

Ministry of Education and Science of Ukraine
Black Sea Universities Network

ODESA NATIONAL UNIVERSITY OF TECHNOLOGY

International Competition of
Student Scientific Works

BLACK SEA SCIENCE 2022 PROCEEDINGS



ODESA, ONUT 2022

Ministry of Education and Science of Ukraine

Black Sea Universities Network

Odesa National University of Technology

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2022

Proceedings

Odesa, ONUT 2022

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Black Sea Science 2022: Proceedings of the International Competition of Student Scientific Works / Odesa National University of Technology; B. Iegorov, M. Mardar (editors-in-chief) [*et al.*]. – Odesa: ONUT, 2022. – 749 p.

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INTRODUCTION

International Competition of Student Scientific Works “Black Sea Science” has been held annually since 2018 at the initiative of Odesa National University of Technology (formerly Odesa National Academy of Food Technologies) with the support of the Ministry of Education and Science of Ukraine. It has been supported by Black Sea Universities Network (the Association of 110 higher education institutions from 12 countries of the Black Sea Region) since 2019, and by Iseki-FOOD Association (European Integrating Food Science and Engineering Knowledge into the Food Chain Association) since 2020.

The goal of the competition is to expand international relations and attract students to research activities. It is held in the following fields:

- Food science and technologies
- Economics and administration
- Information technologies, automation and robotics
- Power engineering and energy efficiency
- Ecology and environmental protection

The jury includes both Ukrainian and foreign scientists. In the 4 years that the competition has been held, the jury included scientists from universities of 24 countries: Angola, Azerbaijan, Benin, Bulgaria, China, Czech Republic, France, Georgia, Germany, Greece, Israel, Italy, Kazakhstan, Latvia, Lithuania, Moldova, Pakistan, Poland, Romania, Serbia, Slovakia, Switzerland, Turkey, USA.

At the same time, every year the geography has expanded and the number of foreign jury members has increased: from 46 jury members representing 25 universities from 12 countries in 2018, to 73 jury members of the 46 universities from 19 countries in 2022.

More than a thousand student research papers have been submitted to the competition from both Ukrainian and foreign institutions from 25 countries: China, Poland, Mexico, USA, France, Greece, Germany, Canada, Costa Rica, Brazil, India, Pakistan, Israel, Macedonia, Lithuania, Latvia, Slovakia, Romania, Kyrgyzstan, Kazakhstan, Bulgaria, Moldova, Georgia, Turkey, Serbia.

The interest of foreign students in the competition grew every year. In 2018, the students representing 15 institutions from 7 countries have submitted 33 works. In 2021 the number of submitted works increased to 73, authored by the students of 40 institutions from 18 countries.

The competition is held in two stages. In the first stage, student research papers are reviewed by members of the jury who are experts in the relevant fields. In the second stage of the competition, the winners of the first stage have the opportunity to present their work to a wide audience in person or online.

All participants of the competition and their scientific supervisors are awarded appropriate certificates, and the scientific works of the winners are included in the electronic proceedings of the competition. Every year the competition receives a large number of positive responses from Ukrainian and foreign colleagues with the desire to participate in the coming years.

3. INFORMATION TECHNOLOGIES, AUTOMATION AND ROBOTICS

DECISION SUPPORT SYSTEM FOR SUPPLYING LOGISTICS WHEN SUPPLYING RESIDENTS OF SMALL CITIES WITH DRINKING WATER IN EXTREME CASES

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Abstract. *This work is devoted to solving the problem of water delivery to residents of small settlements with a temporary disruption of their traditional water supply. The existing software tools are considered, their shortcomings are analyzed. The task of developing specialized software is formulated – a decision support system that allows you to calculate the optimal number of tanks, pave the way for each tank, and also determine the places of their best location in each district to maximize the satisfaction of all its inhabitants. Models and methods of the traveling salesman problem, finding the center of a cluster taking into account the weights of objects, connecting google maps to an autonomous application are described. An example of using the developed system for calculating the route and position of tanks providing the city of Toretsk in Donetsk region is given. The ways of further improvement of the model and application are outlined.*

Keywords: *water delivery, traveling salesman problem, optimal route, cluster center, google maps.*

I. INTRODUCTION

The task of providing water to settlements that have suffered as a result of environmental disasters or military operations is currently extremely urgent. Provision of drinking tap water is a strategic task of the state to ensure the life and sanitary and hygienic safety of the population [1-2].

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

The purpose of the work is to find the optimal travel routes and locations for vehicles that carry a certain amount of water for injured or deprived people of resources, using specialized software of our own design.

The object of the research is the delivery of water to the consumer using specialized road transport. The subject of the research is models, methods and information technologies for solving the problem.

II. LITERATURE ANALYSIS

Currently, there is a number of software solutions that allow you to calculate the optimal route for transport.

The Route4Me Route Planner [5], equipped with an English interface, allows you to calculate the best route when you need to go to several places. However, the calculated route is not always accurate.

ABM Rinkai TMS [6] is a program for automating the transport logistics of an enterprise. One solution combines route planning, execution control, customer information, analysis and assessment of the efficiency of using transport resources, including rented cars. The cloud service provided for rent does not require installation on the company's servers. Features are in access exclusively through the site (online), as well as the availability of paid content.

"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. The system cannot ensure the accuracy of the route construction, has a rather long registration period and does not have a demo version.

Google Maps [8] is a collection of applications built on top of a free mapping service and technology provided by Google. Solves the main problem such as finding the optimal route from one point to another. It can be used as an aid when developing your own application.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

We will consider the problem of providing water to the inhabitants of the city of Toretsk [9]. The settlement is located the closest to the demarcation line, accidents on the water supply network are frequent, their elimination is associated with a number of problems, and the city must be provided with water for several days using specialized vehicles.

The city is conditionally divided into six micro-districts, each of which is a home to a certain number of residents (Table 1).

Table 1. Number of inhabitants, people

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

Water is supplied from the starting point (as a rule, this is the Samanny area), and the car must then go around all the districts of the city (Table 2). The entire journey follows straight lines, there is no shortcut or detour. As a rule, there is only one tank, which increases the time of delivery of water to certain areas. Also, due to the difference in the number of people in different areas, it is difficult to calculate the time of arrival of the car in each of them.

Table 2. Distance between microdistricts, m

	Samanny	Microdistrict	Private sector	Center	Central market	Zabalka
Samanny	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

There are two main tasks to solve:

- to determine the optimal route for the movement of specialized equipment and draw up its schedule;

- to determine the optimal placement of tanks in each area.

We assume the following:

- there are N specialized vehicles (tank trucks), $N \geq 1$;
- there is a list of M districts (micro-districts) of the city, indicating the size of the population S_i in each (total for the city of 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;
- there may be restrictions on the volume of dispensed water per person.

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

It is necessary to solve the following tasks.

1. Assuming that only one machine is operating, calculate its optimal route (the total path length should be minimal). The starting point of the path (the first of the neighborhoods) is specified by the user.

2. Having the optimal path, draw up a schedule of movement along the calculated route (time of arrival in each microdistrict), taking into account the average service time of one resident and the percentage of the population leaving for water.

3. Calculate the recommended (optimal) number of cars N ($1..N_{max}$), based on the restrictions: a) the minimum and maximum volumes of water per inhabitant; b) allocated fuel limits. Movements between microdistricts can be ignored here.

4. Assuming that N cars are working, calculate the optimal route of movement of each of them 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. Also draw up traffic schedules along the calculated routes (arrival time in each microdistrict).

5. Determine in each district such a location for the cistern so that it is equidistant from all nearby houses and as convenient as possible for residents.

The first point is solved by using the classical problem of finding the optimal path - the “traveling salesman problem” [10-11], which looks like this: there are N

cities that the traveling salesman must go around with minimal costs; a traveling salesman must visit each of the cities exactly once. In our case, the task will look like this:

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

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 $i, j = 1..M, i \neq j$.

We have restrictions:

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

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

Condition (2) means that the tank leaves each area only once; condition (3) – enters each region only once; condition (4) guarantees that a route containing microdistricts M is closed and has no closed internal loops.

Since movement along one-way streets is possible, 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:

$$C_{ik} \neq C_{ji} \quad (5)$$

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 exhaustive search method, which requires no more than $(n-1)!$ options ($5! = 120$).

The solution of tasks 2 – 4 follows from the solution of the first task - the determination of the optimal path. To find the optimal number of transport units, it is necessary to repeat the calculation of the best routes for different values of the number N, and then choose the most suitable one. The timetable is compiled automatically after entering the time to enter the route.

The last point of the assignment can be mathematically described as follows. Each of N districts has M_i houses ($i = 1..N$), each house D_j ($j = 1..M_i$) has conditional coordinates D_{jx} and D_{jy} . It is necessary to define such C_{ix} and C_{iy} so that the average distance from the house to the collection center (machine location) was minimal:

$$F_i(C_{ix}, C_{iy}) = \frac{\sum_{j=1}^{M_i} \sqrt{(D_{jx} - C_{ix})^2 + (D_{jy} - C_{iy})^2}}{M_i} \rightarrow \min, i = 1..N \quad (6)$$

We will find the centers of the aggregates of houses in this way. First, we find the preliminary coordinates:

$$C_{ix} = \frac{\sum_{j=1}^{M_i} D_{jx}}{M_i}, C_{iy} = \frac{\sum_{j=1}^{M_i} D_{jy}}{M_i} \quad i = 1..N \quad (7)$$

Then we refine these coordinates by the coordinate descent method [12]. We also use the following assumptions: we consider the coordinates of a house to be its “geometric center” (the number of houses of a “special shape” is small, and we do not take them into account); since in each district there are houses of approximately the same number of storeys, the number of inhabitants in each house is calculated in proportion to the area of this house.

We will calculate the centers of aggregates of houses in three ways:

- "usual" geometric center of the cluster;
- taking into account the number of houses (see the previous paragraph);
- taking into account the number of inhabitants.

The last step is to connect to the Google Maps service application and demonstrate all calculations on the maps.

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

IV. RESULTS

The structure of the designed system in the form of a class diagram [13] is shown in Fig. 1.

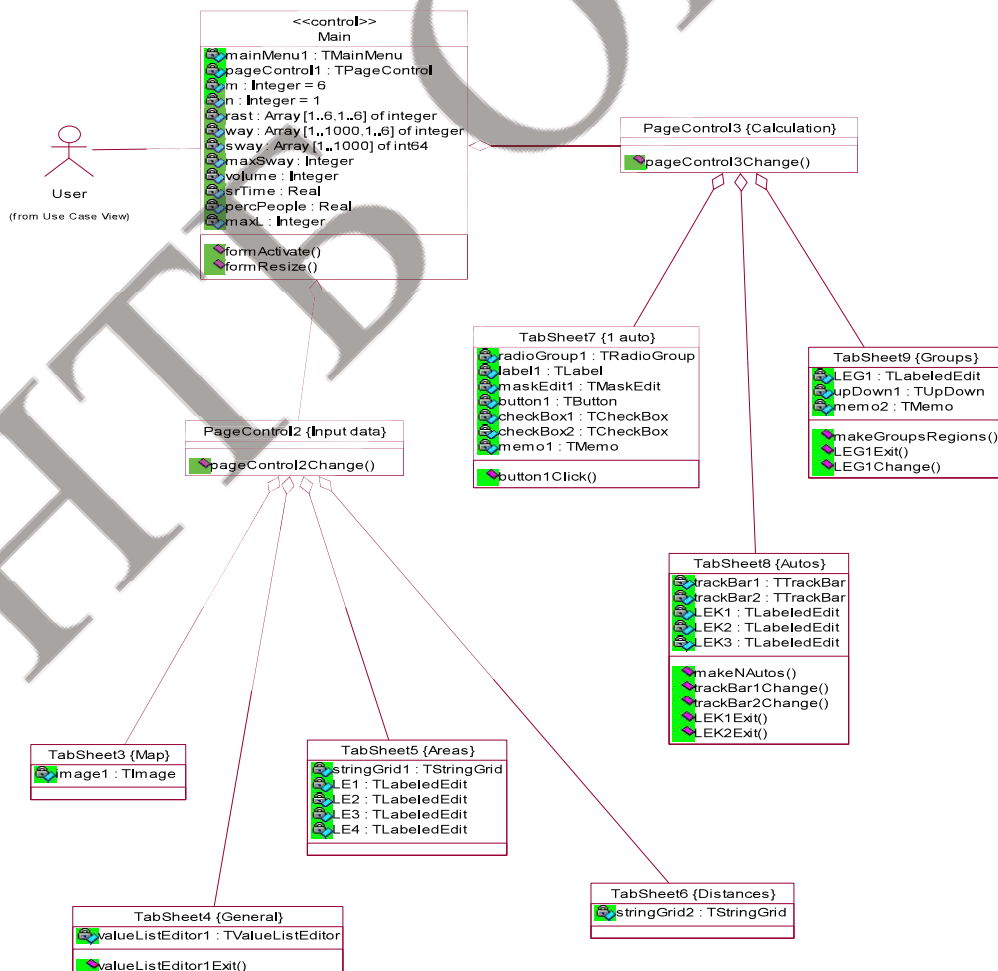


Fig.1. Class diagram

The main tabs of the application form are shown in the following figures. Fig. 3 provides general information that we need for calculations. The entered data on the population in the districts, restrictions on the volume of supplied water, the total number of residents, the time of service to the population in minutes and hours are shown in Fig. 3. Data in Fig. 4 show a list of distances between districts. Fig. 5 shows a map of the city in question.

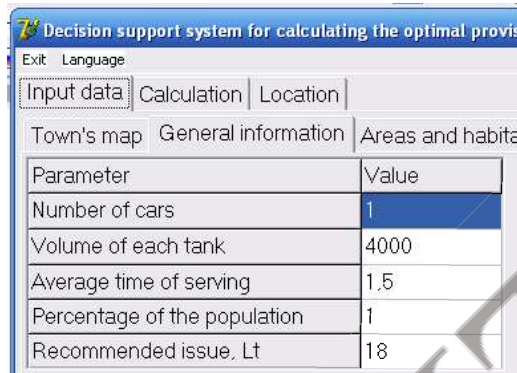


Fig.2. General Information

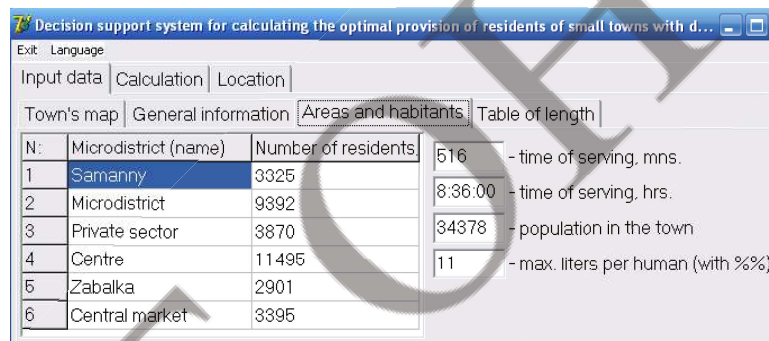


Fig. 3. Data on the number of population in the regions

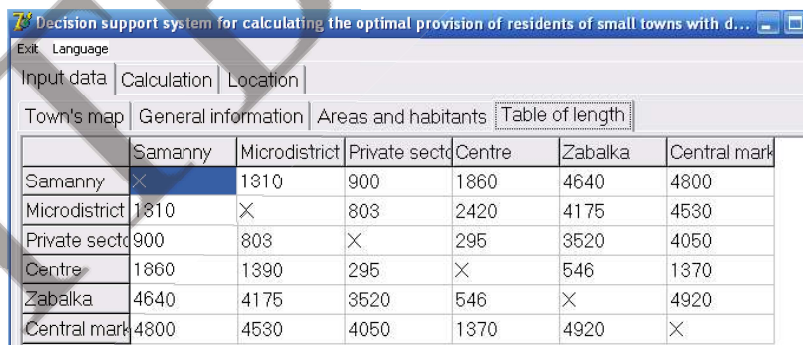


Fig. 4. Distances between areas

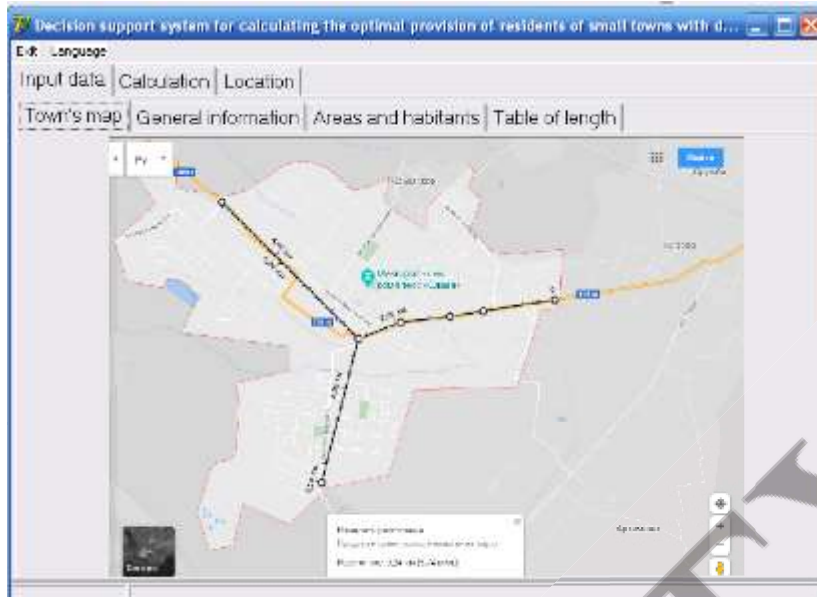


Fig. 5. Map of the studied city

In Fig. 6 shows the construction of the route from 9:00, taking into account the time of service by one car.

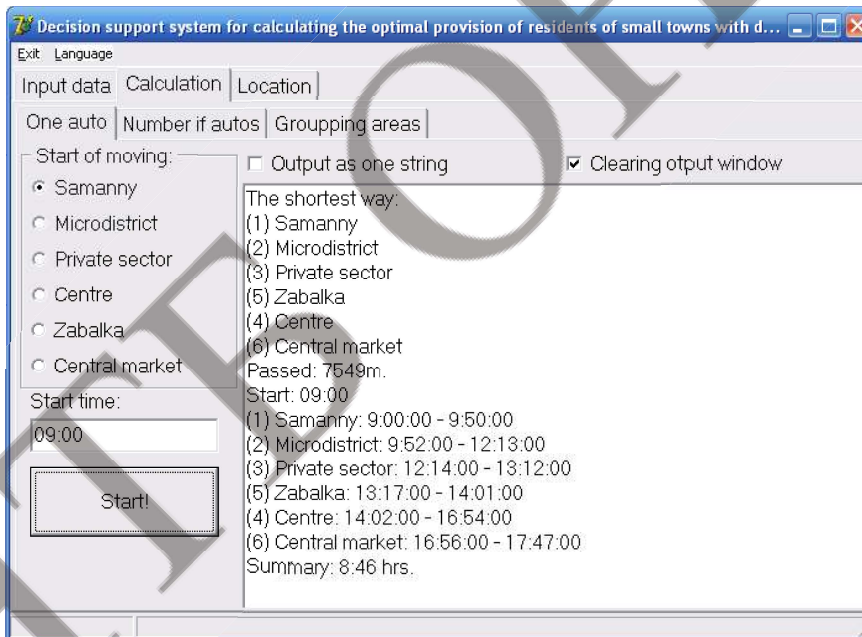


Fig. 6. Working distance traveled by one machine

Using the enumeration method, we found that the maximum possible and required number of cars is three units, as shown in Fig. 7. At the end of each line, the number of residents served by the specified car is indicated.

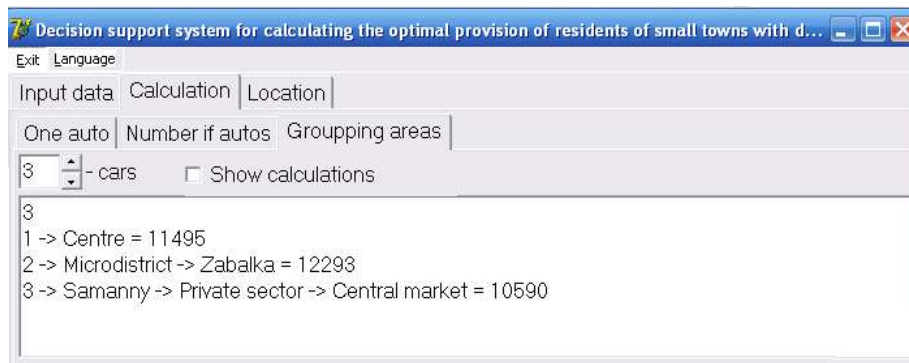


Fig. 7. Required maximum car availability

The problems considered were described in [14-16], the implementation is presented in [17].

But now let's look at the "Location" tab, where maps of the districts are loaded in the form of graphic files-schemes with the indication of houses (the maps were previously saved from the Google service). The system administrator marks residential buildings on the diagram, then the algorithm determines the center of the "cluster", and the administrator "corrects" it on the map so that it "hits" the road.

In the lower right corner, the coordinates of the "center" and the average total "deviation" (ie the average path to the tank) are shown.

The blue "point" is the geometric center of the district, the red point is the center, taking into account the location of houses and residents (you can mark "taking into account residents"). In fig. 8 - 9 show examples of calculation for the Zabalka region.

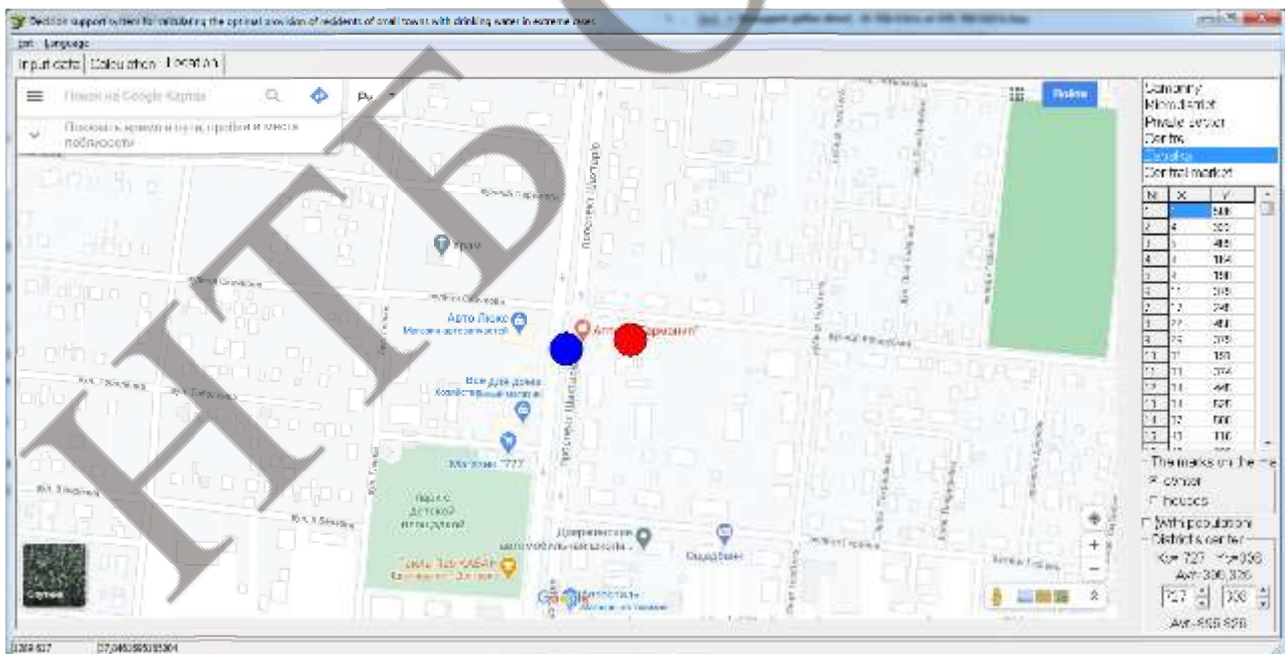


Fig. 8. Calculation of the centers of the Zabalka district, taking into account houses

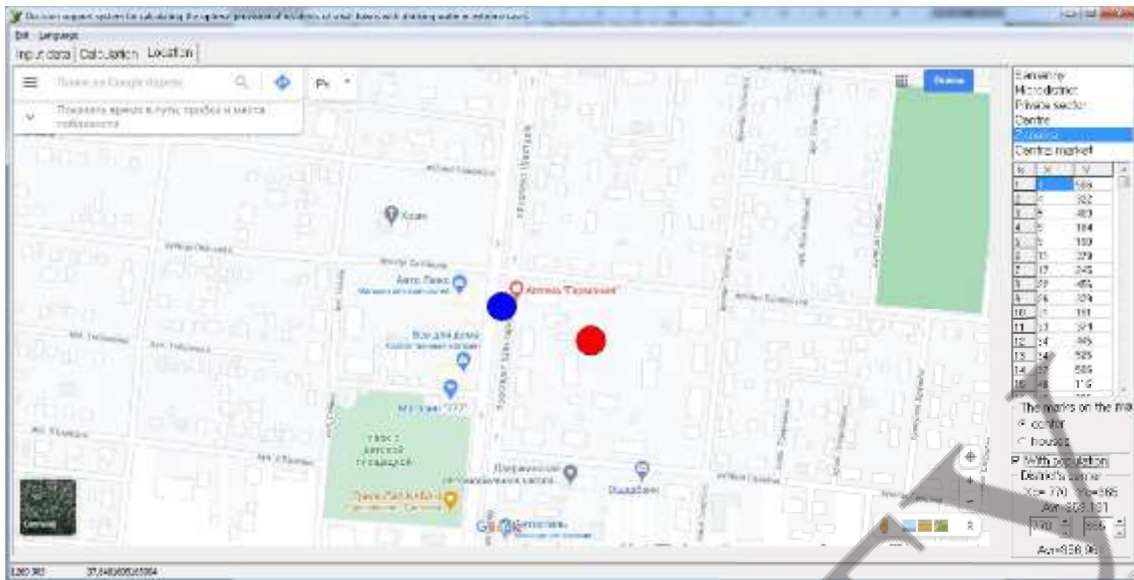


Fig. 9. Calculation of the centers of the Zabalka district, taking into account residents

As you can see, the geometrical center of the district, the center, taking into account the location of the houses, and the center, taking into account the inhabitants, are different.

The next stage of work was to determine the exact coordinates of the location of the tank on the ground. Files are created that contain GPS coordinates (Fig. 10).

	Забалка.loc
1	48.382514, 37.838940
2	48.379248, 37.851017

Fig. 10. Coordinates of the Zabalka region

When switching to the "Input data" / "City map" item, the system checks the availability of Internet access, and if there is such, it loads a Google map with an automatic display of the district center (Fig. 11).

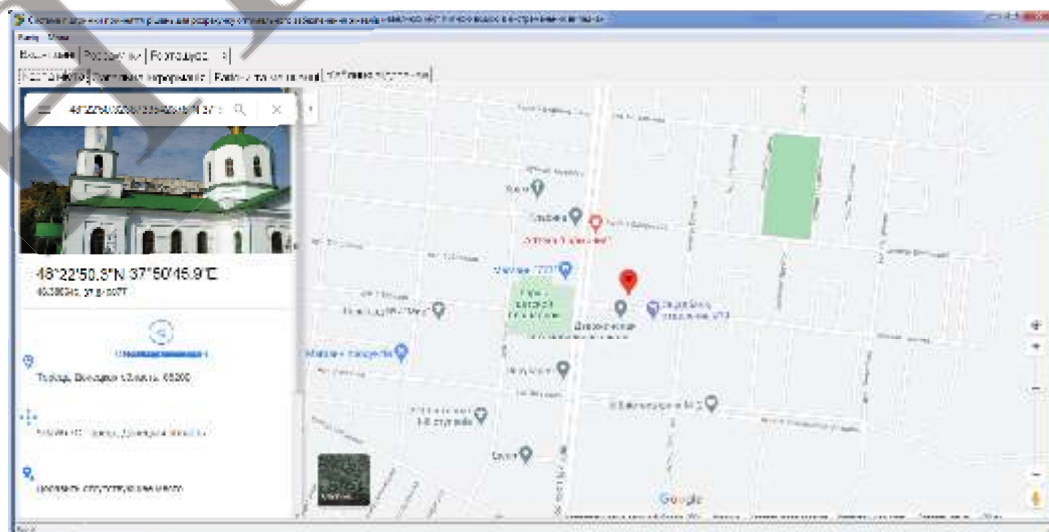


Fig. 11. Google-map of the Zabalka area

Next, we repeat the calculations for other areas of the city (Fig. 12 - 17).

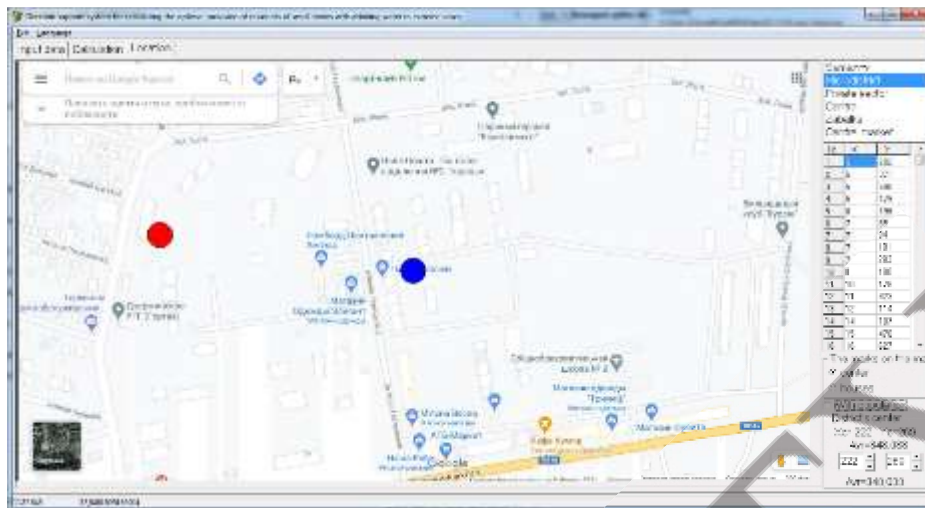


Fig. 12. Calculation of the centers of the district Microdistrict, taking into account houses

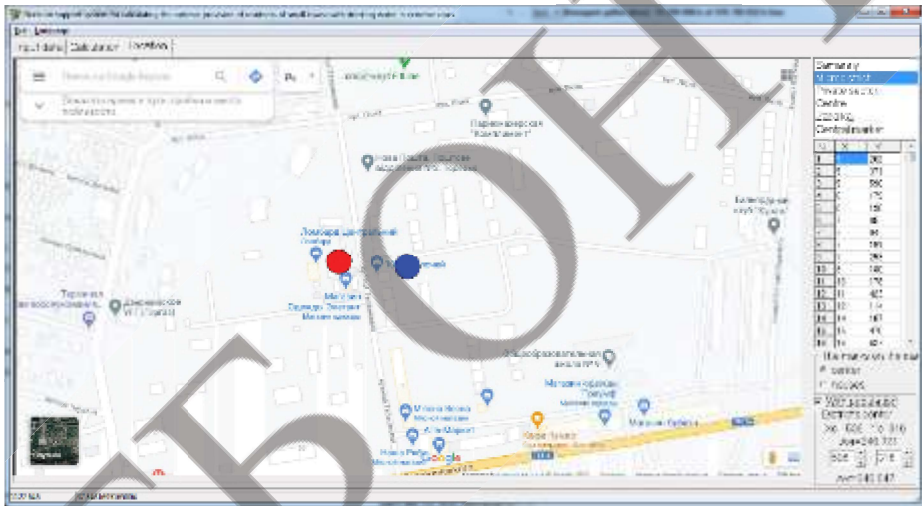


Fig. 13. Calculation of the centers of the district Microdistrict, taking into account residents



Fig. 14. Calculation of the centers of the Center district, taking into account houses



Fig. 15. Calculation of the centers of the Center district, taking into account residents

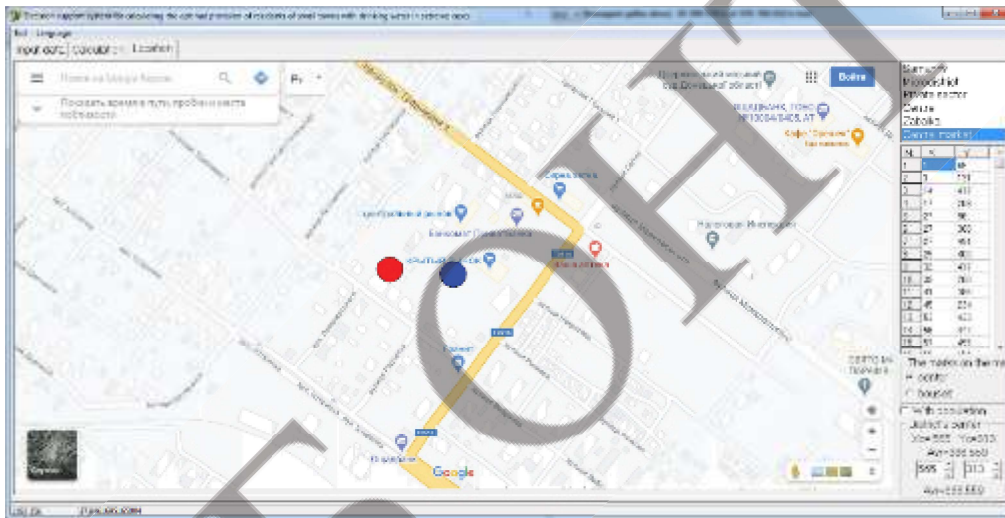


Fig. 14. Calculation of the centers of the Central Market district, taking into account houses

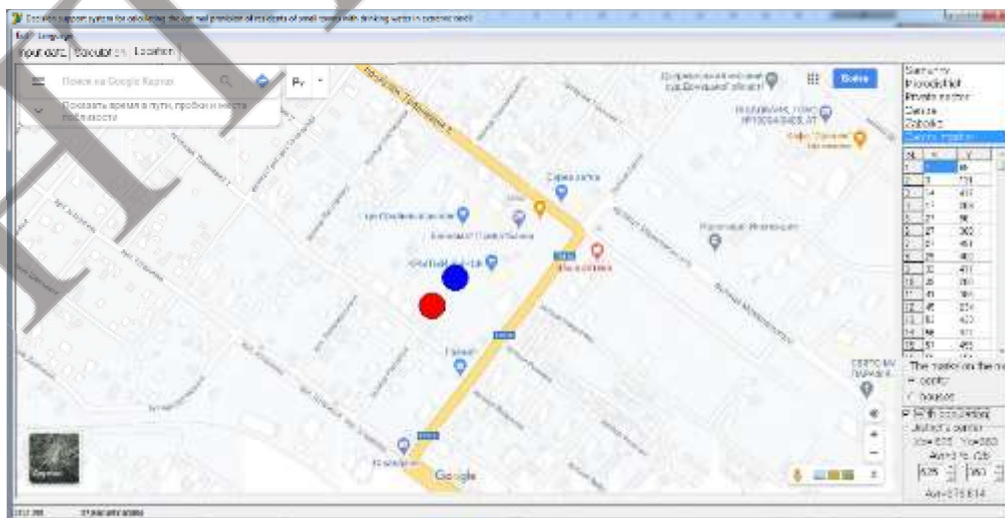


Fig. 15. Calculation of the centers of the Central Market district, taking into account residents

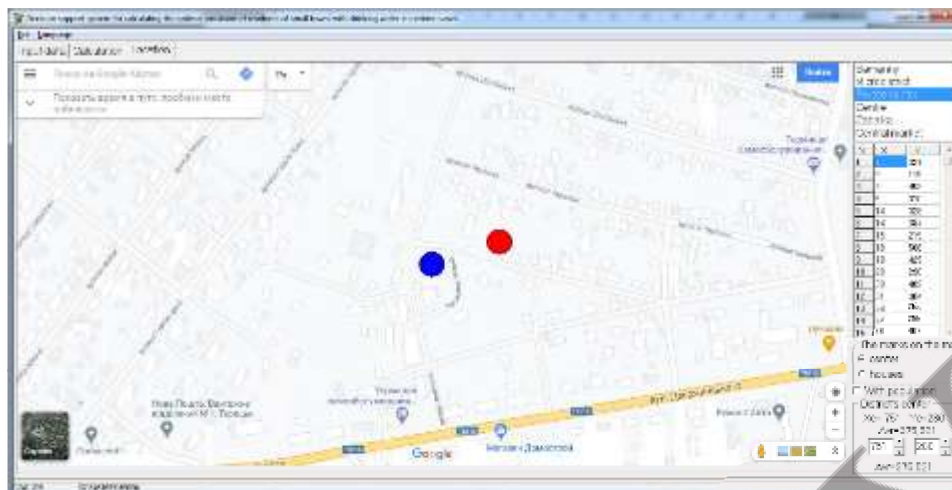


Fig. 16. Calculation of the centers of the district Private sector, taking into account houses

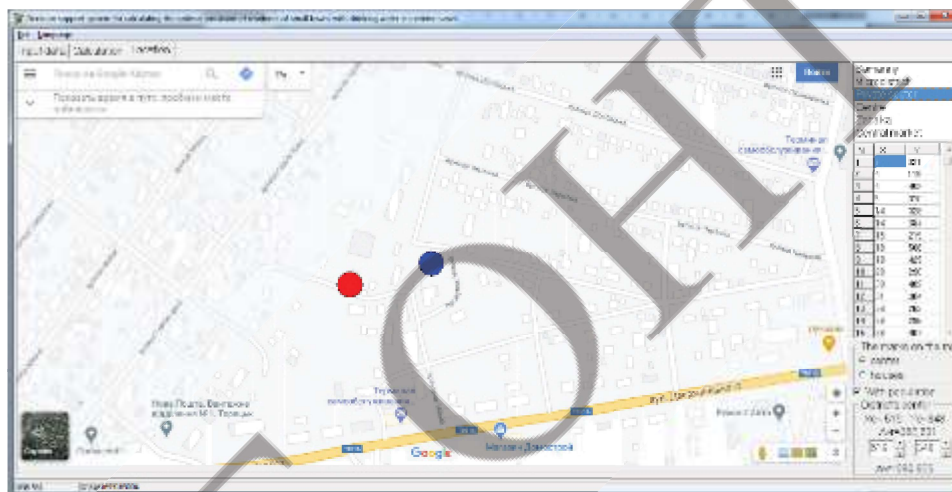


Fig. 17. Calculation of the centers of the district Private sector, taking into account residents

V. CONCLUSIONS

The work is devoted to the creation of an application that allows you to calculate the optimal route of the tank, providing residents of small cities with water in case of damage to the water supply system, as well as to determine the optimal location of the tank in each area to maximize the satisfaction of all its inhabitants [18].

Models and methods were used - the traveling salesman problem, finding the center of a cluster taking into account the weights of objects, connecting google maps to an offline application.

An example of using the developed application for calculating the route and position of tanks providing the city of Toretsk is given. However, when entering data for another city, the system will show the same satisfactory results.

The ways of further improving the model and application are outlined: if there are statistical data on accidents that occurred earlier on the water supply system of a given city, and the duration of repair work in each case, it is necessary to provide (ie predict) the duration of repair work to restore the city's water supply [19].

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