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APPLICATION OF GENETIC ALGORITHM OF OPTIMIZATION DURING THE PROCESS OF URBAN PASSENGER TRAFFIC MANAGEMENT

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The paper proposes a generalized logistic model of the urban passenger transportation system, and on its basis, there has been developed a modified model that allows for determining a set of organizational and economic indicators in each state of a system. To solve the optimization problem of the transportation process system under conditions of dynamically changing passenger traffic flows, there has been justified searching for a balance between the effectiveness and quality of solutions due to the «survival of the strongest alternative solutions» y to earn system of operational control buses on the route. There has been proven the advantage of using genetic algorithm to optimize the processes of organizing and managing the system of urban passenger transport with the aim of maximizing the profits of an enterprise at minimal cost.

Keywords: *urban passenger traffics, optimization, genetic algorithm, traffic schedule, logistic model.*

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ПРИМЕНЕНИЕ ГЕНЕТИЧЕСКОГО АЛГОРИТМА ОПТИМИЗАЦИИ В ПРОЦЕССЕ УПРАВЛЕНИЯ ГОРОДСКИМИ ПАССАЖИРСКИМИ ПЕРЕВОЗКАМИ

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В статье предлагается обобщенная логистическая модель системы городских пассажирских перевозок, а на ее основе разработана модифицированная модель, позволяющая в каждом состоянии системы определить набор организационно-экономических показателей. Для решения задачи оптимизации системы перевозочного процесса в условиях динамически изменяющихся пассажиропотоков, обоснован выбор генетического алгоритма осуществляющего поиск баланса между эффективностью и качеством решений за счет «выживания сильнейших альтернативных решений». Разработана система оперативного управления автобусами на маршруте. И доказано преимущество использования генетического алгоритма для оптимизации процессов организации и управления системой городских пассажирских перевозок с целью максимизации прибыли предприятия при минимальных затратах.

Ключевые слова: *городские пассажирские перевозки, оптимизация, генетический алгоритм, расписание движения, логистическая модель.*

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At present, passenger transport is a prerequisite for the functioning of the national economy and lives of the people. The largest share in the passenger turnover is covered by interurban bus transportation, which is in turn a complex socio-economic system, since they include a large number of interconnected and interacting components, having a complex structure and functioning in a holistic way. The steady increase in the intensity of passenger and transport flows, the development of the route network, the longer average distance of movements on passenger transport and the increase in unevenness of passenger traffic flows in time and the directions necessitate the use of new optimization solutions in organizing urban passenger transport.

When solving the problem of optimizing the movement of route vehicles, taking into account overlaying the route schemes [1], there are proposed the situational and mathematical models and the models for calculating the traffic capacity and delays, based on determining the velocity on the route, route saturation and traffic intensity using convex programming problems and numerical simulation methods. By means of them, there have been developed the theoretical bases for assessing the operational properties of buses, allowing proposing a methodology and criterion for choosing the optimal number of buses on the route, taking into account environmental factor. However, the need for this kind of methodology arises only when establishing new routes.

Considering that the process of providing passenger transportation services is influenced by a large number of factors, it should be emphasized that a prerequisite for finding the best option to comprehensively solve the problems of improving the quality of public services and increasing the profits of motor transport companies, when modeling and optimizing passenger transport in major city, it is necessary to take into consideration the maximum possible number of indicators. Based on this, it can be said that in order to achieve the most accurate results of solving organizational and management problems listed above, it is especially important and relevant to choose the required and sufficient number of parameters to be considered when modeling and optimizing the number of possible states of the transport system for passenger service. Due to the fact that it is possible to identify hundreds of parameters and states, which are relevant in optimizing the passenger transportation system, given its complexity for operating conditions in large cities, there is a need to simplify the task, decompose it and reduce the number of characteristics taken into account. The majority of the modern models focus on the application of tools that are developed and allow for obtaining the new accurate results: an operation research tool, systems modeling, and statistical optimization methods. However, under conditions of the tasks set, such methods cannot be applied due to their high dimensionality. Another option for solving high-dimensionality problems is the use of modern search methods, in particular, genetic algorithms (GA). The main feature of these algorithms is the use of a variety of alternative solutions, allowing for search for promising solutions in terms of the used functional and restrictions [2].

The main feature of such algorithms is also the possibility of using, firstly, the objective function during optimization, and not its estimates or approximations, and secondly, taking into account the required number of restrictions. During operation, the genetic algorithm (GA) processes a variety of alternative solutions, organizing the search for promising solutions in terms of the used functional and restrictions. Thus, it is proposed to formulate and solve the problem of optimizing the operation of the passenger motor transport company by the criterion of maximizing the profit of the enterprise, especially if it is possible to take into account the maximum set of indicators S that affect the activities of motor transport company. To this end, the following groups of indicators are proposed to identify: economic, organizational, legislatively regulated, normative, management systems, quality of service, traffic conditions; technical and operational indicators of route buses, technical and operational indicators of routes and other indicators that are not included in these groups:

$$S = \{X, E, Y, H, K, D, M, U, G, Q\},$$

where S – a set of groups of indicators; X – a set of economic indicators; E – a set of organizational indicators; Y – a set of the management system's indicators; H – a set of technical and operational indicators of route buses; K – a set of technical and operational indicators of routes; L – a set of legislatively regulated indicators; M – set of normative indicators; U – traffic conditions indicators; W – service quality indicators; Q – other indicators.

To solve the set problem of optimizing the process of passenger transport management, it is proposed to use genetic algorithm adapted to the problem setting. In doing, due consideration should be given to the notions of chromosome, gene, population, as well as random variations operators [3, 4].

As a chromosome, there is considered the option of a solution to the problem, consisting of the elements of the solution – genes. The options of the solution make up the population [5-7].

To solve the problem and build the chromosome, as input parameters there were used:

– time of moving off of each bus on the line;
– arbitrary number of the moving off stop;
– the number of travels for time on duty;
– the number of motive power on the line.

Given these parameters, the proposed chromosome A will take the following form (see Table 1):

$$A = (\alpha^1, \beta^1, \delta^1, \gamma^1_{1,2}, \gamma^1_{2.3} \cdots \gamma^1_{i,j} \cdots \gamma^1_{i-1,k}, \mu^1_i;$$
$$\alpha^v, \beta^v, \delta^v, \gamma^v_{1,2}, \gamma^v_{2.3} \cdots \gamma^v_{i,j} \cdots \gamma^v_{i-1,k}, \mu^v_i;$$
$$\alpha^z, \beta^z, \delta^z, \gamma^z_{1,2}, \gamma^z_{2.3} \cdots \gamma^z_{i,j} \cdots \gamma^z_{i-1,k}, \mu^z_i)$$

For example, gene $\alpha = (\alpha^1, \alpha^2)$ carries information on the number of journeys;

Gene $\beta^v = (\beta_1^{v,N}, \beta_2^{v,N}, \ldots \beta_{14}^{v,N})$ determines start of the v^{th} bus motion in minutes during the N^{th} journey $v = \overline{1,z}$, where z – is number of buses on the route for time on duty.

Genes

$$\gamma^{v.N}_{1,2} = ({}^l\gamma^{v.N}_{1,2,1}, {}^l\gamma^{v.N}_{1,2,2}, {}^l\gamma^{v.N}_{1,2,3}), \ldots,$$
$$\gamma^{v.N}_{j,i+1} = ({}^l\gamma^{v.N}_{j,i+1,1}, {}^l\gamma^{v.N}_{j,i+1,2}, {}^l\gamma^{v.N}_{j,i+1,3}), \ldots,$$
$$\gamma^{v.N}_{k-1,k} = ({}^l\gamma^{v.N}_{k-1,k,1}, {}^l\gamma^{v.N}_{k-1,k,2}, {}^l\gamma^{v.N}_{k-1,k,3})$$

represent the time interval vectors of passing through the route sections by v^{th} bus during the N^{th} journey, where $i = \overline{1,k}$.

Gene $\mu^v = (\mu_1^{v,N}, \mu_2^{v,N}, \ldots, \mu_t^{v,N}, \ldots, \mu_k^{v,N})$ sets the point of the start of the v^{th} bus motion, $v = \overline{1,z}$, where z – is number of buses on the route for time on duty.

Comparison of chromosomes is made as follows: from the analyzed population $P = \left({}^1A, \ldots, {}^vA, \ldots, {}^zA\right)$, the best one is considered the chromosome with the smallest violations of the restrictions, and among the chromosomes with equal violations, the chromosome with a large value of the objective function $F\left({}^lA\right)$ is selected.

Thus, there have been obtained the structure of the chromosome, which is a coded version of the bus motion on the route for time on duty. Each chromosome is characterized by the magnitude of the violation of restrictions and the value of the objective function.

Table 1

Gene	Gene symbol	Value	Problem situation
Number of journeys	α	*bin(α)*	Binary representation of the number of journeys of z^{th} bus for time on duty
Moving off start time in hours	β	*bin(β)*	Binary representation of moving off start time in hours of z^{th} bus for time on duty
Moving off start time in minutes	δ	*bin(δ)*	Binary representation of moving off start time in minutes of zth bus for time on duty
Time intervals required for passing through the route from the 1st to the 2nd stop	$\gamma^{z,N}_{1,2}$	$bin(\gamma^{z,N}_{1,2})$	Binary representation of time interval required for passing through the route from the 1st to the 2nd stopping point during the N^{th} journey
Time intervals required for passing through the route from the j^{th} to the i+j^{th} stop	$\gamma^{z,N}_{j,i+1}$	$bin(\gamma^{z,N}_{1,2})$	Binary representation of time interval required for passing through the route from the j^{th} to the i+j^{th} stopping point during the N^{th} journey
Time intervals required for passing through the route from the k-1th to the k^{th} stop	$\gamma^{z,N}_{k-1,k}$	$bin(\gamma^{z,N}_{1,2})$	Binary representation of time interval required for passing through the route from the k-1th to the kth stopping point during the N^{th} journey

The arbitrary number of the moving off stop	μ_i	$bin(\mu)$	Binary representation of the arbitrary number of the moving off stop of z^{th} bus

In order design the genetic algorithms, there have been developed the random variations operators [7–10] transforming the chromosomes, analyzing the new chromosomes, and selecting the chromosomes that are promising for development. When implementing genetic algorithms in relation to the set problem, it is necessary to clarify and specify the operators used. As reproduction operators, there have been used the double-parent and multi-parent crossing-overs, and the multi-point mutation is used as mutation operators.

In addition, when designing genetic algorithms, it is necessary to switch in operators making random variations that affect not the entire chromosome, but one specific gene. The need to develop such operators was identified during the process of the numerical experiments with genetic algorithms. This is because the fact that at the final stage of the performance of the algorithm, when the chromosomes are obtained, corresponding to those, which are close to the optimal solutions, it is advisable to provide variations with one gene or one group genes. The self-organization of genetic algorithm is based on the competition of reproduction and mutation operators, setting up an effective number of parents for random variations operators. Additionally, there is organized the competition of chromosome genes to carry out genetic operations of mutation and reproduction. For operators, there are determined their shares in the total number of operations carried out at one iteration, as well as the effectiveness of each operator. Taking into account the obtained values, there are corrected the shares of operators in the total number of operations of one iteration for the next iteration, the effective number of parents for multi-parent operators, as well as a promising gene for performing genetic operators. Thus, there was proved the relevance and provided the formulation of problem of optimizing passenger transport in large city, taking into account the maximum possible number of influencing factors; there was justified possibility of using genetic algorithms to solve the optimization problem under conditions of high dimensionality and a large number of restrictions; there were shown the principles of chromosome design, chromosome comparison, transformations of the restrictions of the optimization problem, and random variations operators were specified with regard to the formulated problem; there were determined and introduced into the algorithm genetic operators of random variations, taking into account the described principles of self-organization.

In case of schedule slippage of more than 10 minutes, dispatcher analyzes the traffic situation using information from sensors installed on buses, which make it easy to determine whether the bus hit a traffic jam or is off the route for technical reasons.

Thus, the main functions of the developed control and management system include:

– determination and release on the road the optimal number of motive power per day;
– determination of the optimal number of motive power on the line during rush hour;
– optimal scheduling for each bus every 24 hours;
– determining the traffic situation at a given time;
– correction of the bus schedule at the time depending on the traffic situation;
– determination and correction of the speed of each bus depending on the traffic situation;
– determining the cause of schedule failure.

These indicators allow for calculating the productive program of the effectiveness of using motive power, correcting a schedule showing working hours and rest period of drivers, as well as for finding the optimal ways to work while maximizing the profits of the enterprise at minimum cost.

The proposed models and algorithms for optimizing the management process of urban passenger traffic have been used when improving the operation of motive power, taking into account the required number of significant parameters, and the economic efficiency during the introduction of a system was 4.83%.

CONCLUSIONS

1. There is proposed a generalized logistic model of the urban passenger transportation system, and on its basis, a modified model has been developed that allows for determining the set of organizational and economic indicators in each state of the system, as well as for calculating the objective function based on the values of the selected parameters.

2. Studies of passenger traffic flows in the city allowed for gathering complete and reliable information to optimize the operation of motor transport companies and rational management of the transportation process, which necessitated the optimization of indicators as follows: number of buses released on the road;; the number of journeys of each bus released on the road; moving off starting time of the first and subsequent journeys of each bus; the moving off starting point of bus in each journey; minimum time intervals required for passing through the route sections for each journey; minimum time intervals required for passing through the route sections for each journey.

3. In order to solve the problem of optimizing the transportation process under conditions of dynamically changing passenger traffic flows, there is justified the choice of genetic algorithm searching for a balance between the effectiveness and quality of solutions due to the «survival of the strongest alternative solutions».

4. There is proposed a modified genetic algorithm and the principles of chromosome design and random variations operators are determined with regard to the problem under consideration; genetic operators of random variations have been developed, and the expediency of including them in genetic algorithms has been justified.

5. There has been developed a system of operational management of buses on the route, allowing for increasing the degree of controllability of vehicles on the route, as well as for correcting the speed of movement; traffic schedule; the number of motive power on the line; the passage through the individual route sections during rush hour; time of each journey.

6. There has been proven the advantage of using genetic algorithm to optimize the processes of organizing and managing the system of urban passenger transport with the aim of maximizing the profits of an enterprise at minimal cost.

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