Fuzzy optimization of route networks urban passenger transport

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Abstract. The work aims to study methods for optimizing the route networks of urban passenger transport with fuzzy initial information since the process of passenger transportation in cities has many factors of uncertainty and stochasticity and is quite complex, including a whole range of initial data. Heuristic fuzzy optimization methods are proposed. The study's main result is the improvement of methods for optimizing the route networks of urban passenger transport. These methods today make it possible to take into account the opposing interests of the participants in the process of transporting passengers in the city, as well as to set a large set of initial parameters and restrictions for the mathematical model of optimizing the urban route network. A fuzzy transport problem has been solved, a computational experiment has been carried out, and results have been obtained to illustrate the proposed method. This method is easy to understand and apply to find the optimal solution in fuzzy transport models of real problems. An algorithm for finding L alternate routes and determining the ideal route for vehicle traffic control based on a graph database allows vehicle traffic control.

1 Introduction

In the world, scientific research is being carried out related to developing methods and algorithms for researching the problems of regulating vehicle traffic and determining perfect route reserves using automated systems. In this regard, one of the important tasks is developing a set of software tools to regulate the movement of vehicles and reduce congestion in cities using graph theory, intelligent data analysis methods, and algorithms. In our republic, special attention is paid to improving the quality of technical, interactive, and intellectual services to the population, organizations, and production sectors based on information and communication technologies, including regulating the movement of vehicles, reducing traffic jams in cities, obtaining geolocation data of important objects, and identifying reserve roads.

The optimization of route networks is currently a relevant direction.

The route networks of urban passenger transport are presented in [1-6]. Their authors

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divide all existing methods into three groups:

1) optimization of route networks of urban passenger transport in an automated mode;

2) combination of optimization of route networks of urban passenger transport in an automated mode and expert evaluation of the results by a specialist;

3) decision making based on experience and non-formalized analysis of experts.

A new stage in the development of scientific developments in the optimization of route networks began in 1976 when a large number of works were devoted to this problem [7-15]. Thus, the number of acceptable routes is reduced, and hence the number of analyzed options for route networks, which will significantly reduce the time spent on forming route networks and the complexity of the optimization process. The criterion is the average intensity of passenger traffic between the combined microdistricts.

Thus, the optimal variant of route networks is determined by analyzing the redundant population. It is worth noting the following advantages of this method: reduction of time costs and labor intensity of the process of optimizing route networks due to the formation of an excessive set of routes; taking into account such a factor as a limited number of rolling stock of urban passenger transport and taking it into account when optimizing route networks; the content in the optimality criterion of such an important indicator of the efficiency [8-10].

However, along with the significant advantages of the proposed method, it has several disadvantages. So, for example, the association of microdistricts at the first stage of design according to the criterion of the average intensity of passenger traffic between them is not completely taken into account [11-14].

As a result, routes with a large coefficient of non-linearity may be obtained. To solve this problem, we represent the task of optimizing route networks as a four-criteria problem of synthesizing a multi-commodity network. The following indicators are defined as criteria:

1st criterion - the total time of movement of passengers;

2nd criterion - the number of rolling stock on the most loaded haul;

3rd criterion - the cost of travel;

The 4th criterion is the cost of creating and operating route networks [15-17].

An algorithm for solving the problem using the proposed method was proposed. A program was created based on the algorithm. This program can be used by vehicle owners. Start the program and enter the address. The software will suggest the most optimal route for the real situation. The software may not provide users with the shortest path because there may be traffic on the shortest route. Taking this into account, the software will suggest another alternative route that is close to the shortest route. The software can be used by all drivers [18-20].

2 Methods

The transport problem represents a special class of linear programming problems. Mathematically, the fuzzy transport problem can be formulated as follows [21-22]:

MinimizeEquation Chapter (Next) Section 1

$$z = \sum_{i=1}^{m} \sum_{j=1}^{n} \tilde{c}_{ij} x_{ij}. \qquad (1)$$

Subject to restrictions

$$\sum_{j=1}^{n} x_{ij} = \tilde{a}_i,\ j = 1,2,...,n, \tag{2}$$

$$\sum_{i=1}^{m} x_{ij} = \tilde{b}_j,\ j = 1,2,...,m, \tag{3}$$

$$x_{ij} \geq 0, \qquad i = 1,2,...,m, \qquad j = 1,2,...,n, \tag{4}$$

where m : is total number of sources.

n : is total number of destinations.

$\tilde{a}_i$: is fuzzy offer of public transport.

b_j : is fuzzy demand for public transport at destination j.

c_{ij} : is fuzzy transportation costs per transportation unit from the i-th source to the j-th destination.

x_{ij} : is fuzzy quantity transported from the i-th source to the j-th destination (or fuzzy decision variables) to minimize the overall fuzzy transportation.

Fuzzy transport problem-solving algorithm:

Step 1. Fuzzy transport problem compilation and placement of data in the form of a matrix, i.e., an indefinite cost matrix.

Step 2. Getting an initial basic possible solution (IBFS). Three different methods are proposed for this, which are as follows:

- Fuzzy transportation issue northwest corner method.
- Lowest cost method.
- Fuzzy method.

The algorithms of these methods for the fuzzy transport problem, where all cost coefficients are fuzzy numbers and all demand and supply are exact numbers, are as follows:

Fuzzy transportation issue northwest corner method.

1. Start with the cell in the northwest corner of the transport matrix and, if possible, distribute the first row and the first column, i.e., equal to the minimum supply and demand value.
2. The accepted row or column is cut off and ignored for further consideration.
3. Repeat the procedure until all offers from different sources and demand in different directions are satisfied.

The least cost method.

The goal of the Fuzzy transport issue is to minimize fuzzy transportation costs. To achieve this, as far as possible, the transport unit is transported through the cells (fuzzy transport cost matrix) with the lowest cost of fuzzy transportation. The steps for the minimum cost method are as follows:

In the whole indefinite transport table (matrix), select the cell with the lowest unit value (i.e., select the cell with the minimum level of fuzzy value $\tilde{c}$) and, if possible, separate this cell and remove the row or column (draw)). at each step where demand or supply is exhausted. If both rows and columns are done simultaneously, only one is drawn.

If the smallest fuzzy unit price is not single (i.e., if several fuzzy unit prices are the same), select the cell that can be separated the maximum.

Repeat the procedure with the lowest fuzzy unit price between the remaining rows and columns of the fuzzy transport schedule until all deliveries from different sources and demand in different directions are met.

Vogel's fuzzy method.

Vogel's fuzzy method is a heuristic method in which each separation is made on the basis of penalty costs if the separations are skipped to specific cells with a minimum transport unit. In this method, deductions are made to minimize the cost of the fine. The steps in Vogel's tentative style are as follows:

Calculate the penalties for each row (column) on the same row (column), considering the difference between the smallest and subsequent smallest fuzzy unit transportation costs. This difference indicates the cost of the fine to be paid if the camera with the lowest fuzzy transport cost is not allocated.

Select the row or column with the largest penalty (i.e., the row or column with the highest penalty cost) and, if possible, place the cell with the lowest fuzzy cost on the selected row or column. If the penalty values are equal, it can be broken by selecting the maximum separable cell.

Crossing a satisfactory row or column, correcting supply and demand. If the row and column are satisfied at the same time, only one of them is truncated, and the remaining zero claim or claim row (column) should not be used in calculating future penalties.

Repeat steps 1-3 until all offers available in different sources and demand in different directions are met.

Step 3. The initial solution obtained by each of the three methods must meet the following conditions:

The solution must be purposeful; it must meet all the constraints of supply and demand.

The number of positive separations should be m + n - 1, where m is the number of rows and n is the number of columns.

Step 4. The primary key is testing to optimize a possible solution.

Finding the optimal solution.

3 Results and Discussion

To solve the routing problem, a software package was created.

The software package consists of three main modules:

• Network manager;
• Route search module;
• Communication network visualization module.

The program input is a network - a graph (N, E), a set of parameters for each arc from E, a service for which the route is being built.

It also indicates which connection parameters (arcs from E) are criteria and which are constraints. For the selected n criteria, you need to specify n-1 quantitative or interval estimates of importance.

Both in the quantitative assessments of the importance of criteria and interval assessments of the importance of criteria, the values of all criteria must be reduced to the same scale. For this, the normalization procedure described in the work above is applied. An example of a network that is loaded into the system is shown in Figure 1.

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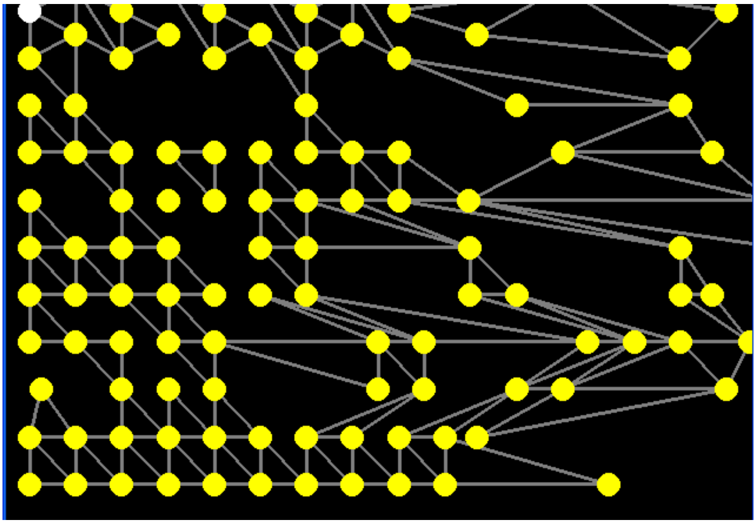
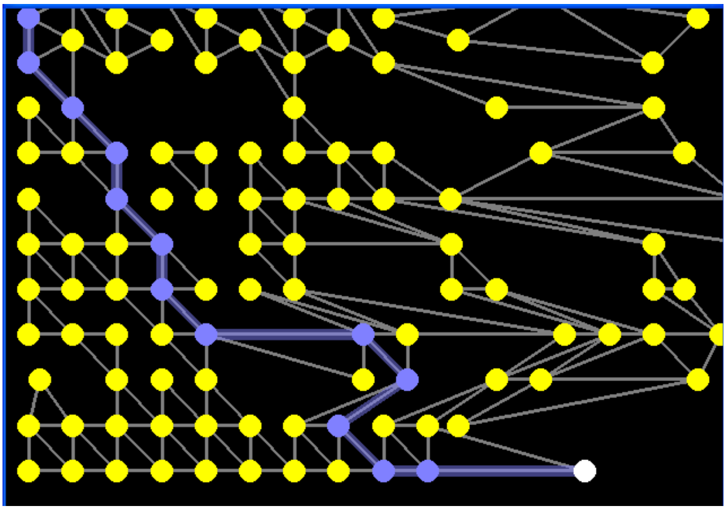


Fig 1. Communication network model

Each connection is characterized by the following parameters:
•Price;
• Workload;
• Error rate;
• Available bandwidth;
• Delay factor.

The cost parameters load are the criteria by which optimization takes place, and the parameters available bandwidth and delay coefficient are the restrictions by which the initial filtering takes place from the initial set of possible paths. The error rate parameter is both a constraint and a criterion. The cost, utilization, error rate, available bandwidth, and delay ratio parameters are calculated using the following formulas respectively. Figure 2 shows the solution to the routing problem.



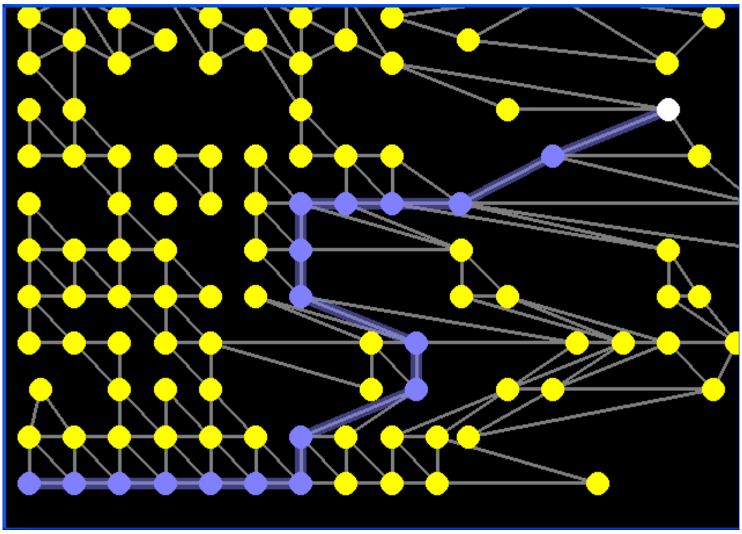


Fig 2. Solution of the routing problem

The proposed approaches not only solve the problem more accurately but also make it possible to take into account, in addition to the technical characteristics of the route, its cost, reliability, and other parameters [23-27].

The creation of software tools for regulating vehicles in cities allows for regulating the flow of urban traffic and greatly helps save drivers' destination and travel time. At present, the solution to the above problem is being partially implemented with the help of programs working through global navigation systems. However, they have not been adapted to serve all cities, or enough information environments have not been developed for the systems to work [28-30].

It is known that the route chosen by the drivers when going from one place to another remains homogeneous when the traffic of vehicles is observed in cities. All drivers like to drive on highways. As a result, traffic jams occur on highways, resulting in lost time for drivers and passengers and increased vehicle costs. However, in the real situation, the possibility of the total crossing of the roads will be very large. To solve this problem, the following services were offered in the program:

- can send requests to find the most optimal routes and get the most optimal route;
- they can monitor the movement of transport vehicles in the city, and get information about collisions and traffic jams.

The L-optimal path finding module finds the most optimal routes from one place to another. A graph database is used and checked against dynamic parameters when choosing a route. The routes that can be traveled with the least time are offered first. The rest of the roads are also offered. In this case, the user can use any of the found paths.

4. Conclusions

The currently known methods for optimizing urban passenger transport route networks are studied and analyzed in chronological order. The proposed approaches not only solve the problem more accurately but also make it possible to take into account, in addition to the technical characteristics of the route, its cost, reliability, and other parameters.

As a result, there was an opportunity to provide user-friendly interactive services to regulate vehicle traffic and reduce city congestion.

Application of the software tool to solve the problem of route selection in telecommunication networks, finding optimal routes in the network, and enabling decision-making in the stable operation of the network is based on its cost-effectiveness.

The creation of a software tool for the problem of choosing routes based on graphs in the regulation of vehicle traffic allows users to determine optimal routes, visually view data, search for information about important objects, obtain information about traffic jams, and help traffic safety authorities make decisions.

Information on the application of the software developed for regulating the movement of vehicles in cities, monitoring of vehicles based on geolocation data, management of public transport vehicles, perfect regulation of the traffic flow of vehicles, and the use of public transport routes is given.

The mentioned software tool facilitates the work of the dispatchers of the regional department of the transport agency. It allows the public to monitor public transport. It controls the departure of public transport drivers from the schedule and ensures their orderly movement in the city according to the designated route. This service benefits both parties and improves the quality of service provided to the population.

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