Imitation modeling of passenger traffic delivery activities

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Abstract. In this paper, the concept of building a new route network is investigated. The guiding idea of the concept is the functioning of transport as a coherent system. Under the given conditions, it is impossible to organize the stable operation of the passenger transport complex without eliminating the existing contradictions. In order to establish a balance of interests of all cooperating parties, a mechanism for regulating the route network is proposed in the work, the calculation of which makes it possible to select the type of vehicle on the route, as well as calculate the number of flights, based on the condition of achieving a break-even transport process for carriers of various forms of ownership.

1. Introduction

In order to comprehensively plan the system of urban public transport routes, the measures taken to introduce modeling include the improvement of the updated digital base on the relevant indicators of the transport system, the development of mathematical models of the transport system, artificial intelligence in the introduction of short- and medium-term urban planning It is especially important to consider the implementation of use of mechanisms [1-2].

The routes and types of cargo that can be technologically used in passenger transport of different models of passenger vehicles will be somewhat limited, and it will be necessary to take into account that the efficiency and cost of work are different for different routes and types of cargo. On this basis, it will be possible to develop models of transport process management, taking into account the different service options for common situations that are real and complex [3].

It is known that the main indicator of the quality of transportation services to consumers is to meet their needs in the volume of transportation within a specified period. As a result, in the practice of providing transport services, the status of the implementation of transport services assigned to consumers for connection addresses is constantly monitored and taken into account in the management solution developed for each subsequent period [4].

2. Create a model of the problem

The status of fulfillment of contracted volumes of transportation for consumers and the need to constantly improve it are taken into account in the management model as follows [5-6].

First of all, the set of interconnected addresses belonging to the k-consumer – $U_{km}$, the situation that occurred in the period before each management solution $U_{km}^{\text{op}}$ – the local set, the set of
interconnected addresses lagging behind in the plan of performance of contracted volumes. The set of interconnected addresses $U_{k}^{op}$ lagging behind the plan consists of a set of addresses $U_{k}^{Bop}$ — passenger in $U_{k}^{op}$ — out

$$U_{k}^{op} = \left\{ U_{k}^{op}, U_{k}^{Bop}\right\} . \quad (1)$$

In this case, the difference between the rates of the following separate service interconnected addresses determines the $U_{k}^{op}/U_{k}^{op} = \left(U_{k}^{Bop} / U_{k}^{Bop}\right)$ rates of addresses where the established contractual levels of traffic are fulfilled or exceeded. It is not advisable to separate the local set of addresses in the set of route service interconnected addresses, where the planned indicators of contract traffic are fulfilled, because the volume of traffic on rational routes is determined on the basis of mutual equalization of traffic volumes on all its lines [7].

The management of traffic volumes on transport lines and interconnected addresses is carried out on the basis of periodic distribution and redistribution of passenger transport on the lines, depending on the situation achieved. In order to solve the problem of optimal distribution of passenger vehicles on the lines and routes, first of all, the problem of routing must be solved. On this basis, there is a possibility of complex distribution of vehicles to all interconnected addresses on separate transport service lines and rational routing services [8-10].

As a result of optimal routing of long-distance passenger traffic $U_{k}^{MX}$, $u \in U_{k}^{MX}$ the local system of interconnected addresses providing route transportation services, the set of numbers (d) on the routes of rational routes for each connecting address and l-mode of transport Dul and the volume of each d-route passenger is $Q_{d}$ determined. As a result of routing, it will be possible to divide the set of passenger lines in l-type transport for u- interconnected addresses into Julto $J_{ul}$ and $J_{MK}$ and local packages, where, here $J_{ul}$, $J_{MK}$ — sets of routes that provide separate and routed transport services belonging to u-digital interconnected addresses, respectively [11-12].

For each m-digit interconnected addresses $J_{MK}$ — type of passenger transport, the set of rational set of routes passing through this address consists of the combination of all the Dul-elements (d ∈ Dul) of the set of transport lines Juld, i.e.

$$J_{MK} = \bigcup_{d \in Dul} J_{ald} . \quad (2)$$

If we take the combination of the local set of rational routes Dul by all types of u-interconnected addresses and l, then we form the set of rational routes D in the district where the transport service is provided:

$$D = \bigcup_{u,l} D_{ul} . \quad (3)$$

If we denote by a local set of routes, which includes the $D_{j}$ digit traffic direction, then the combination of such local packages on all j-lines gives the set D, i.e.

$$D = \bigcup_{j} D_{j} . \quad (4)$$

We define each d-route with the parameter of a set of modes of transport that carry passengers on all lines of transport. The main constraints and target functions of the model of complex transportation services to consumer addresses are as follows:
Ensuring that the volume of imported (exported) cargo for each type of cargo provided to each interconnected addresses separately (from) and the route service is in the range of possible values 

\( Q_{iil}^{\min} + Q_{iil}^{\max} \) within its needs

\[
Q_{iil}^{\min} \leq \left( \sum_{i=I_{jt}} \sum_{j=J_{jt}} X_{ij}Q_{ij} + \sum_{i=I_{jt}} \sum_{j=J_{jt}} Y_{id}Q_{ijd} \right) \leq Q_{iil}^{\max},
\]

\[
u \in \left( \overline{U}_k \setminus \overline{U}_k^{\text{op}} \right) \cup U_k^{3\text{MX}}, \quad l \in L_u^{MX}, \quad J_{il} = \bigcup_{d \in D_{il}} J_{al}, \quad k \in K = \left\{ K^{\text{w}} \cup K^{T}_{\text{MX}} \right\}
\]

\[
Q_{iil}^{\min} \leq \left( \sum_{i=I_{jt}} \sum_{j=J_{jt}} X_{ij}Q_{ij} + \sum_{i=I_{jt}} \sum_{j=J_{jt}} Y_{id}Q_{ijd} \right) \leq Q_{iil}^{\max},
\]

\[
u \in \left( \overline{U}_k \setminus \overline{U}_k^{\text{Bop}} \right) \cup U_k^{BMX}, \quad l \in L_u^{BMX}, \quad k \in K = \left\{ K^{\text{Bop}} \cup K^{\text{a13}} \right\}.
\]

• The volume of passenger traffic on each j-line should be within \( Q_j^{\min} + Q_j^{\max} \) its technological capabilities:

\[
Q_j^{\min} \leq \left( \sum_{i=I_{jt}} X_{ij}Q_{ij} + \sum_{i=I_{jt}} \sum_{d \in D_{id}} Y_{id}Q_{ijd} \right) \leq Q_j^{\max},
\]

\[
j \in J = \bigcup_{a,l} J_{al}, \quad l \in L_u, \quad u \in U_k^1, \quad k \in K = \left\{ K^{\text{w}} \cup K^{T} \right\}.
\]

• The planned volumes of passenger traffic on rational routes should be fulfilled:

\[
\sum_{j \in J_l} \sum_{i \in I_{il}} Y_{id}Q_{ijd} = Q_{id}, \quad d \in D,
\]

• The needs of passengers in addition to the volume of traffic included in the rational routes designed for demanding consumers are met within the capabilities of the passenger transport fleet:

\[
\left( \sum_{i=I_{jt}} \sum_{d \in D_{id}} Y_{id}Q_{ijd} + \sum_{i=I_{jt}} \sum_{j=J_{jt}} Y_{id}Q_{ijd} \right) \leq Q_{id}^{\max}, \quad u \in U_k, \quad k \in K^{T}, \quad l \in L_u,
\]

• The number of passenger vehicles used in the transportation process should not exceed the number of used passenger vehicles:

\[
\sum_{j \in J_l} \left( X_{ij} + \sum_{d \in D_{id}} Y_{id} \right) \leq A_i, \quad i \in I.
\]

The following evaluation criteria can be taken as a target function of the issue:

• If the planned passenger traffic is minimal, this criterion applies when the company has sufficient capacity:

\[
\sum_{i=I_{jt}} \sum_{j=J_{jt}} X_{ij}S_{ij}Q_{id} \rightarrow \min,
\]
where the cost of passenger transport by i-type transport on the j-line.

• Ensuring the maximum volume of passenger traffic This criterion is applied when the capacity of the enterprise is sufficient:

\[
\sum \sum X_{ij}Q_{ij} \rightarrow \text{max}.
\]

Mathematically, the above model is a general problem of linear programming, and effective algorithms have been developed to solve it. However, it should be noted that in many cases, the adoption of criteria such as minimizing or maximizing transportation efforts as a target function of the model does not allow to take into account the economic losses of consumers due to lack of transportation capacity or insufficient transportation needs. To take such cases into account, it will be necessary to formulate multi-criteria optimization problems. Determining the limiting carrying volumes in the balance equations of the above model can be brought to the problem of dynamic programming. If we want to justify the solutions in the model taking into account the probabilistic nature of the parameters A and their dependence on several parameters, then we need to formulate the problem in the form of a probabilistic linear optimization model.

3. Problem solving algorithm

From point B to junction points \( j = \{1, 2, \ldots, n\} \) passengers must be transported. Each passenger is given the amount of passengers to be transported. \( l \) number of vehicles can be involved in passenger transportation. The load capacity \( q_i \) for the vehicle of \( k \) transport is known as \( k \in \{1, 2, \ldots, L\} \). The serial numbers of the transport \( l = \{1, 2, \ldots, l\} \) are defined in such a way that the following condition must be met:

\[
q_1 \leq q_2 \leq \ldots \leq q_l.
\]

The route created for each transport is a sequence of known addresses \( \{B, j_1^k, j_2^k, \ldots, j_s^k, B\} \), in which \( B, j \in R_k = \{B, j_1^k, j_2^k, \ldots, j_s^k, B\} \). It is necessary to determine the route for each transport in such a way that the sum of the number of passengers receiving the addresses should not exceed the number of passengers in the transport, ie

\[
\sum_{j \in R_k} Q_j \leq q_k, k \in \{1, 2, \ldots, L\}.
\]

In this case, the following conditions must be met for all sets of routes \( \{R_k\} \):

- no receiving address should be included in two routes, for example (\( R_k \) and \( R_r \)) in other words, the intersection of receiving points belonging to \( R_k \) and \( R_r \) should be empty, ie

\[
r \neq k \rightarrow R_k \cap R_r = \emptyset, \quad r, k \in \{1, 2, \ldots, l\},
\]

passengers must be taken to all addresses, ie

\[
\bigcup_{k \in \{1 \ldots l\}} R_k = \{1, 2, \ldots, l\};
\]

– the structured routing system should provide the minimum walking distance.

\[
\sum_{(j_i) \in R} d_{ji} \rightarrow \text{MIN},
\]

Here

\( R_k^1 = \{(R, j_1^k), (j_1, j_2), \ldots, (j_s^k, B)\} \) – a set of pairs of points on the transport route;

\( R^1_l = \{R^1_1, R^1_2, \ldots, R^1_r, \ldots, R^1_l\} \) – a set of double points on all routes;

\( d_{ji} \) – elements of the matrix of the shortest distances between points.

The problem statement and the model assembly route are also almost no different from the above. It should be noted that to date, no universal methods of routing small-batch passenger transport have been developed.
Typically, when interconnecting routes based on the shortest connecting network, two interrelated issues are solved in series:
1) determine the rational sequence of transportation of goods to the addresses;
2) inclusion of points in the routes taking into account the car load capacity.

The Clark-Wright method allows to solve these two problems at once, that is, to create rational routes for cars with different passenger capacity.

According to the essence of the method, first of all, an initial plan of passenger transportation is made. In this case, each recipient will be allocated a separate route and transport with a capacity corresponding to the amount of passengers transported.

In subsequent iterations, the two routes are paired with each other, resulting in a distribution route. The remaining routes and the distribution route are combined, and the option is chosen so that the pairing minimizes transportation costs. If it is not possible to reduce costs as a result of any subsequent pairing, or if the carrying capacity on the combined route exceeds the load capacity of the rolling stock, then the unloading process is stopped and the found plan is considered optimal.

Using the Clark-Wright algorithm, we can now proceed directly to solving the problem. Here, we give relevant explanations, citing the possibilities of using this algorithm for the issue under consideration.

Step 1. The maximum km in the matrix \((i^*, j^*)\). Find the cell that wins \(S_{\text{max}}\):

\[
S_{\text{max}} = \max_{i,j} s(i, j) = s(i^*, j^*). \tag{15}
\]

In this case, the following three conditions must be met:
1) points \(i^*\) and \(j^*\) are not part of the same route;
2) points \(i^*\) and \(j^*\) are the beginning or (or) end point of the route on which the route is included;
3) cells \((i^*, j^*)\) are not blocked (i.e. discussed in previous steps of the algorithm).

If it is possible to find a similar cell that satisfies these three conditions, proceed to step 2. If no such cell is found, proceed to step 6.

2 – Step. In the route, we define as the 1st route which \(i^*\) point is included in the route.
Correspondingly, we define which route \(j^*\) is part of as Route 2.

We enter the following symbols:
\(N = \{1, 2, \ldots, n\}\) is the number of consignees;
\(N_1(N_1 \subseteq N)\) – 1 number of points included in the route;
\(N_2(N_2 \subseteq N)\) – 2 number of points included in the route.

Hence, \(i^* \in N_1, j^* \in N_2\) and \(N_1 \cap N_2 = \emptyset\) (according to step 1, condition 1).

We calculate the total traffic volume for routes 1 and 2:

\[
q_1 = \sum_{k \in N_1} q_k, \quad q_2 = \sum_{k \in N_2} q_k, \tag{16}
\]

where \(q_k\) is the required volume of \(k\)-point, pieces.

Step 3. We check that the following condition is met:

\[
q_1 + q_2 \leq c, \tag{17}
\]

where \(c\) is the passenger capacity of the vehicle.
If the condition is met, go to step 4, if not, go to step 5.

Step 4. We combine routes 1 and 2 into one common X-ring route. We assume that point \(i^*\) is the last point of route 1, and point \(j^*\) is the beginning of route 2. When combining routes 1 and 2, we ensure that the following conditions are met:
1) the sequence of points on Route 1 does not change from the beginning of the route to point \( i^* \);
2) point \( i^* \) is connected with point \( j^* \);
3) The sequence of points on Route 2 does not change from point \( j^* \) to the end.

Step 5. Until \( S_{\text{max}} \) is reached, steps 1-4 can be repeated when the three conditions in step 1 are not met.

Step 6. The total distance covered by passenger transport is calculated.

4. Conclusion
The advantages of the simulation modeling method include:

- Carry out simulation analysis on the system model if the implementation of a real experiment is not possible for any reason (life-threatening, valuable, past, etc.);
- Solve problems where analytical methods cannot be applied, such as continuous-discrete factors, random effects, nonlinear descriptions of system elements, and h. in situations;
- The ability to analyze general system situations and make decisions using computers, including for complex systems where it is not possible to select criteria for comparing behavioral strategies at the design stage;
- In the search for optimal project solutions based on some criteria for reducing time and evaluating efficiency;
- Analysis of various control algorithms to study the effects of changes in system parameters on the characteristics of large system structures options.

5. References
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