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МОДЕЛИРОВАНИЕ ХИМИКО-ТЕХНОЛОГИЧЕСКИХ СИСТЕМ И АНАЛИЗ ЭФФЕКТИВНОСТИ ТЕПЛОМАССООБМЕНА

Предложена методика топологического моделирования химико-технологических систем на основе парного взаимодействия потоков. Такое представление производственных схем дает возможность формализовать их структуру и создать язык описания, позволяющий разрабатывать программное обеспечение для создания математической модели. Определены интегральные характеристики для оценки эффективности тепломассообмена в элементах системы. Выполнена проверка на адекватность метода моделирования.

Ключевые слова: производственная схема, топологическое и математическое моделирование химико-технологических систем, эффективность тепломассообмена.

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MODELING OF INTERCITY PASSENGER TRANSPORTATION SYSTEM

Досліджено засоби проведення оцінювання параметрів ефективності функціонування системи маршрутів пасажирських транспортних систем. Запропоновано послідовність формування транспортної системи міжміського пасажирського транспорту, яка спирається на досягнення науки і практики, та враховує закономірності розподілу транспортних кореспонденцій між містами від транспортної мережі. Доповнено функції тяжіння між містами відповідно до кількості мешканців і купівельної спроможності.

Ключові слова: *система маршрутів, ефективність перевезень, пасажирські кореспонденції, транспортний процес.*

1. Introduction

The role of transport and its infrastructure can't be overemphasized in the overall system of economic relations of any society. Relations between legal entities and individuals, their development and diversity are largely based on information, material, financial and other flows. In this case, physical changes in the location of people are of great importance. For this purpose, passenger transportation systems are being developed and are functioning.

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These systems consist of separate subsystems of different types of transport, which work together and compete in the market for population transfer services. The reliability of production, cultural and other processes in society depends to a large extent on how effectively and qualitatively these systems work [1–3].

It should be noted that passenger transportation systems embody the production capacities with their infrastructure on the one hand and people, passengers, on the other. If the interest of the first lies in the economic interests, in obtaining maximum profit, then the other, namely people, interested in a fast, convenient and cheap transport service. That is, if the first try to get the maximum revenues from transportation with a minimum of costs that requires an increased cost of travel, then people want a cheap and reliable service. This contradiction at first sight slows down the interaction of transport enterprises and passengers, and on the other hand ensures the struggle of opposites – the driving force of any development [3–5].

At different stages in the development of passenger transport, scientists and practitioners were directed to such compromise of their aspirations, in which the transportation process ensured the satisfaction of economic interests of transport enterprises on the one hand. And on the other hand, the transportation process would be affordable, reliable and would meet the purchasing power of people. The search for various options for technologies of interaction between the society and the transport industry is constantly at the stage of searching for the best possible methods of transportation organization. This process is permanent, it is based on analytical, experimental and even intuitive approaches. Therefore, any studies to improve the methods of passenger transportation organization are relevant [2, 6–8].

2. The object of research and its technological audit

The object of research is a modern intercity passenger transportation system in Ukraine. In this research, intercity passenger transport correspondence is considered. They are formed in the existing system.

One of the most problematic places is research of the actual values of permanent intercity correspondence, which consists in obtaining up to now undefined corrective coefficients used in the calculation of potential correspondence between cities. The received knowledge gives an opportunity in application of the considered method of correspondence calculations between cities in relation to the market of passenger transportations in Ukraine. Technological audit is carried out in the transport network by collecting statistical information.

3. The aim and objectives of research

The aim of this research is the formalization of the algorithm for mathematical modeling of the transport process of intercity passenger transportation.

To achieve this aim, the following tasks must be solved:

1. To formulate the target function of improving the intercity passenger transportation.

2. To mathematically describe the components of the objective function.

4. Research of existing solutions of the problem

In recent decades, researches of intercity passenger transportation systems to model their functioning have undergone various approaches [9–13]. Some scientists believed that the best passenger transportation system is a system that provides minimum transportation costs, namely:

$$\sum_{n=1}^{n} B_i \to min, \tag{1}$$

where B_i is the costs of the i-th transport enterprise for the transportation of passengers; n is the number of transport enterprises.

At the same time, the condition was defined that all passengers should be transported in a timely manner with an established level of convenience, that is:

$$\sum_{ii} H_{ij} \to const(\text{satisfied}\, i), \tag{2}$$

where H_{ij} – correspondence from any departure point i to any destination point j.

The convenience of the trip is mainly due to the fact that the number of passengers in the vehicles γ_i in each separate one should not exceed the permissible value γ_{max}:

$$\gamma_i \le \gamma_{\max}. \tag{3}$$

Since the price for travel was determined by the purchasing power of the population and other marketing indicators, the revenues from transportation were accepted by any. This approach has placed the obligation on transport enterprise to transfer all passengers with a specified level of convenience. At the same time, in order to achieve maximum profit, transport enterprises used such technologies, which provided a minimum of costs for carrying out the transportation process.

Some period in the assessment of the functioning of passenger transportation systems, the approach prevailed, in which everything was considered to provide the maximum social component. In particular, the total time spent by citizens on movement should be minimal [12, 14, 15]:

$$\sum_{ij} H_{ij} T_{nij} \to min, \tag{4}$$

where H_{ij} is correspondence from any departure point i to any destination point j; T_{nij} is the definite travel time from i to j.

However, at the same time, there were restrictions: the carrying capacity of vehicles was limited and permanent:

$$\sum_{i=1}^{m} A_i V_i T_{nij} \to const, \tag{5}$$

where A_i is the number of i-th vehicles; V_i is operating speed of vehicles; T_{nij} is the period of use of i-th vehicles to meet all transportations.

In the modern period of development of civilizational relations [16], an approach based on the assertion that the best technology of passenger transportation is one that, with all existing restrictions, minimally tires passengers.

The hypothesis is grounded that the passenger does not accurately determine and pays attention to the duration of the trip and its convenience. His subconscious mind to some extent combines these parameters. The passenger is tired and this fatigue and determines for him the attractiveness of the trip. It is determined that a longer trip, but with greater amenities, attracts the passenger more and is given priority.

In this case, the objective function has the form:

$$\sum_{i,j,k} H_{ijk}\left(IFL\right)_{ijk} \to const, \tag{6}$$

where TFL_{ij} is the equation of transport fatigue of the k-th passenger, which travels from i to j.

In this case, restrictions are imposed, as in the previous cases, namely:

– transport capacity of vehicles is constant and limited;

– all passengers are transported in a timely manner and with a minimum utilization factor of passenger capacity γ;

– pricing, as in previous cases, is determined by marketing parameters.

In different periods, researchers [17, 18] have established a dependence on the level of transport fatigue of passengers and the productivity of their production activities. The increase of TFL_{ij} is the equation of transport fatigue of the k-th passenger, following from i to j, reduces the performance of his activity $P_{ij\kappa}$ by a certain percentage that is:

$$P_{ijk} = f\left(IFL\right)_{ijk}. \tag{7}$$

Taking into account such functional dependence allowed to interpret the given objective function in a more widespread form:

$$\sum_{ijk} H_{ijk} P_{ijk} \to min. \tag{8}$$

The above set of scientific approaches to the improved system of passenger transportation allows to conclude that consideration of the functioning of this system from different social and economic positions can be combined.

5. Materials of research

The given model of calculation of transport correspondences and ways of transportation of passengers between any pairs of cities allows to determine the flows of passengers on a set of routes along the chains of their formation. To assess the adequacy of the proposed scientific approach, full-scale measurements are carried out on passenger routes along the route sections (Table 1).

Comparison of actual and theoretical values of passenger flow on the chains of the transport network is carried out by the criterion of relative error $\varepsilon\varepsilon$.

$$\varepsilon\varepsilon = \frac{\left|F_c - F_f\right| \cdot 100}{F_f}, \tag{9}$$

where F_c and F_f – calculated and full-scale passenger flow, respectively, pas/day.

Table 1

Comparison of current and calculated passenger flows on sections of the transport network

Type of transport	Network arc	Passenger flows, pas/day		Difference	Error, %
		Full-scale F_F	Calculated F_C		
Railway	16–28	372	352	20	5.38
Railway	34–12	4212	4316	104	2.71
Railway	08–63	2068	1824	244	11.80
Railway	09–14	916	1020	104	11.36
Railway	07–79	3076	2988	88	2.86
…	…	…	…	…	…
Automobile	16–28	124	118	6	4.84
Automobile	34–12	482	498	16	3.32
Automobile	08–63	338	321	17	5.03
Automobile	09–14	96	102	6	6.25
Automobile	07–79	412	436	24	5.83
…	…	…	…	…	…

Concerning railway routes, the relative error is 5.83 %, the road transport route $\varepsilon\varepsilon_r$ is 4.18 %. At the same time on railway transport, the relative error in high-speed and conventional routes differs and requires additional clarification.

The objective function of improving intercity passenger transportation is in maximization of KO – the operation usefulness of a given system, namely:

$$KO = D_c B_c \to max, \tag{10}$$

where D_c is the revenues of the system; B_c is the expenses of the system.

In turn, the revenues B_c of the system are:

$$B_P = \sum_{ijk} H_{ijk}\left(PR\right)_{ijk}, \tag{11}$$

where $(PR)_{ijk}$ is the fare from i to j of k-th passenger.

Expenses of the system:

$$B_c = B_F + B\ , \tag{12}$$

where B_F are expenses of transport enterprises; B_P is the incomplete income of passengers due to their transport fatigue.

In turn, the costs of the system consist of the incomplete revenues of the passengers due to their transport fatigue B_w, the total payment for transport work taking into account the budgetary surcharges B_v and the costs of transport enterprises B_F.

$$B_c = B_w + B_v + B_F. \tag{13}$$

In this case:

$$B_w = \sum_{ijk} H_{ijk} P_{ijk} ND_k. \tag{14}$$

where ND_k is the share of the national income attributable to the k-th passenger per day.

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$$B_v = \sum_{ijk} H_{ijk} (PR)_{ijk}, \quad (15)$$

where PR is the total fare from i and to j of the k-th passenger, taking into account budgetary surcharges.

$$B_F = \sum_{ijk} H_{ijk} S_{ijk}, \quad (16)$$

where S_{ijk} is the cost of transportation of the k-th passenger from i and to j.

Concerning passenger transport technologies, the revenues of the system are the monetary expenses of passengers for travel. That is, the expenses of passengers – this is revenues of the system D_c:

$$D_c = B_v = \sum_{ijk} H_{ijk} (PR)_{ijk}. \quad (17)$$

Generally:

$$KO = \left(\sum_{ijk} H_{ijk} S_{ijk} + \sum_{ijk} P_{ijk} ND_k \right) \to \min. \quad (18)$$

To determine the size of transport correspondence between the cities of iteration and absorption, the well-known principle of attraction models can be used. Namely:

$$H_{ij} = \frac{H_{ni}^{x1} H_{nj}^{x2} k_j d_{ij}}{\sum_{i=1}^{n} H_{nj}^{x2} K_j d_{ij}}, \quad (19)$$

where K_j is the balancing coefficient.

$$d_{ij} = \frac{1}{L_{ij}^{x_3'}}, \quad (20)$$

where L_{ij} is the distance between the cities i and j; x'_3 is an indicator of the degree of function, which requires research in each specific case.

Or

$$d_{ij} = \frac{1}{T_{ij}^{X_3''}}, \quad (21)$$

where T_{ij} is the travel time between cities i and j; x'_3 is an indicator of the degree of function, which requires research in each specific case.

The attraction function in hyperbolic form can be refined by the dependence:

$$d_{ij} = \frac{1}{2\sqrt{2\pi}} e^{tt_{xij}^{x_3''}/(2\delta)2} \text{ or } d_{ij} = \frac{1}{2\sqrt{2\pi}} e^{t_{xij}^{x_3'}/(2\delta)2}. \quad (22)$$

To clarify the attraction function between cities i and j, it is possible to use full-scale observations in which, in relation to the city of departure i and arrival j, the following parameters:

– population in cities i and j;
– the total daily number of residents leaving from i and arrive at j per day;
– the distance between i and j and at the same time the period of movement and i and j on the network of the current routes;
– the estimated number of H_{ij} for various indicators x_3' and x_3'';
– the amount of H_{ij} per day from observations that can be grounded on the reporting figures for the sale of tickets.

A comparison of the calculated and full-scale H_{ij} on the magnitude of the absolute and probable error can make a conclusion about the advisability of using indicators x_3' and x_3'' in the models for d_{ij} determination.

6. Research results

For the modeling of passenger flow between cities i and j it is not enough to know the correspondence between them H_{ij}. It should be taken into account that they can be realized by different routes, different modes of transport. In this case, the passenger selects a particular route taking into account its attractiveness. The attractiveness function of route Z relative to other possible routes depends on the time of travel on this route, the cost of travel and the convenience of staying in the cabin:

$$f_z = f\left((\tau_z ; \tau_{av}); (PR_z ; PR_{av}); (IFL_z' ; IFL_{av}) \right), \quad (23)$$

where τ_z and τ_{av} – accordingly the time on the route Z and the average time on the alternative routes; PR_z and PR_{av} – respectively the fare on route Z and the average on alternative routes; IFL'_z and IFL_{av} measure both the fatigue level of passengers on route Z and the average on alternative routes.

Along with this, the value of the attractiveness function f_z and the weight of its components depend on their ratio:

$$f_z = \frac{\tau_{av} k_\tau PR_{av} k_{PR} (IFL)_{av} k_{IFL}}{\tau_z PR_z (IFL)_z'}, \quad (24)$$

where k_{PR}, k_{IFL}, k_τ are the coefficients taking into account the weight of the corresponding parameter, respectively.

At the same time, depending on the time period of the trip, day or night, priorities change. For example, during the day, k_τ prevails, and at night k_{IFL}. The values of these coefficients depend on the state of society, its purchasing power, season, etc. and have to be specified by special sociological research. Any transport correspondence H_{ij} is distributed along alternative routes. Moreover, only part of H_{ij} is attracted on route Z:

$$H_{ijz} = \frac{f_z}{\sum_{z=1}^{r} f_z} H_{ij}, \quad (25)$$

where r is the number of alternative routes.

In this case:

$$H_{ijz} = \frac{\dfrac{\tau_{av} k_\tau (PR)_{av} k_{PR} (IFL)_{av} k_{IFL}}{\tau_z (PR)_z (IFL)_z'} f_z}{\sum_{z=1}^{r} \left(\dfrac{\tau_{av} k_\tau (PR)_{av} k_{PR} (IFL)_{av} k_{IFL}}{\tau_z (PR)_z (IFL)_z'} \right)} H_{ij}. \quad (26)$$

The resulted quantity of transport correspondences on each route Z H_{ijz} is only the estimated value. It reflects the demand and can be realized with a certain proposal. That is, there should be such offers of the capacities of routes in which these correspondences can be realized. Any significant deviation from the rational value of supply or demand can negatively affect the transport process. This determines the feasibility of modeling the functioning of the routes in such way as to be able to determine the functional relationship between the transportation needs H_{ij} and the transportation offer, which can be represented as carrying capacity.

The capacity on the route PM_z is mostly expressed by the formula:

$$HM_z = \varsigma_z A_i V_i T_{nij}, \qquad (27)$$

where ς_z is passenger capacity of vehicles on route Z; A_i is the number of i-th vehicles; V_i is operating speed of vehicles; T_{nij} is the period of use of i-th vehicles to meet all transportations.

It is desirable that possible W_{zm} necessary transport work W_{zp} on Z route is met the transportation capability:

$$W_{zp} = \sum_{ij} H_{ijz} L_{ij} = \sum_{z=1}^{r} g_z A_z V_z T_p, \qquad (28)$$

where L_{ij} is the distance between the cities i and j; T_p is period of use of i-th vehicles to meet all transportations; H_{ij} is correspondence from any departure point i to any destination point j.

In turn, transport correspondents H_{ij} can be distributed among alternative routes in proportion to their alternative offer, that is:

$$H_{ijz} = \frac{H_{ij} g_z A_z V_z}{\sum_{z=1}^{r} g_z A_z V_z}. \qquad (29)$$

Taking into account the influence on H_{ijz} of the attraction functions of the sets of routes Z connecting i and j, the function takes the form:

$$H_{ijz} = \frac{H_{ij} g_z A_z V_z \dfrac{\tau_{av} k_\tau (PR)_{av} k_{PR} (IFL)_{av} k_{IFL}}{\tau_z (PR)_z (IFL)'_z}}{\sum_{z=1}^{r} g_z A_z V_z \dfrac{\tau_{av} k_\tau (PR)_{av} k_{PR} (IFL)_{av} k_{IFL}}{\tau_z (PR)_z (IFL)'_z}}. \qquad (30)$$

Along with this, there are several points of departure and arrival of passengers on the routes of intercity passenger transportation (Fig. 1).

It is clear that the cities of arrival j or departure j of the passengers are located on the transport network so that the routes are duplicated partially or completely. At the same time, market mechanisms will act in such way that the supply and demand on the alternative routes are leveled, that is, the transport work W_z offered on route Z corresponds to the potentially possible W_{Mz} on this route. The proposed transport work on route Z can be represented as a carrying capacity, that is:

$$W_Z = g_z A_z V_z T_c, \qquad (31)$$

where T_c is the travel time on the route.

Possible transport work on the route depends on H_{izjz}. In this case, only the pair i and j take place on considered route Z, and there are only correspondences H_{ij} on route Z.

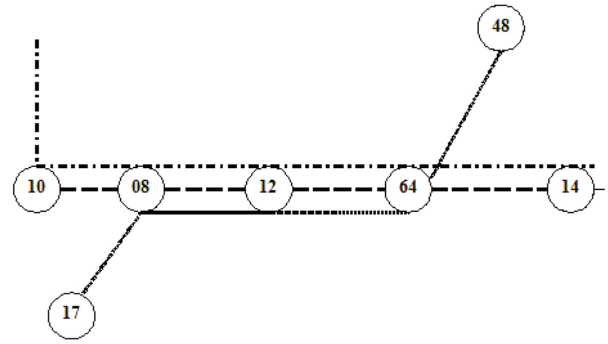

Fig. 1. Fragment of the route network

The correspondence of the proposed and possible transport work to the set of routes can be some constant ε. That is, on any route Z:

$$W_{MZ} = \sum_{iz;jz} H_{iz;jz} L_{z;jz}, \qquad (32)$$

or

$$W_{MZ} = \sum_{z;jz} \frac{H_{z;jz} g_z A_z V_z \dfrac{\tau_{av} k_\tau (PR)_{av} k_{PR} (IFL)_{av} k_{IFL}}{\tau_z (PR)_z (IFL)'_z}}{\sum_{z=1}^{r} g_z A_z V_z \dfrac{\tau_{av} k_\tau (PR)_{av} k_{PR} (IFL)_{av} k_{IFL}}{\tau_z (PR)_z (IFL)'_z}} L_{z;jz}. \qquad (33)$$

Using the hypothesis that the ratio of ε modes of transport is a constant, route parameters q_z; A_z; V_{ez} can be determined from the dependence:

$$\frac{W_{MZ}}{W_Z} \rightarrow const = \varepsilon, \qquad (34)$$

$$\frac{1}{g_z A_z V_z T_c} \left(\sum_{z;jz} \frac{H_{z;jz} g_z A_z V_z \dfrac{\tau_{av} k_\tau (PR)_{av} k_{PR} (IFL)_{av} k_{IFL}}{\tau_z (PR)_z (IFL)'_z}}{\sum_{z=1}^{r} g_z A_z V_z \dfrac{\tau_{av} k_\tau (PR)_{av} k_{PR} (IFL)_{av} k_{IFL}}{\tau_z (PR)_z (IFL)'_z}} L_{z;jz} \right) = \varepsilon. \qquad (35)$$

The scheme of the algorithm for modeling the functioning of the system of intercity passenger routes with the purpose of determination of their parameters determining the attraction of potential movements between pairs of transport regions is shown in Fig. 2.

The resulted modeling sequences, which are presented in Fig. 2, allow consistently to formulate an array of routes of intercity passenger transport with the determination of their parameters:

– ways of the route;
– number and passenger capacity of vehicles;
– traffic speed;
– passenger transport utility, which determine the route volumes of traffic, etc.

The next step may be to check the parameters of the functioning of the transport network relative to the total travel time of passengers on the network:

$$\sum_{iz;jz} H_{iz;jz} r_{ijz} \rightarrow \min. \qquad (36)$$

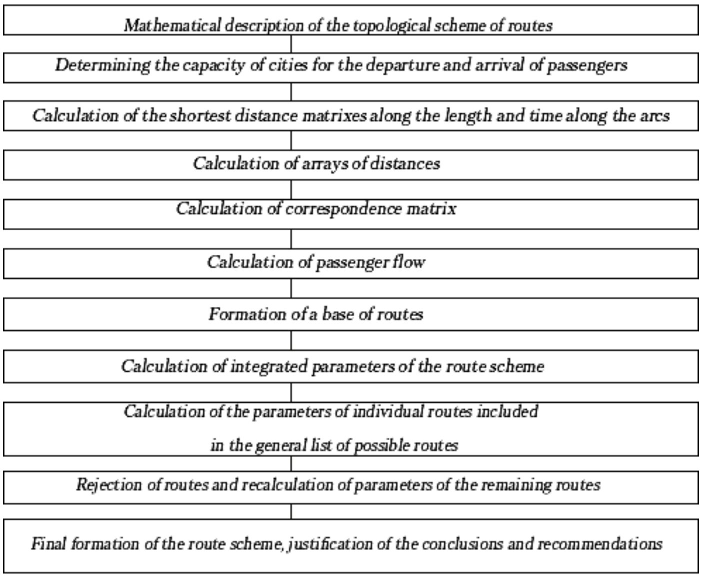

Fig. 2. The scheme of the algorithm for modeling the functioning of intercity passenger transportation system

To do this, it can take advantage of the fact that the preliminary calculations include an array of H_{ijz}, a list of routes Z and the time of movement of vehicles along the arcs of the route network. Step by step, in an interactive mode, relying on the intermediate calculations «rejection of inexpedient routes», it can be conclude that the system of intercity passenger transport routes is minimized in order to minimize the travel time of passengers. A similar approach can be applied to check the parameters of the route network to minimize passenger fatigue. To do this, it is sufficient to use the network action parameters in the intermediate calculations.

7. SWOT analysis of research results

Strengths. To the strengths of this research can be attributed evidence of the possibility of applying the chosen model to the system of intercity passenger transportation in Ukraine. New information has been obtained on the modeling of transport route systems for transportation of passengers between cities within the investigated system. Modern scientific achievements that are reviewed in the literature indicate in favor of this assertion. With these circumstances, it is appropriate to use models predicting the parameters of the functioning of the system in the practical conditions. The use of the obtained data on the optimal values of the invented means provides the possibility to ensure the inclusion of qualitative performance indicators and planning parameters of considered transportation system. Taking into account the above, new information about investigated system is obtained in terms of planning indicators of the functioning of the parameters of the functioning of the transportation system for transportation of passengers on common routes between cities. The obtained results can be used to carry out calculations for the transportation of passengers between cities in Ukraine. This is more advantageous in comparison with the analogues due to:

– ensuring the registration of social and economic characteristics of the population of Ukraine;
– a possible increase in productivity by optimizing the use of the route network;
– satisfaction of economic interests of the transport industry.

Weaknesses. The shortcomings of the conducted research and obtained results include the failure to take into account the fact of existing passenger correspondence between cities that are implemented using passenger cars. However, it should be noted that the aim of the work is to study the correspondence of passengers implemented on public routes. Also, when receiving data on permanent correspondence, the fluctuations in correspondence related to seasonal changes in the mobility of the population are not taken into account. At the same time, the work provides taking into account the socioeconomic status of passengers. It should be determined that the introduction of research results into the passenger transportation system does not have additional financial burdens on transport enterprises or passengers.

Opportunities. Accurately calculated value of passenger intercity transport correspondence on public routes allows to ensure planning of interaction between systems of different modes of transport to meet the needs of the population of the country in meeting the needs of its inhabitants for movement within the investigated system. At the same time, it is possible to improve the quality of the financial flows of production by optimizing the allocation of resources over time throughout the passenger system.

Threats. There are threats in applying the research results. This is due to the fact that the application of the results requires the modernization of the existing transport infrastructure. Perhaps, there is such state of the system, in which it will require transport enterprises to provide large volumes of transportation services.

8. Conclusions

1. The objective function of the improvement of intercity passenger transportation is formulated, which, unlike those proposed by other researchers, ensures that the social and economic situation in the society is taken into account. The proposed approach is based on a mathematical description of joint activities of not only routes, but also their impact on public activities, taking into account transport fatigue.

2. The sequence and content of studies of rational parameters of the intercity passenger system that can be used in similar formalization of the operation of this system in the consideration of international route systems are obtained. At the same time, the transportation systems of a number of countries can form a common system of territory in a modular manner. They are combined according to any principle.

The existing transportation system of intercity passenger transport relies on modern achievements of science and practice, takes into account the patterns of distribution of transport correspondence between cities from the transport network, attraction functions between cities, the number of inhabitants and purchasing power.

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МОДЕЛИРОВАНИЕ СИСТЕМЫ МЕЖДУГОРОДНЫХ ПАССАЖИРСКИХ ПЕРЕВОЗОК

Исследованы средства проведения оценки параметров эффективности функционирования системы маршрутов пассажирских транспортных систем. Предложена последовательность формирования транспортной системы междугородного пассажирского транспорта, которая опирается на достижения науки и практики и учитывает закономерности распределения транспортных корреспонденций между городами от транспортной сети. Дополнена функция притяжения между городами в соответствии с количеством жителей и покупательной способностью.

Ключевые слова: система маршрутов, эффективность перевозок, пассажирские корреспонденции, транспортный процесс.

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CONTROL SYSTEM SYNTHESIS OF FORMATION OF CARBON PRODUCTS

Запропонована нова система керування, яка передбачає керування з ітеративним навчанням (КІН) процесом формування продавлюванням електродної маси через мундштук відповідної форми у гідравлічному пресі. Запропоновано відповідний КІН-алгоритм. Дане дослідження підтвердило, що КІН-алгоритм забезпечує високу якість керування в умовах відсутності початкових невизначеностей та зовнішіх збурень.

Ключові слова: *вуглецеві вироби, керування з ітеративним навчанням (КІН), система керування, КІН-алгоритм.*

1. Introduction

Consumers of carbon products are various industries in which production is associated with the need for the use of electrothermal technological processes. In particular, such enterprises include enterprises of ferrous and nonferrous metallurgy, machine building, chemical industry and others.