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INFLUENCE OF RESERVE OF CARRYING CAPACITY OF STOPPING POINTS ON THE TIME IDLE PARAMETERS OF PASSENGER TRANSPORT VEHICLES

Розглянуто вплив резервування пропускної здатності зупиночних пунктів міського громадського пасажирського транспорту на тривалість простою транспортних засобів в транспортно-пересадочних вузлах. На основі виділеного контурного зв'язку взаємодії суб'єктів формалізовані складові оцінки фактичної тривалості знаходження транспортних засобів на зупиночному пункті. Експериментально встановлена характеристична залежність впливу резервів пропускної здатності зупиночного пункту на рівень відповідності фактичного та технологічного часу простою.

Ключові слова: *міський громадський пасажирський транспорт, транспортно-пересадочний вузол, зупиночний пункт, час простою.*

1. Introduction

Today, in the conditions of the rapid development of city urbanization, the issues of ensuring the quality of transport services for the population are very acute. The modern city has become a large territorial structure where population displacement becomes a long-term and inconvenient process that takes up a large part of the daily time. The solution of tasks aimed at reducing the duration of transport movements of the population is today one of the fundamental principles for shaping the improvement of the quality of transport services and largely determines the conditions for the social and marketing perception of transport by the population. In the structure of urban public passenger transport (UPPT), a significant role is played by transport-transfer stations (TTS), which warm the role of the basic frame element of its route network. Within the TTS framework, transshipment processes take place, which are an integral part of the general cycle of passengers' travel. Reduction of the time for the stay of passengers in TTS is realized due to the creation of effective conditions for technical and technological cooperation between the subjects of the UPPT route network and provides a reduction in unproductive vehicle's idle time. The basic element of TTS, where the technological interaction of the subjects is directly occurring, is the stopping points (SP). Elimination of unproductive vehicle's idle times within the SP is achieved by creating appropriate resource conditions for their operation, which should adequately absorb destabilizing unmanaged effects of the input route flow. Determination of the influence of the level of throughput SP capacity on the vehicle's idle time and their functional state allows to substantiate rational limits of resource conditions and is the determining factor in the formation of effective interaction of subjects in the TTS space.

2. The object of research and its technological audit

The technological process of the operation of the UPPT routes provides for the implementation of a set of basic and auxiliary operations. The main operations that are implemented along the routes include the movement of vehicles along the sections of the network. The main technological operations can't be separated from the implementation of auxiliary processes, which in the functional environment are represented by a set of technologically necessary omissions of vehicles for loading and unloading of the passengers. A common parametric characteristic, which affects the efficiency of implementing the technological process of transporting passengers on the route, is the time of the voyage. It consists of the duration of the main and auxiliary operations. An analysis of idle times of the vehicles on certain routes in Kharkov showed that in real conditions the duration of actual passes for the SP is up to 40 % of the time. This leads to a significant decrease in the actual transport capacity of the routes and limits the possibility of full realization of their potential. Under such conditions, transport enterprises are compelled to compensate for the loss of transportation opportunities for attracting additional vehicles, which is the reason for reducing the resource efficiency of their work. The main source of increasing the duration of simple vehicles in SPs is non-productive simple ones that arise as a result of ineffective organization of interaction in TTS, where a significant number of routes intersect. Elimination of unproductive passes of vehicles in TTS can be realized by creating the appropriate reserve capacity of the SP, which have assignments to compensate for the negative impact of destabilizing factors of the UPPT operation.

The object of research is the process of functioning of the stopping point within the UPPT TTS. Correspondence of the capacity of the incoming route flow of the SP capacity determines the level of its reserve provision and directly affects the probability of non-productive downtime of the vehicle in TTS. An important stage in the creation of conditions for effective interaction of subjects in solid waste is the determination of the effect of zones of rational parameters of the SP resource supply for the actual duration of the vehicle's idle time. The justification of their influence on the level of change in the actual vehicle's idle time in the stochastic nature of the input

flow requires conducting the relevant studies aimed at establishing the characteristic dependence «resource level of the capacity of the AP – the actual vehicle's idle time». This dependence allows to form technical and technological requirements for the distribution of routes between the TTS SPs and determine their actual functional state in relation to the conditions for stabilizing the technological processes of the UPPT.

3. The aim and objectives of research

The aim of research is establishment of the laws of changing the compliance coefficient of with the idle times of vehicles, depending on the level of resources of TTS capacity.

To achieve the aim it is necessary to solve the following tasks:

1. On the basis of the selected contour link, formalize the components of the model of determination of the time parameters of the simple vehicle in the SP.

2. Experimentally establish the characteristic areas of the impact of the SP resource supply on the level of compliance with the idle times of vehicles.

4. Research of existing solutions of the problem

The study of the UPPT functioning from the standpoint of reducing the idle time of UPPT vehicles at SP is of scientific and practical interest. On the basis of the carried out literature analysis, it is possible to distribute approaches to improving the SP operation in terms of the type and conditions of using control actions to reduce the vehicle's idle time, namely:

– choosing a rational number and location of stopping points [1, 2];

– ensuring compliance of the actual traffic intensity of route transport with the throughput capacity of the SP [3–6];

– coordination of the time for servicing vehicles in the SP [7–10].

The choice of a rational number of SPs and their location is aimed at ensuring a reduction in the conflict of vehicle motion. In work [1] the author considers the problem of dispersing the location of stopping points, proceeding from the condition of ensuring minimum time for passengers to change between routes and objects of attraction of passenger traffic. The use as a criterion for estimating the time of passenger transplantation reflects the general principles of UPPT improvement, but does not allow to fully assess the duration of idle time and does not reflect a causal relationship between the impact of the SP capacity for the vehicle's idle time. With this approach, the main mechanism for controlling the duration of simple vehicle in TTS is the number of SPs that can't always be increased in the conditions of existing territorial spaces. Based on the identified shortcomings, it can be concluded that this form of using the control effect on the duration of the vehicle's idle time at the SP can't be applied within the available TTS resources.

In work [2] it is offered to consider the placement and planning structure of TTS from the viewpoint of representing it as the center of concentration of passengers. Conditions for effective functioning are dedicated and stages of planning the structure are justified. The presented approach is a conceptual form in which consideration of technological processes is not given.

Justification of the use of the intensity of the incoming route flow as a parameter for the duration of the vehicle's idle time at SP is realized in [3]. The authors describe the dependence of the influence of the level of correspondence of the input route flow of the throughput of the SP to the level of the queue occurrence. Based on the conducted analytical studies, it is established that the permissible level of loading of the SP should not exceed 70 % of its throughput. These dependencies confirm the expediency of taking into account the influence of the level of resource provision of SP as a key characteristic of the formation of the time of unproductive vehicle's idle time. However, this regularity has an analytical form of description and does not fully take into account the stochasticity nature of the incoming route flow.

In [4], the authors consider the effect of idle vehicles at stopping points on the performance of their work. It has been established that an effective tool for increasing the productivity of rolling stock is the idle time reduction. To implement this, the use of different types of transit systems is proposed. The main drawback, as in the previous work, is that the presented models have an analytical form.

The effective mechanism for reducing the idle time at the SP is the coordination of the arrival of vehicles in TTS. With this method, the driving parameter is the arrival time of the vehicle in the TTS. In [8], it is proposed to implement an algorithmic procedure for coordinating the arrival of vehicles in the SP on the basis of allowance for the allowed periods for their servicing. The main disadvantage of this approach is its technological limitations, which consists in the possibility of obtaining a real result only within the allowed service time-out period of the vehicles. In case of exceeding the time of technological vehicle's idle times at the SP, coordination becomes impossible.

In work [9] the algorithm of synchronization of movement of a rolling stock on the basis of formation of adjacent pairs of runs is presented. The algorithm aims to provide a clear schedule for the arrival of vehicles of adjacent routes to stop points. The main criterion is the condition of observing the necessary interval of movement along adjacent routes. Using a single interval of traffic leads to the need to adjust the voyage time, which can negatively affect the performance of the vehicle.

In work [11], models for predicting the time of arrival of the vehicle in the SP are used to synchronize traffic. The basis for the forecast values is the dependence of the arrival time deviation, the nature of which is described by the lognormal distribution law. To ensure a reduction in the time for passengers to change in the forecasted conditions, the rolling stock adjustments are used. The increase in the number of vehicles positively contributes to reducing the time of passenger transfer, but necessarily leads to an increase in the transportation capacity.

Given the identified shortcomings of existing approaches, there is a need to conduct studies aimed at identifying the patterns of the impact of resource provision of SP on the vehicle's idle time. In the framework of such studies, it is necessary to take into account the stochastic conditions for the formation of the flow of services and to identify the allowable SP resource support areas as a factor in stabilizing the TTS operation.

5. Methods of research

Technological interaction in terms of TTS operation can be represented in the form of a structural model, which consists of a combination of elements, subjects and the contour of their interrelationships. The generalized structure of TTS elements is represented by service zones of trackless and rail transport, in which there are sets of stop points SPt_n, stations of transport of extraterrestrial message SB_n and stations of non-urban passenger traffic ET_n. The stopping point has a corresponding number of N_{SPt} service stations, where at the same time there may be vehicles arriving at it. The vehicles of the corresponding routes of the N_{SPt}, which are considered as the basic subjects of the input stream, arrive at the land transport service areas. Each arrival of the vehicle in TTS is characterized by a set of Pv_R, the component parts of which reflect the technical and technological parameters of the effect on the duration of their technological idle in the SP:

$$Pv_i^R = \{q_i, \gamma_i, p_i, \omega_i\}, \tag{1}$$

where q_i – the capacity of the vehicle, pass.; γ_i – filling level of the vehicle; p_i – passenger exchange of TS in TTS, pass.; ω_i – average time of loading (unloading) of the passenger, s.

Depending on the distribution of routes along the SP, the total flows of orders λ_{SPt} are generated in them. The main technological characteristic of the order flow in the SP is the total duration of the planned vehicle's idle time in the period t:

$$\lambda_{SPt}(t) = \sum_{i=1}^{N} \xi_i, \tag{2}$$

where ξ_i – the time of planned technological vehicle's idle time at the SP, s; N – the number of flights arriving in the SP for the period t.

As the serving flow μ_{SPt} t, the capacity is in the SP, which is determined by the number of N_{SPt} maintenance posts and the duration of the period t. The ratio of the order flow at the SP to the proposal determines the level of its load:

$$\rho_{SPt}(t) = \frac{\lambda_{SPt}(t)}{N_{SPt} \cdot t}. \tag{3}$$

Vehicles after the completion of technological operations leave from the TTS with a visible value of the parameter Px_R, which are formed on the basis of the capacity level, which reach the realization of the passenger station in the TTS. At the TTS limit, the passengers ρ_{SPti-j} are moving, which are formed at the expense of passenger traffic when vehicles of all types arrive by transport and the passengers approach to the SP from the adjacent territory.

The outline of the relationships between the TTS model is shown in Fig. 1.

Based on the structure of the structural model, the main functional object of TTS is ZP, which can be represented as its main type part. The change in the SP state occurs on the basis of the presence in its territorial boundaries of a conflict situation between the arriving vehicles. According to the conditions for stabilizing the TTS work, it is possible to distinguish the following types of SP states that can arise when vehicle arrives: a free, conflict-free queue, a conflicting queue. The prerequisites for the emergence of conflict situations at SP are:

– controllable factors: irrational distribution of routes between TTS SPs;

– uncontrollable factors: fluctuations in the passenger, the level of filling the vehicle, the random nature of the change in the arrival interval of the vehicle, caused by the instability of road traffic conditions along the street-road sections of the routes.
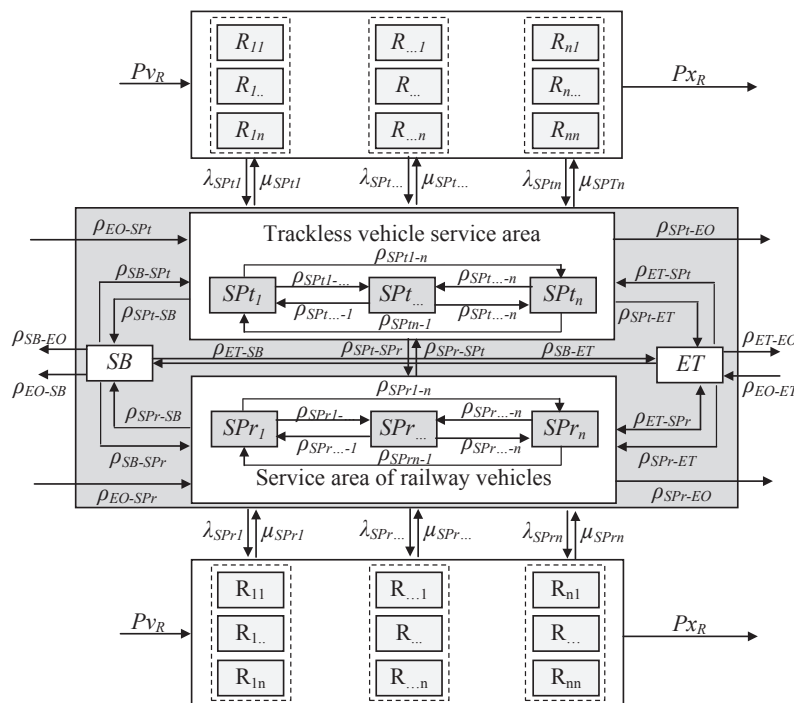

Fig. 1. The outline of the connections of the structural model of the transport and transfer unit

The distribution of routes between SPs should be based on taking into account the values of the total input stream λ_{SPt} and provide such level of their loading, at which stabilization of their work is achieved. Variants of the distribution of routes between SPs can be considered as a set of strategies for technical and technological management of TTS. Each variant of the distribution of routes between SPs leads to appropriate levels of its loading and planned reserve of its throughput. Choosing parameters of uncontrolled factors through random quantities and determining the conditions for the formation of the SP reserve capacity as a mechanism for controlling the TTS operation, it is possible to formulate a general description of the problem situation:

$$Z:K\times\Lambda\to A(E),\qquad(4)$$

where K – a set of strategies for the distribution of UPPT routes between the SPs, which determines the level of its loading and the reserve capacity; Λ – a set of values of uncontrolled factors characterizing the arrival and the time of finding the vehicle in the TTS; E – a set of possible evaluation of the results reflecting the SP state; $A(E)$ – a set of indicators for estimating the idle time of the TS on the SP; Z – reproduction, which puts a lot of indicators of results in line with the set of strategies and influence factors.

A problematic situation is the choice of such reserve capacity of the SP, which provides its corresponding level of the preference function. The benefit function reflects the degree of correspondence between the actual vehicle's idle time on the SP to the technological one. The amount of technological downtime is determined based on the estimated total duration of the aggregate of elementary operations in TTS.

To evaluate the advantage of the strategy, it is possible to use the coefficient of correspondence of the vehicle's idle time at the SP:

$$K_\xi(t)=\frac{\xi_s(t)}{\xi_k(t)}\to\max,\qquad(5)$$

where $\xi_s(t)$ – the total technological vehicle's idle time at the SP, s; $\xi_k(t)$ – total actual vehicle's idle time at the SP, s; N – the number of vehicles arriving at the SP during the period.

The form of the indicator of the advantage evaluation of the strategy is presented in accordance with the social marketing principles of assessing the quality of the transport service and in its essence reflects the gap between the marketing need and the technological offer provided by transport. Based on the conditions of the organization of traffic along the route, the maneuvering of the vehicle when arriving to the SP, the parameters of the passenger exchange and the characteristics of the duration of loading operations, the required technological time of finding the vehicle in the SP is determined:

$$\xi_s(t)=\sum_{i=1}^{N}\Big(t_{mi}+\omega_i\cdot\max\big(q_i\cdot(1-\gamma_i);p_i\big)+t_{ai}\Big),\qquad(6)$$

where t_{mi} – the maneuvering time for the arriving of vehicle to the SP, s; t_{ai} – the time of additional planned vehicle's idle time in the SP, s.

In the case of conflict situations, an increase in the time of actual vehicle's idle time occurs:

$$\xi_k(t)=\xi_s(t)+\xi_q(t),\qquad(7)$$

where ξ_q – the total time in the queue before the SP for the vehicle, s.

A rational strategy for the distribution of routes involves the introduction of such mode of traffic and planned vehicle's idle time, which provides an appropriate level of reserve capacity of the SP. The level of reserve capacity of the SP reflects the specific gravity of the planned free time of its work and aims to create, through compensatory actions, conditions for containing negative consequences of the factors of its destabilization. The level of SP reserve capacity in the period t is calculated based on its planned load:

$$K_R^{st}(t)=1-\rho_{SPt}(t).\qquad(8)$$

The account of the total time of vehicles' idle times in the SP is realized by simulation. It is based on the principles of discrete-event modeling, which provide for the representation of processes in the form of their chronological sequence. The characteristic component of the period t is the moments of time τ, which are its smallest indivisible part. The components of the SP functioning model vary in time and can be represented as an array of instantaneous values x_τ in the period x_t. The total set of requirements for the vehicle's maintenance at the relevant points in time forms a common array of the claimed requirements for the SP:

$$R=\begin{bmatrix} R_{11i}^{\tau_1} & R_{12i}^{\tau_2} & R_{1...i}^{\tau_{...}} & R_{1ni}^{\tau_n} \\ R_{..i}^{\tau_1} & R_{..i}^{\tau_2} & R_{...i}^{\tau_{...}} & R_{..ni}^{\tau_n} \\ R_{n1i}^{\tau_1} & R_{n2i}^{\tau_2} & R_{n...i}^{\tau_{...}} & R_{ki}^{\tau_n} \end{bmatrix},\qquad(9)$$

where $R_{ki}^{\tau_1}$ – the vehicle order of the i-th run of the k-th route at the time τ_1.

The vertical dimension of the array R is determined by the number of routes that are assigned to the SP, horizontal – by the total number of time points during the TTS operation. Depending on the type of actions that occur with the vehicle in the TTS, an array of operations is formed at each moment of time:

$$O=\begin{bmatrix} O_{R1i}^{\tau_1} & O_{R1i}^{\tau_2} & O_{R1...}^{\tau_{...}} & O_{R1m}^{\tau_n} \\ O_{R...i}^{\tau_1} & O_{R...i}^{\tau_2} & O_{R...}^{\tau_{...}} & O_{R...m}^{\tau_n} \\ O_{Rk_i}^{\tau_1} & O_{Rki}^{\tau_2} & O_{Rk...}^{\tau_{...}} & O_{Rkm}^{\tau_n} \end{bmatrix},\qquad(10)$$

where $O_{Rki}^{\tau_1}$ – the term belonging to the performance of the corresponding technological operation of the vehicle of the i-th run of the k-th route at the time τ_1.

The state of each route arriving at the TTS is assessed by the presence of a conflict situation at the SP at that time. Based on the assessment of the type of state of the vehicle during the arrival of the vehicle, an array of flight route states is formed:

$$S=\begin{bmatrix} S_{m1}^{\tau_1} & S_{m1}^{\tau_2} & S_{m1}^{\tau_{...}} & S_{m1}^{\tau_n} \\ S_{m...}^{\tau_1} & S_{m...}^{\tau_2} & S_{m...}^{\tau_{...}} & S_{m...}^{\tau_n} \\ S_{mk}^{\tau_1} & S_{mk}^{\tau_2} & S_{mk}^{\tau_{...}} & S_{mk}^{\tau_n} \end{bmatrix},\qquad(11)$$

where $S_{mk}^{\tau_1}$ – of the vehicle of the i-th run of the k-th route at the time τ_1.

The total time of vehicle in the queue can be determined based on the duration of the moments of the conflicting states of the routes in the period:

$$\xi_q(t) = \sum_{i=1}^{R} \sum_{j=1}^{t} \tau_{st_{ij}}, \qquad (12)$$

where τ_{st_i} – the state of the i-th time point of the conflict state.

The establishment of the characteristic effect of the parameters of the reserve level of SP capacity to the service-time compliance coefficient determines the zones of their rational value and is the basis for the formation of a rational structure of the distribution of routes between SPs. Under conditions of a random change in the arrival intervals of the vehicles and their input characteristics, the search for such relationship can be realized in the framework of experimental studies.

6. Research results

Based on the selected connection contour and the developed analytical dependencies of the vehicle's idle time parameters, a corresponding calculation module of the simulation model of the TTS operation is created. The condition for carrying out experimental studies is the determination of the parameters of the variation of random variables that reflect the external impact on the conditions of vehicle's maintenance. These parameters include the arrival interval of the vehicle, the deviation from it, the number of passengers in the vehicle, the number of transfer passengers. On the basis of field observations at the SP «Metro station Prospect Gagarina» of TTS «Levada» (49.981225, 36.241933) for the period from 17 to 18 hours, the parameters of order flows and the nature of the change in random variables are established (Table 1).

The range of changes in the level of SP capacity resources is ensured by a change in the number of service stations and the time of additional scheduled idle time of the vehicle. To determine the regularity of the influence of the SP resource supply on the level of compliance with the service time, the corresponding cycles of computational studies are carried out, which provide for a period of one hour per one series of experiments. A total of 38 series of experiments were carried out. Based on the conducted experiments, the corresponding distributions of the correspondence coefficient of the vehicle's idle time have been established, depending on the level of resource support for the SP (Fig. 2).

On the basis of the obtained data, it is possible to establish regression dependence $K_\xi - K_R^{st}$ for the isolated TTS. By statistical processing of the obtained results, the form of the function describing the dependence of the idle time match coefficient on the resource level of the throughput capacity of the SP is established:

$$K_\xi = 1.0152 + 0.1371\ln(K_R^{st}). \qquad (13)$$

The adequacy degree of certain regression dependence is confirmed by the obtained values of determination coefficient, which is 0.8928. The obtained indices testify to the statistical reliability of the accepted hypothesis and allow to draw a conclusion about the possibility of using the presented regression model for analyzing the influence of the reserve level of the SP capacity to the level of compliance with the actual idle time.

Within the framework of the considered SP, three options for changing the resource capacity are analyzed: existing, increasing and decreasing the number of service posts. For certain values of the mathematical expectation of random variables using the established relationship (13), calculations of the vehicle's idle time parameters are performed (Table 2).

Table 1

Parameters for changing random variables

| Parameter	Distribution law	Mathematical expectation	Range of change	
			Min	Max
Arrival time of vehicle, min	Lognormal	1.8	0.9	5.4
Level of vehicle filling for transit routes	Gamma distribution	0.658	0.318	1.107
Passenger traffic for transit routes, pass	Lognormal	9.5	4	19
Passenger traffic for initial routes, pass	Lognormal	29.7	18	62
The time of loading(unloading) of the passenger, s	Gamma distribution	2.5	1.2	6.8
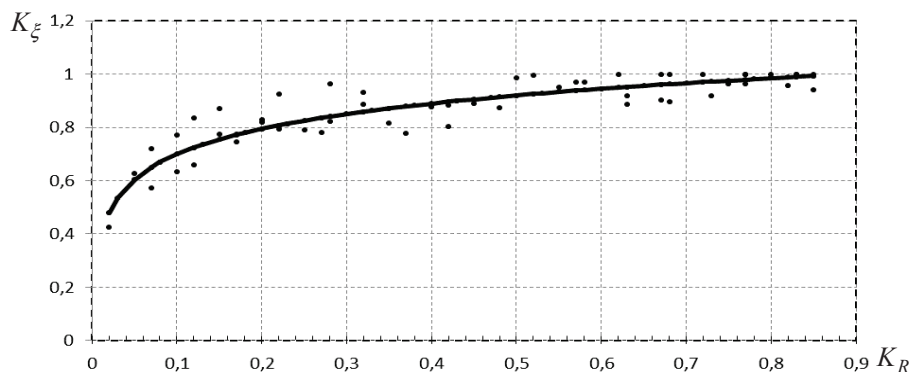
Fig. 2. Distribution of vehicle's idle time ratio

Table 2

Indicators of options for resource provision of the transport-transfer stations

Option	Decreasing	Existing	Increasing
Number of service stations	2	3	4
The level of SP reserve capacity	0.08	0.45	0.58
The indicator of the conformity assessment of the vehicle's idle time	0.685	0.879	0.907
Average time of unproductive vehicle's idle time, min	1.75	0.57	0.42
Specific weight of non-productive vehicle's idle time, %	45.9	13.8	10.3

Based on the information given in Table 2, it is possible to conclude that in the SP «Metro station Prospect Gagarina» there is a sufficient number of service posts, their increase will not lead to a significant decrease in the proportion of non-productive downtime of the vehicle. In the case of decrease in the number of service stations or an increase in the number of routes, the level of the reserve capacity of the reserve will decrease, which will lead to a rapid growth of unproductive idle times of the vehicle. On the basis of the selected regularity for existing SP, it can be concluded that it is necessary to keep the level of the SP capacity reserve at least 0.45. With this option, it is possible to ensure the stabilization of the TTS operation without applying the UPPT priority movement on the sections of the road network and synchronizing the timetables of the routes.

7. SWOT analysis of research results

Strengths. As a strength of research, it should be noted that the proposed approach to estimating the duration of idle time of vehicles in the SP takes into account the random nature of the changes in the parameters of the arriving vehicles and ensures that this takes into account the actual conditions for the TTS functioning. The adaptation of the elements of analytical calculation to the principles of discrete-event modeling, which is presented in the form of a chronological sequence of time moments, allows to find the real form of determining the length of the vehicle's idle time in the SP. And also provides a compromise in achieving the required accuracy of calculations in conditions of limited information exchange. A feature of the proposed approach to the assessment of a simple one is also that it involves considering this process from the point of view of comparing the actual idle time with the technological one, which varies depending on the passenger of each vehicle.

Weaknesses. The weak side of research is that in order to ensure the appropriate value of the SP capacity reserves, it is necessary to form such combination of the distribution of routes between the SPs, at which the necessary volume of the total order flow is achieved equal to the planned level of loading. The search for such combination is complicated by the fact that its basic components are of a discrete nature that does not allow obtaining a wide range of variation of quantities. The solution of such problem can be realized by introducing a procedure for selecting combinatorial combinations based on a genetic algorithm. This algorithm will allow to reduce the list of possible variants of distribution of routes along SP and to maximally approximate the obtained discrete values of reserve capacity level of the curve of its distribution.

Opportunities. The proposed approach to determining time parameters of vehicle's idle time opens up prospects for using the slot-coordination models for the timetable for the UPPT movement in TTS. Based on the presented dependence of the change in the indicator of the correspondence between the vehicle's idle time and the level of SP reserve capacity, it is possible to establish the actual state of the organization of UPPT interaction in TTS and to estimate the specific weight of the unproductive idle times. The availability of information on the level of unproductive vehicles' idle times allows further implementation of the procedure for a comprehensive assessment of the efficiency of the UPPT routes. Within the framework of such assessment, it is possible to allocate specific SPs that affect the rolling stock performance, calculate the specific weight of a simple vehicle in the run duration, and identify priority areas for the implementation of optimally constructive management actions aimed at increasing the UPPT effectiveness.

Threats. The complexity of determining the time parameters of the vehicle's idle time in the SP is the need to use information about the variation of the random values of the input flow for each individual TTS. The values of the variation parameters of random variables are decisive in the formation of zones of the characteristic effect of the reserve capacity of the SP and can be determined with the help of field observations or by using telemetric monitoring systems for UPPT operation. The use of objective information about the parameters of the input flow will increase the accuracy of the model and ensure its adaptability to the real working conditions of TTS. The creation of a monitoring system requires the arrangement of stopping points by means of video surveillance for the formation of a route and passenger flow and their integration into the structure of the UPPT dispatching control service.

8. Conclusions

1. It is established that in the actual conditions of the UPPT TTS operation, the main reasons for increasing the downtime are the simultaneous presence of the vehicles in the SP in an amount exceeding its capacity. To assess the effectiveness of the organization of UPPT interaction in TTS, it is expedient to use the correspondence coefficient of the vehicle's idle time, it allows to estimate the level of their unproductive downtime caused by the occurrence of the queue in the SP. The need to create adequate reserves of capacity of the air defense system is based on the conditions for ensuring the conflict-free movement of the vehicle. It is advisable to formalize the components of the vehicle's idle time duration under conditions of

stochasticity of the input flow on the basis of a combination of analytical description elements and discrete-event modeling. This form allows to describe the procedure for the SP operation in the form of a chronological sequence of time points for assessing the condition of the arriving and providing an adequate representation of the processes of their servicing.

2. It has been established experimentally that the conformity coefficient of the vehicle's idle time proportionally depends on the level of SP capacity reserves. An increase in the SP reserve capacity leads to an increase in the efficiency of servicing the vehicle in TTS and allows to approximate the duration of the actual maintenance of the vehicle to the technological level, which is the minimum necessary to provide a passenger. For the selected as an applied research SP «Metro station Prospect Gagarina» of TTS «Levada» (49.981225, 36.241933) it is determined that the existing level of capacity resources is 0.45. At the same time, the indicator of conformity assessment of the vehicle's idle time is 0.887, the average time of unproductive idle time is 0.57 minutes, which is 13.8 % of the time of technological idle time. In the conditions of reducing the reserve capacity through the reduction of the number of service stations, an increase in the level of conflict and the duration of unproductive downtime is expected. At one service level, the share of non-productive vehicle's idle time is 45.9 % of the technological time, 32.1 % more. This situation is critical and can't be realized in practice. An increase in the capacity reserve due to additional posts will lead to a decrease in the time of unproductive idle time to 10.3 %, which is less than the existing version by only 3.5 %. Under such conditions, it can be concluded that an increase in the number of service posts is impractical. Prospects for the development of the presented methodology for estimating the length of the vehicle's idle time are based on carrying out applied research based on them, aimed at forming mechanisms for securing incoming routes between the SPs within the TTS.

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ВЛИЯНИЕ РЕЗЕРВА ПРОПУСКНОЙ СПОСОБНОСТИ ОСТАНОВОЧНЫХ ПУНКТОВ НА ВРЕМЕННЫЕ ПАРАМЕТРЫ ПРОСТОЯ ПАССАЖИРСКИХ ТРАНСПОРТНЫХ СРЕДСТВ

Рассмотрено влияние резервирования пропускной способности остановочных пунктов городского общественного пассажирского транспорта на продолжительность простоя транспортных средств в транспортно-пересадочных узлах. На основе выделенной контурной связи взаимодействия субъектов формализованы составляющие оценки фактической продолжительности нахождения транспортных средств в остановочном пункте. Экспериментально установлена характеристическая зависимость влияния резервов пропускной способности остановочного пункта на уровень соответствия фактического и технологического времени простоя.

Ключевые слова: городской общественный пассажирский транспорт, транспортно-пересадочный узел, остановочный пункт, время простоя.

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