Decision Support System for calculating the Optimal Provision of Residents of Small Towns with Drinking Water in Extreme Cases

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Abstract — This work is devoted to the disclosure of the problem of transporting water to settlements during environmental catastrophes, military operations or unscheduled replacement of the pipeline. The urgency of the work is justified by the frequent lack of water supply to settlements on the demarcation line. A feature of the work is the connection of mathematical formulas that are not used in analog applications. The program was made with the aim of helping people around the world who find themselves in difficult conditions or habitats. The further goal of this program is to promote it to the mass market and its main advantage will be accessibility to everyone and the absence of paid content.

Keywords — lack of water, "traveling salesman" problem, distances, formulas, design, map, logistics, path, speed, distance.

I. INTRODUCTION

The supply of the housing stock with drinking-quality tap water is a strategic task of the state to ensure the life and sanitary and hygienic safety of the population. When selling water supply and sewerage products to the population, it is important not only to solve the problems of profitability of water supply and sewerage enterprises, but also to meet social needs [1-2].

The water supply system available in most cities can be disrupted as a result of man-made disasters or other extreme events, and the task of delivering water to the consumer is carried out using specialized vehicles [3]. In the districts (microdistricts, individual quarters, workers' settlements) of the city, there are temporary points for bottling drinking water from tank trucks into consumer containers [4].

Sources of water for the population are such:

1) water is collected before the overlap or is contained in large supplies on the balconies / under the table, in case water is interrupted;

2) people go to the store and buy drinking water to use as tap water;

3) in winter, people can drain the water from the batteries, which almost leads to an emergency, because there is nothing to heat;

4) in the city, in the landing, 6 kilometers from the microdistrict, there is a source, but it is already drying up, there are two taps, mainly those who are in the rural couple of the city take water, 25% -50% of the private sector.

The purpose of the work is to calculate the optimal provision of residents of small towns with drinking water in extreme cases using specialized software of our own design.

To achieve this goal, it is necessary to solve the following tasks:

– to consider the existing procedure for providing the population of small towns with drinking water in the event of industrial accidents;

– to study methods and models to determine the optimal route;

– to review existing applications to determine the best route;

– to design an application for calculating the optimal provision of residents of small towns with drinking water in extreme cases;

– to implement software implementation in a visual programming environment.

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II. Literature Analysis

Route4Me Route Planner (Fig. 1), unlike conventional maps and navigation systems, gives you the best route when you need to go to multiple locations [5].
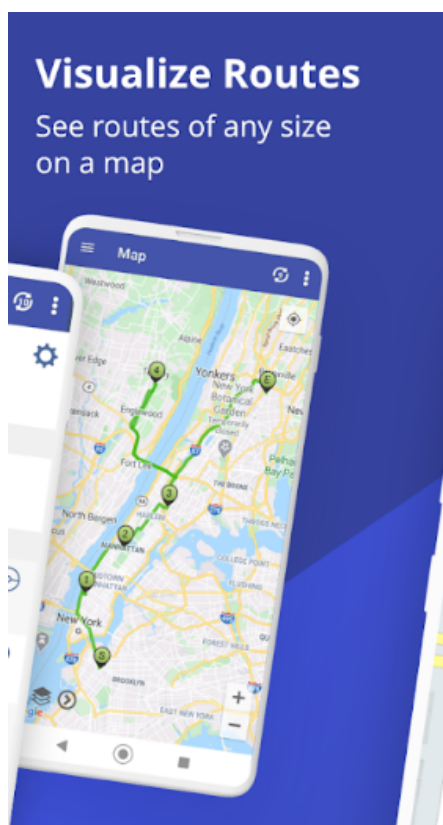

Fig. 1 Route4Me Route Planner

Difference from the task: the lack of accuracy of the set route, also the lack of an interpreter, a purely English interface.

ABM Rinkai TMS [6] is a program for automating the transport logistics of an enterprise (Fig. 2). One solution combines: route planning, execution control, customer information, analysis and assessment of the efficiency of using transport resources, including hired cars. Cloud service, provided for rent, does not require installation on the company's servers.
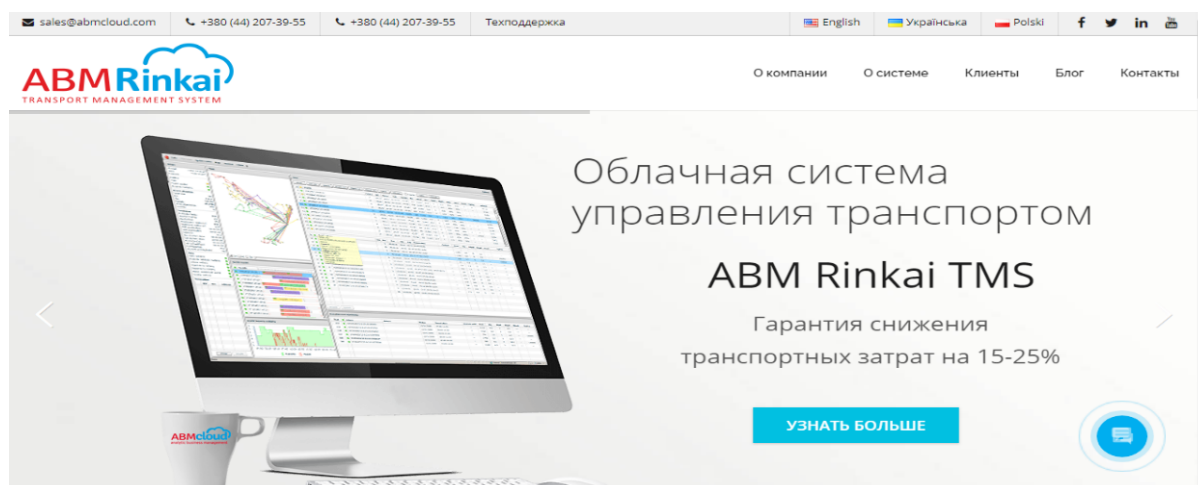

Fig. 2. ABM Rinkai TMS

Difference from our task: access only through the site, long registration and paid content. Only one week trial mode. App obsession - hangs in the background.

"Ant Logistics" [7] is a cloud-based transport management system: automatic route planning, assessment of the profitability of delivery points, GPS control of traffic routes, analytical reporting (Fig. 3).
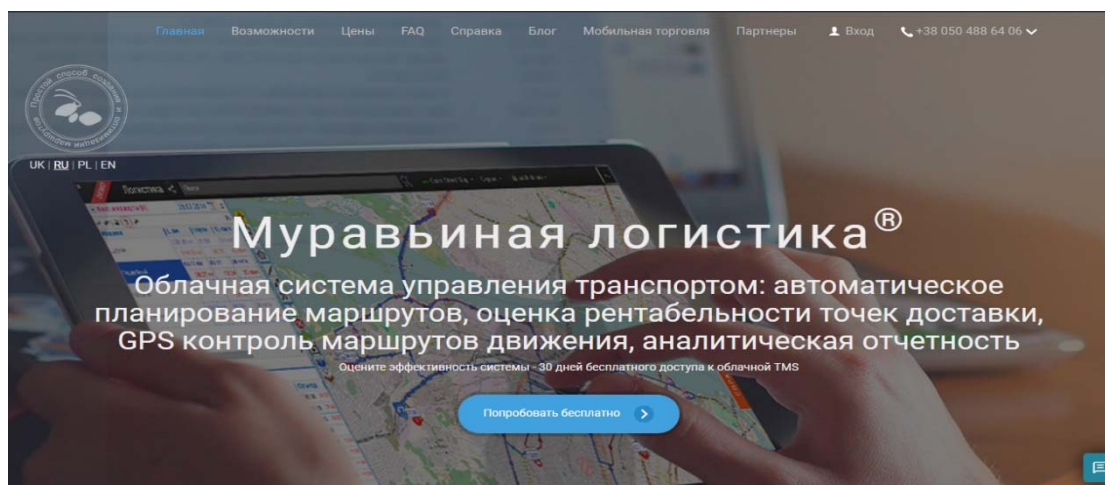

Fig. 3. "Ant Logistics"

Difference from our task: inaccuracy of the method and ways of building the route. Very long registration and filling in information before starting to use the project. Also a paid basis.

Google Maps [8] is set applicationsbuilt on the basis of free cartographic service and technologiesprovided by the company Google (Fig. 4). Created in 2005.

Difference from our task: the impossibility of building a straight route, extra points appear when building. Lack, as in other sites / applications, the ability to track the optimal route and the time to complete it.
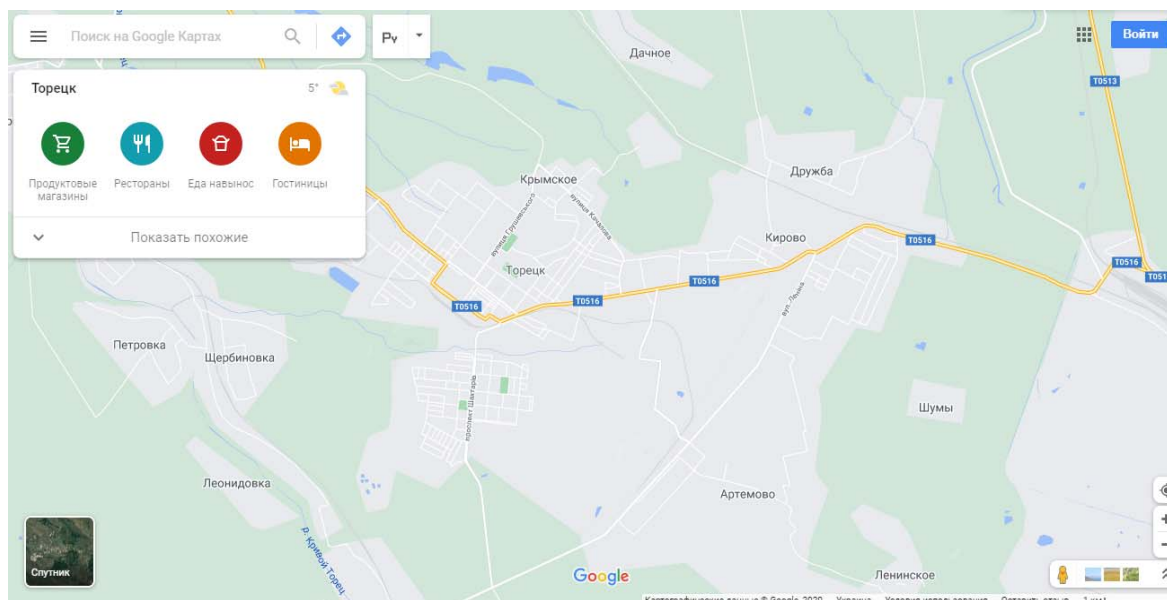

Fig. 4. Google Maps

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Consider the situation in the city of Toretsk. Since it is closest to the collision line, there are frequent signals from the local population about broken water or its absence for a very long time, so I can operate with facts and have access to accurate data that we will need in the course of our work. Link to google map, where the map of the settlement of Toretsk is located [9].
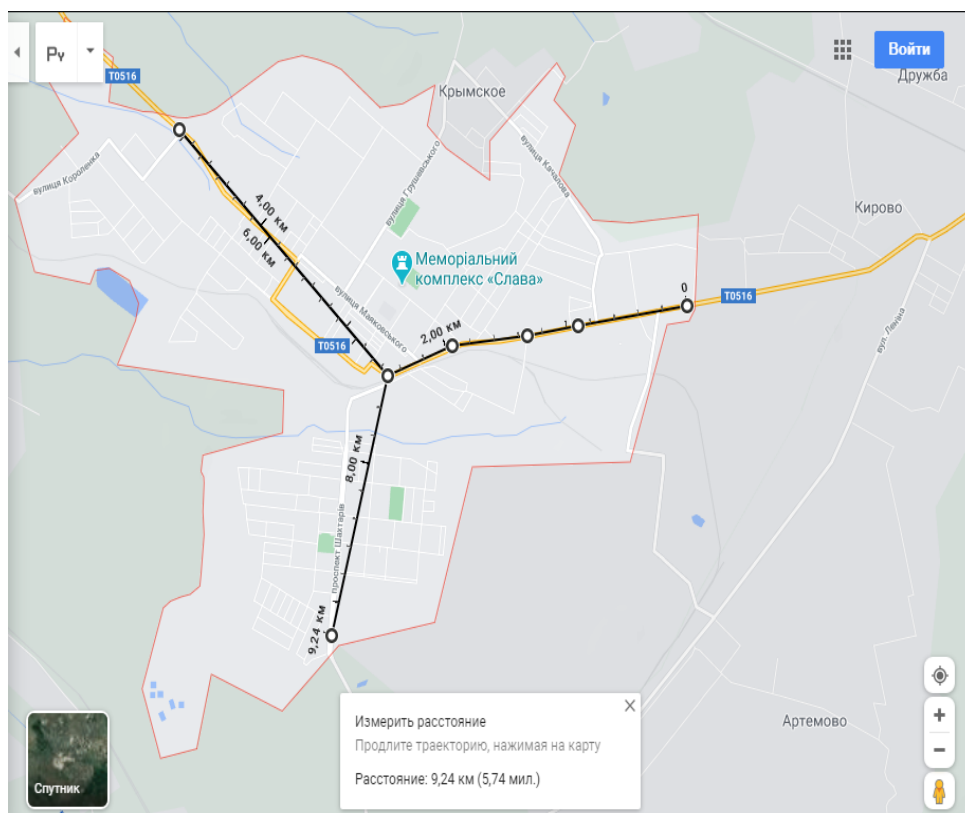

Fig. 5. Map of the city of Toretsk

Fig. 6. An illustrative example of water delivery

In different districts of the city there is a certain amount of population, so the supply is carried out from the starting point, which is taken by "Samanny" and, thus, water is delivered to the next three points to the intersection of the main road: here you will have to choose which point will be the last and which route will be more convenient for the driver himself. But, most likely, the last stop will be "Central Market", because from there the car goes to another settlement – Bakhmut. Where, in fact, it comes from.

The peculiarities of the route are that the entire path goes in straight lines, there is no shortcut or detour.

As for the disadvantages: there is only one car, and this increases the time spent on delivering water to the regions. Also, due to the large difference in the number of people at certain control points, the delivery of water to a certain point is difficult to calculate in the plan at which time it will be.

Benefits. Since the population of this city is accustomed to very frequent water cut-off due to hostilities or the old equipment, in the event of an announcement of a water cut-off, the population knows on what day (most often once a week) and at what time (range changes) the car can arrive ...

Let's check with the data that we have on the population in certain areas. As a calculation example, we take data for the city of Toretsk, Donetsk region, tab. 1, tab. 2.

Table 1. Number of inhabitants, people

No. nn	Microdistrict (name)	Population, people
1	Adobe	3325
2	Microdistrict	9392
3	Center	11495
4	Private sector	3870
5	Central market	3395
6	Zabalka	2901

Table 2. Distance between microdistricts, m

	Adobe	Microdistrict	Private sector	Center	Central market	Zabalka
Adobe	X	1310	900	1860	4800	4640
Microdistrict	1310	X	803	2420	4530	4175
Private sector	900	803	X	295	4050	3520
Center	1860	1390	295	X	1370	546
Central market	4800	4530	4050	1370	X	4920
Zabalka	4640	4175	3520	546	4920	X

It is necessary to solve a number of tasks, for example:
– to determine the optimal route for specialized vehicles;
– to draw up an optimal schedule for the movement of specialized vehicles;
– others.
  • We assume the following:
– there are N specialized vehicles (tank trucks), N ≥ 1;
– there is a list of M districts (micro-districts) of the city, indicating the population Si in each (total in the city $S_s = \sum_{i=1}^{M} S_i$ residents);
– there is a table of distances between areas, taking into account the possibility or prohibition of direct passage between each pair of areas;

– the beginning of the path can be from different places: a) all cars leave from one selected point; b) each car can start moving from the point chosen for it;
– it is possible to introduce a limitation on the volume of dispensed water (18 liters per person).

We also assume that all specialized vehicles (tank trucks) are the same (have identical speed characteristics and can carry the same volume of water).

It is necessary to solve the following tasks.

1. Assuming that only one car works, calculate its optimal route (the total length of the path should be minimal). Feature: the starting point of the path (the first of the microdistricts) is indicated by the user.
2. Continuing the previous task, draw up a schedule of movement along the calculated route (time of arrival in each microdistrict), if there is an average service time for one resident and what percentage of the population immediately goes out for water.
3. Calculate the recommended (optimal) number of cars N (1..N_{max}), based on the constraints: a) the minimum and maximum volumes of water per inhabitant; b) allocated fuel limits. Movements between microdistricts are not taken into account here, the total number of residents in the city is taken.
4. Assuming that N cars work, calculate the optimal travel route for each car so that: a) the total length of each path is minimal; b) the total population in the neighborhoods served by each vehicle was approximately the same. (That is, the difference between the microdistricts "covered" by the car and the average Ssm / N per car should tend to zero).
5. Continuing the previous task, draw up traffic schedules along the calculated routes (arrival time in each microdistrict), if there is an average service time for one resident.

The classical formulation of the problem of finding the optimal path is called the "traveling salesman problem" (6-8) and looks like this: there are N cities that the traveling salesman must go around with minimal costs; the traveling salesman must visit each of the cities exactly once, that is, he must go around all the cities, while not visiting any city twice; the necessary condition and the only content of the problem is to find the most profitable way.

We can formulate the mathematical formulation of our problem so:

$$F(X) = \sum_{i=1}^{M} \sum_{j=1}^{M} C_{ij} \quad X_{ij} \rightarrow \quad \min, \qquad (1)$$

where:

M is the number of microdistricts with tank stops for water consumers;

C_{ij}, i, j = 1..M is the "cost matrix", where C_{ij} is the "transition costs" from the i-th micro-district to the j-th, that is, the distance between these micro-districts;

X_{ij} is transition matrix with components:

$X_{ij} = 1$, if the tank makes a move from the i-th microdistrict to the j-th,
$X_{ij} = 0$, if the tank does not move,
where i, j = 1..M, i □ j.

We have restrictions:

$$\sum_{i=1}^{M} X_{ij} = 1 \, , j = 1..M, \qquad (2)$$

$$\sum_{j=1}^{M} X_{ij} = 1 \, , i = 1..M, \qquad (3)$$

$$U_i - U_j + M \cdot X_{ij} \leq M-1, \, i, j = 1..M, i \neq j. \qquad (4)$$

Condition (2) means that the tank leaves each area only once; condition (3) - enters each region only once; condition (4) ensures that the route containing microdistricts M is closed and does not have closed internal loops.

Since it is possible to drive along one-way streets, the distance between the i-th and j-th microdistricts, on the one hand, and the j-th and i-th, on the other hand, may be different:

$$C_{ik} \neq C_{ji} \tag{5}$$

Thus, we have an asymmetric problem statement. Since the number of microdistricts in the city of Toretsk is 6, to solve the problem, you can use the brute force method, which requires brute force at most (n-1)! options (5! = 120).

Next, we design the application and execute its software implementation in the visual programming environment.

IV. RESULTS

Figure 7 provides general information data that we need when making calculations.

Fig.7. General information
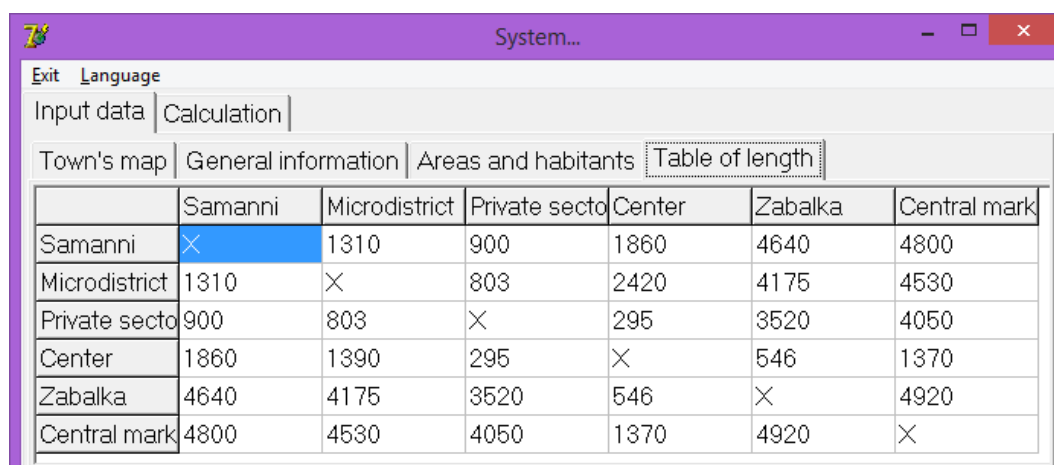
The entered data on the population in the districts, the amount of water in one hand, the total number of people, the total time of service to the population in minutes and hours is shown in Figure 8.

The data in Fig. 9 shows a list of distances between areas.

Fig. 8. Data on the number of population in the regions

Fig. 9. Distances between areas

Figure 10 shows a map of the city on which the program for calculating the shortest path is made.
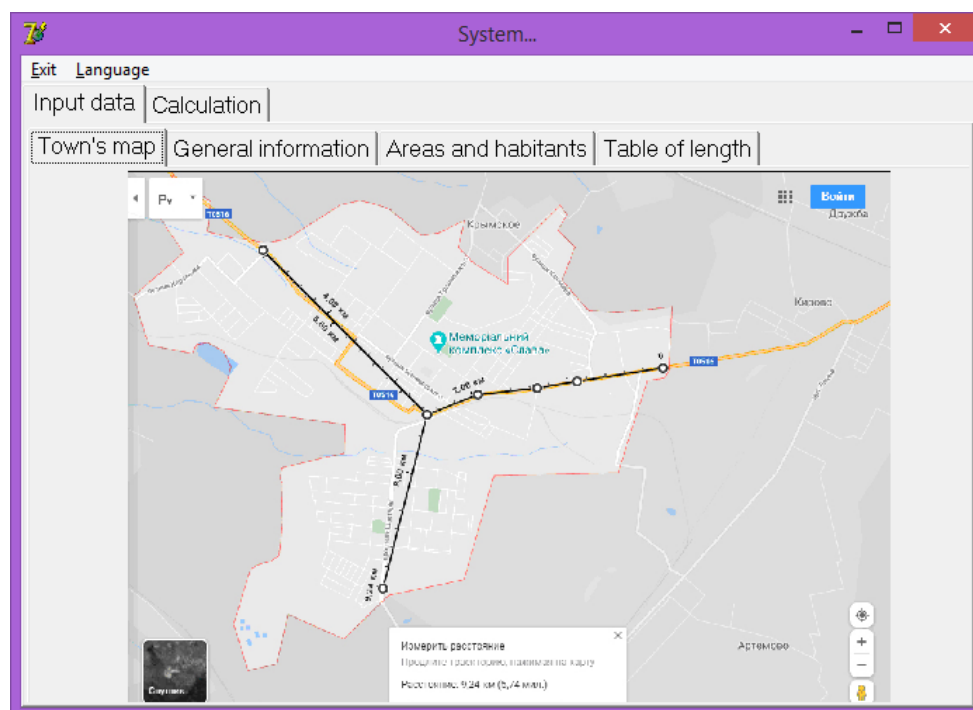

Fig. 10. Map of the studied city

Figure 11 shows the creation of a route from 9:00, taking into account the service time, but this is only taking into account one car.

Fig. 11. Working distance traveled by one machine

The process of tasking data on liters of water per one hand, amount of water and time in Figure 12.

Fig. 12. Setting data on the amount of water and machines

By enumerating, we found out that the maximum possible and required number of cars is six units (64 = 0), shown in Figure 13.
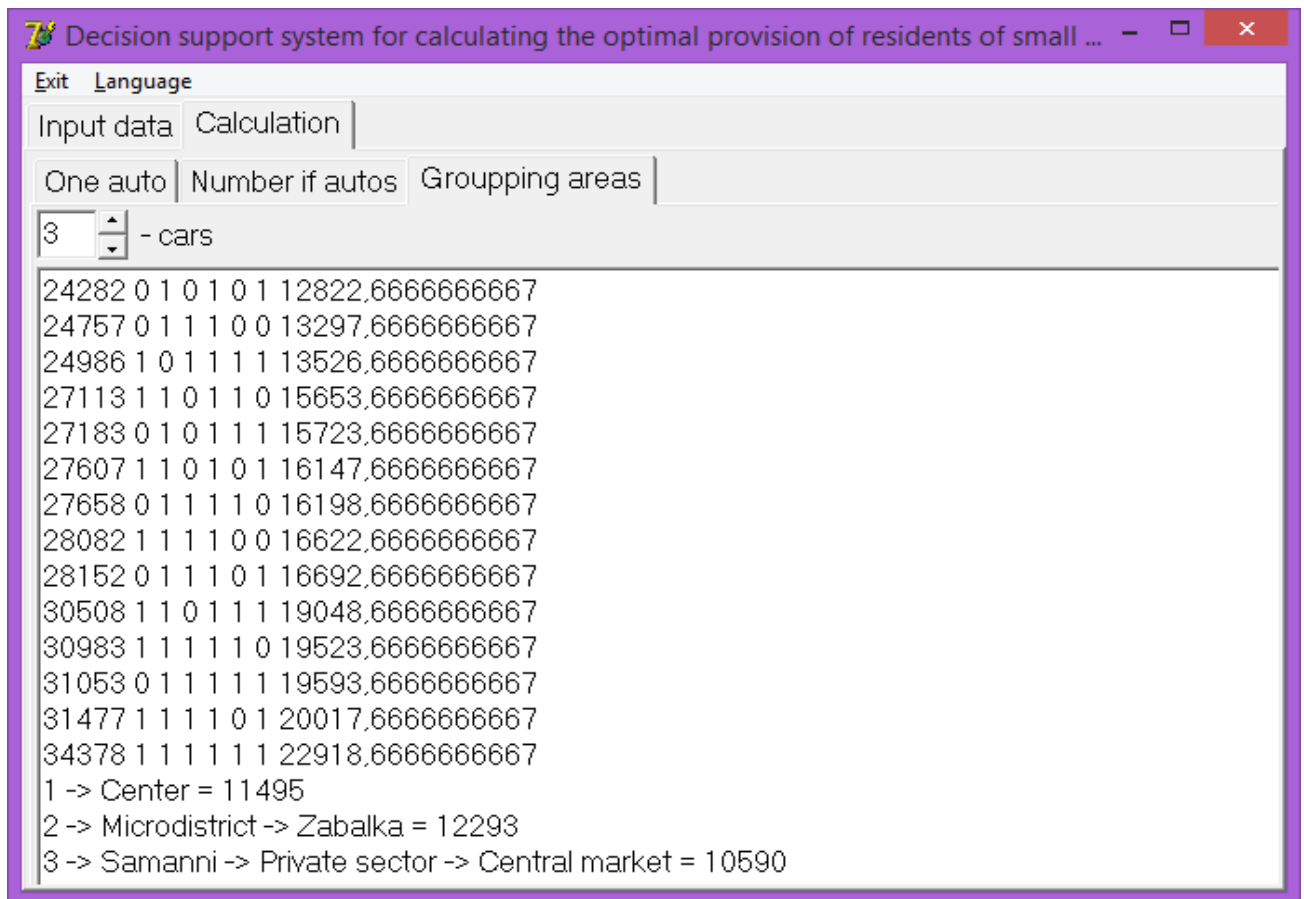
Fig. 13. Required maximum car availability

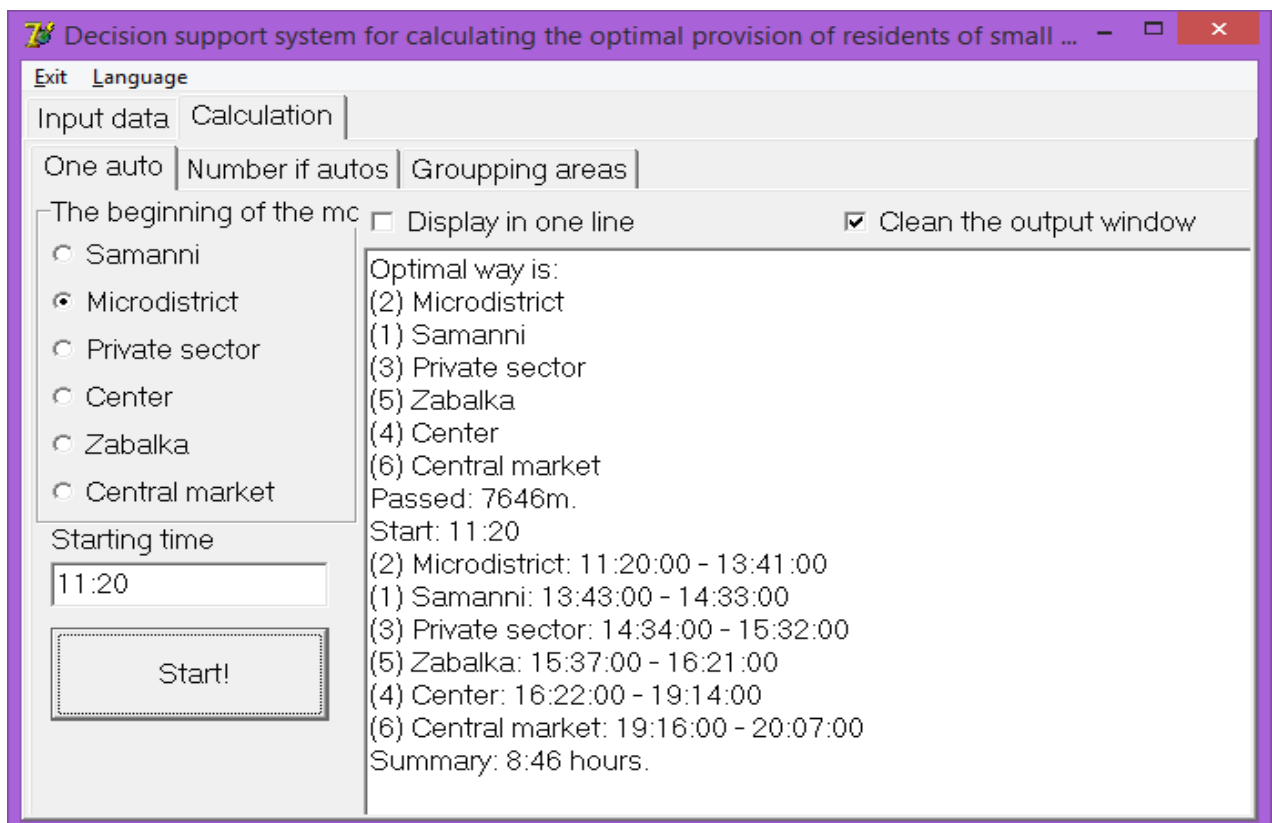Figure 14 shows the route directions, the program works as we needed it to.

Fig. 14. The process of finding the optimal route

V. Conclusions

This work is devoted to the creation of an application that will demonstrate the work of algorithms for concise construction of routes by enumerating them and calculating the distance. Also, everything will be recorded from the data that will be entered into the table. The purpose of the work is based on the desire to make life easier for people in the event of man-made disasters or as a result of the destruction / damage of the pipeline as a result of the Operation of the Joint Forces. Indeed, today any enterprise deals with streams of various information that need quick and efficient processing. Therefore, this program facilitates the work of an enterprise that supplies water to settlements. The amount of information depends mainly on the size of the enterprise and the number of districts and cities that will require assistance from the enterprise. Depends on how much will the reserves for an unforeseen event be filled, or how prepared people will be for this, having made their own reserves as in our example – 98-99% of the city of Toretsk is ready for this because of living in such conditions for almost seven years. In this case, the larger the enterprise, the greater the volume and level of complexity of the processed information.

To create such a system, it was required to know the algorithms for constructing a short route according to the "traveling salesman" problem and enumerating the most optimal from all the options, therefore this application should better help enterprises, private companies or city leaders with the development of water and help the cities of Donbass in emergency situations. And since our program is with extended functionality, it can be applied not only in the above region, but also in any place in our country or on the mainland with a less established infrastructure and work of water supplies.

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