and approximation error. On the basis of the developed models 6–7, the analysis of changing of IRSA after idle time was made. Fig. 2-3 show changing of IRSA during the idle time at the intermediate and final route bus stops.

Table 7. Models of the various factors influence on the change of the IRSA values before and after idle time at the final bus stop

Factors	Type of model	Coefficient of correlation	Coefficient of determination	Fishers criterion	
				Actual	Calculated
Idle time at the final bus stop$T_{П}^{ПК}$, sec	$\Delta P = -0,95 - 0,0003T_{П}^{ПК}$	0,35	0,12	3,72	1,93
Drivers age$B_{Б}$, years	$\Delta P = -2,03 + 0,02B_{Б}$	0,4	0,16	5,81	1,89

Table 8. Parameters of the model of changes in the IRSA rate of the driver during the idle time at the intermediate bus stop

Factors	Symbol, dimension	Measurement borders	Coefficient	Standard error	Student criterion	
					Actual	Calculated
IRSA before idle time at the final bus stop	$P_{Д}^{ПК}$, marks	1-9	0,92	0,04	21,8	2,02
Logarithm period of idle time at the final bus stop in the value degree of IRSA divided into 4	$\ln(T_{П}^{ПК})^{\frac{P_{Д}^{ПК}}{4}}$	2,01-8,58	–0,17	0,03	5,75	2,02
Driver’s age	$B_{Б}$, years	21-60	0,009	0,003	2,74	2,02

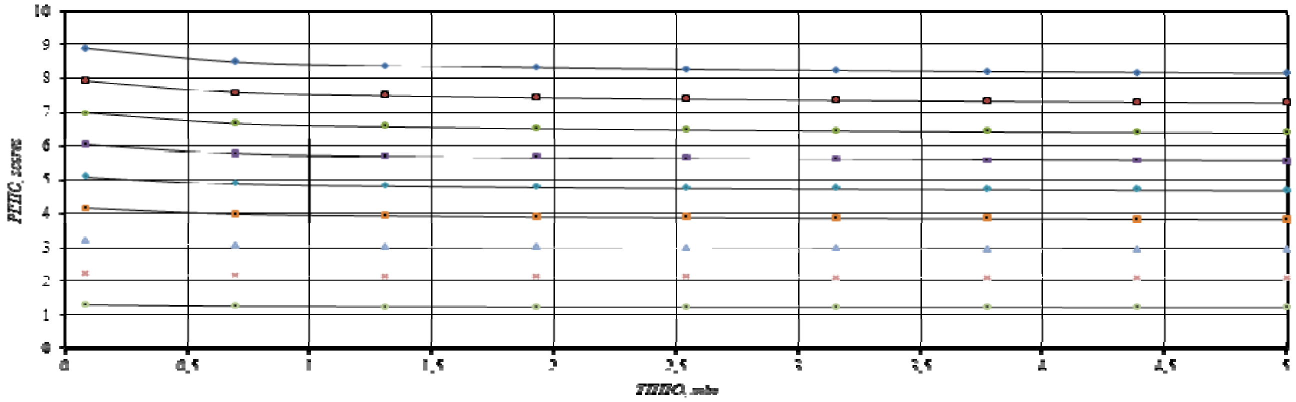

Fig. 2. Changing of IRSA during the idle time at the intermediate bus stop whiles various starting values options: —◇— – 9 points; —+— – 8 points; — ● — – 7 points; - - ✳ - - – 6 points; — ◆ - – 5 marks; — ■ — – 4 points; ······▲······ – 3 points; ——×—— – 2 points; —⊖— – 1 points.

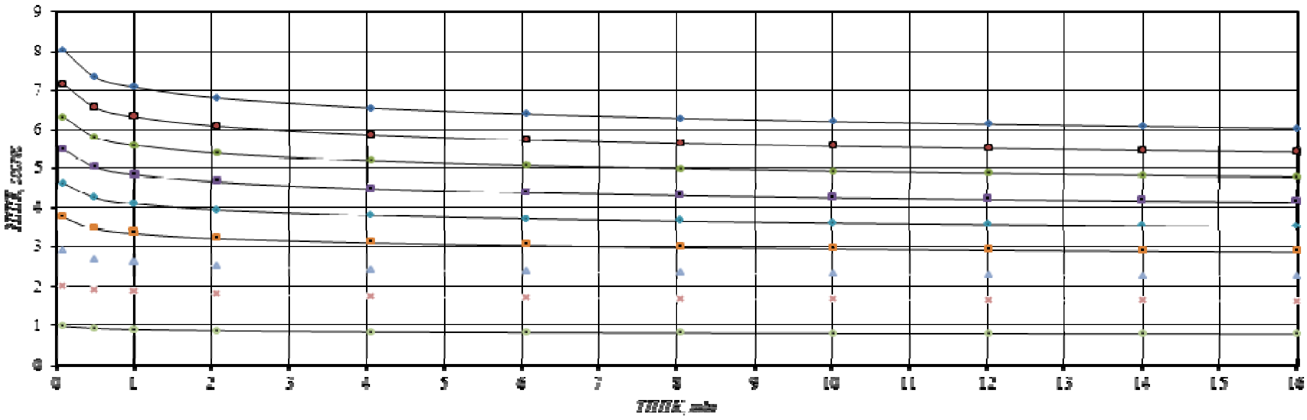

Fig. 3 Changing of IRSA during the idle time at the final bus stop whiles various starting values options: —◇— – 9 points; —+— – 8 points; — ● — – 7 points; - - ✳ - - – 6 points; — ◆ - – 5 marks; — ■ — – 4 points; ······▲······ – 3 points; ——×—— – 2 points; —⊖— – 1 points.

Table 9. Statistical estimation of the model of IRSA rate changes in the during the idle time at the final bus stop

Indexes	Values
Fishers criterion: calculated	1,79
Actual	1172,67
Coefficient of multiple correlation	0,99
Approximation average error, %	8,6

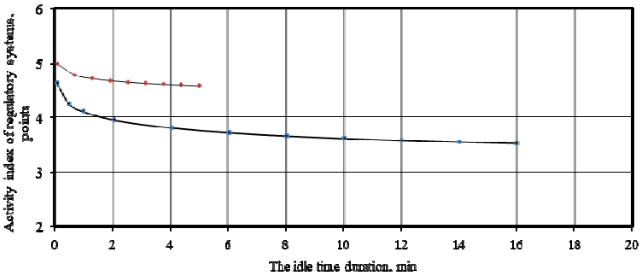

Fig. 4. Comparative analysis of changing of driver’s state on idle time, starting IRSA value - 5 points: —◆— – idle time at the intermediate bus stops; – ■ – – idle time at the final bus stops.

Comparative analysis of driver’s state change during the different types of idle time is shown at **Fig. 4**.

The decreasing of driver’s stress takes place during the idle time at the intermediate and final route bus stops. However, the intensity of decreasing is inversely proportional to the meaning of IRSA before the start of idle time. Besides, it can be seen from the figure, the duration of idle time is necessary to differentiate depending on the driver’s work conditions. The bigger is the driver’s stress after passing the route, the bigger duration of idle time should be at the final bus stops. If the value of IRSA after the route passing is equal to 8-9 points it is necessary to give him 10 min. break. If the value is 6-7 points – 5 min. break, in other cases – no less than 2 min. Comparative analysis of driver’s state changing in various types of idle time Fig. 3 shows the comparability of research results. The type of idle time, which is determined by technological parameters of transportation process, defines the intensity IRSA change.

DISCUSSION

Researches of significance criteria of the quality of work of municipal public transport for passengers demonstrated that first of all for passengers are very important the period of trip, waiting time of vehicle and transportation safety. The quality of urban public transportation functioning can be improved influencing on driver’s work and rest schedule. Received changes of driver’s state during the idle time at the intermediate and final bus stops showed the decreasing of driver’s stress at the idle time at the bus stops. These patterns of change in the driver's state of urban public transport during periods of inactivity in the final and intermediate stops lead to the conclusion that when you're not at the stops of the route there is a reduction of the driver stress. The decreasing intension is inversely proportional to the IRSA before the start of idle time.

Consequently, the duration of idle time must be differentiated depending at the value of the IRSA before the start of idle time, which is influenced via the working conditions. Comparative analysis of driver’s state changes during the different types of idle time shows the comparability of the results of the research. Thus, optimization of the idle time duration for vehicles at the final bus stops should be taken into account and include physiological peculiarities of the driver when the driver’s workday is scheduled. It will allow decreasing the probability of changeover of driver’s systems at the overstress level and adaptation breakdown and increase the level of safety and quality of transportation.

The quantity of road accidents depends on the time that driver spends in front of the steering wheel. The lowest quantity of road accidents occurs over the range from 3 till 7 working shift. 64% accidents happen after 6-7 hours of transport driving. At the end of working day, the incidence rate increases in several times than in the middle of shift (Meng, Li, Cao, Li, Peng, Wang & Zhang, 2015). As the result, the road accidents occur at twice time more often after 7-12 hours of driving and 9 times greater after 12 hours comparing with normal working shift (Mishurin, Romanov, 1990). Statistics shows that the most serious road accidents happen at the end of working day, over the range from 5 p.m. till 12 p.m (Volper, 1979). Occurrence probability of road accident in case of 12-hour working day is higher in 1,3 times than in case of 8-hours working shift (Lobanov, 1980). Drivers who work for more than 7 hours take part in 1/3 of overall accidents (Prasolenko, Burko, Halkin, 2017). Herewith 10 from 11 fatal casualties happen when drivers are working for more than 10 hours (Davidich, et. al., 2018). Drivers, who works more than 12 hours, have road accidents with fatal casualties 1,5 times more often (Osipova, 1984).

Practically, the duration of driver’s working shift is bigger than the period of high level of working efficiency. Practice shows that in Ukraine daily driving duration of 70% of drivers is more than 8-hours. 39,2% of them have 9-10 hours working shifts. 45,5 % of drivers overwork from 20 till 40 hours a month. Consequently, the choice of optimal working day duration takes the main part in the efficient solution of “human–vehicle” problem (Choromański, Grabarek, Spirzewska, 2017).

There exists a balanced schedule of work and rest for fatigue decreasing and increasing of working efficiency. This schedule includes prescriptive breaks for the rest.

Different variants of breaks which depend on working day duration, route and vehicle characteristics present in (Volper, 1977). Suggestion making or adding the short break in most traffic periods to decrease accident risk was made in (Hale, Stoop, Hommels, 1990). The time for rest can be estimated according to the physiological characteristics and driver's behavior (Galkin, et. al., 2018).

Extended analysis revealed of necessary to have some stress degree in average normal life activity (Galkin, et. al., 2018). But over-stress of human can lead to breakdown of adaptation with inadequate changes of functioning of his main systems and appearance of pathological syndromes and illnesses. Recommendations to driver's schedule management provide parameter's limits boundaries for staying in optimal state during overall shift (Gavrilov, 1976). Regulation of these parameters enables to control the driver's state, and as results to improve quality of transportation services.

CONCLUSIONS

The organization of passenger transport services should be focused on meeting the needs of urban residents in moving in accordance with the necessary norms of time, comfort, cost and safety. In accordance with this premise, it is necessary that decision makers in determining the parameters of the technological process of transporting passengers be aware of the influence of these parameters on the condition of the driver, on which traffic safety depends significantly. The existing methods of designing the transport process do not fully take into account the regularities of changes in the driver's condition when moving along the route and the influence of technological parameters on the level of his fatigue due to the lack of mathematical formalization of changes in the parameters of the driver's condition when serving passengers. The proposed concept of improving the quality of public transport by optimizing the driver's schedule is based on the human factor and technological process of transportation. Its advantage lies in taking into account the behavioral of drivers, depending on the functional state and age. The proposed mathematical model of changes in the state of the driver for various types of idle time is based on the technological parameters of the transportation process and the driver's parameters. The obtained data on changes in the driver's condition depending on the parameters of vehicle idle time at 2 types of bus stop increase awareness of the degree of influence of the transportation process technology on indicators of the state. The proposed models will help the municipality to assess the workload on the driver. This will make it possible to determine such arrangements in transport policy for safety organization of public transport services.

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