ҚАЗАҚСТАН РЕСПУБЛИКАСЫНЫҢ КӨЛІК ЖӘНЕ КОММУНИКАЦИЯЛАР МИНИСТРЛІГІ
МИНИСТЕРСТВО ТРАНСПОРТА И КОММУНИКАЦИЙ РЕСПУБЛИКИ КАЗАХСТАН

ҚАЗАҚСТАН РЕСПУБЛИКАСЫНЫҢ БІЛІМ ЖӘНЕ ҒЫЛЫМ МИНИСТРЛІГІ
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«ҚАЗАВТОЖОЛ» ҰЛТТЫҚ КОМПАНИЯСЫАКЦИОНЕРЛІК ҚОҒАМЫ
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РЕСПУБЛИКАНСКОЕ ОБЩЕСТВЕННОЕ ОБЪЕДИНЕНИЕ «СОЮЗ ДОРОЖНИКОВ»

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СБОРНИК НАУЧНЫХ ТРУДОВ ЮБИЛЕЙНОЙ МЕЖДУНАРОДНОЙ НАУЧНО-ПРАКТИЧЕСКОЙ КОНФЕРЕНЦИИ «АВТОМОБИЛЬНЫЕ ДОРОГИ И ТРАНСПОРТНАЯ ТЕХНИКА: ПРОБЛЕМЫ И ПЕРСПЕКТИВЫ РАЗВИТИЯ», ПОСВЯЩЕННОЙ 100-ЛЕТИЮ СО ДНЯ РОЖДЕНИЯ Л.Б. ГОНЧАРОВА

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В сборнике представлены материалы традиционной международной научно-практической конференции «Автомобильные дороги и транспортная техника: проблемы и перспективы развития», в которой приняли участие ведущие ученые, административные работники, крупнейшие специалисты автодорожной отрасли, профессора и преподаватели высших учебных заведений из Республики Казахстан, Российской Федерации, Бельгии, Польши, Республики Узбекистан, Республики Кыргызстан и др.

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ROUTE PLANNING OF WASTE COLLECTION

Мақалада Польшада жекеменшік үйлерден тұратын шағын ауданда қоқыс жинайтын машинаның қозғалысын жоспарлау әдісі келтірілген.

В статье показан польский способ планирования маршрута машины, собирающей отходы в выбранном микрорайоне, состоящем из частных домов.

In the article, there is shown a method of planning the route for a car, which collects waste from one area of a chosen commune with individual building in Poland.

1. INTRODUCTION

In the chosen commune a collection of mixed municipal waste is executed in a single-stage system of transport - garbage trucks collect waste in the operated area and transport them directly to the point of treatment. After filling up the car, the waste is transporting to a landfill or to a recycling centre. Empty car returns to the point, from which it left. The route of a garbage truck isn't planned. It depends on driver and this is the reason, why in the analysing area, it is necessary to examine routes from the point of view of their optimization.

While planning that route, it is essential to consider a number of factors, such as traffic organization (one-way street) and other difficulties in traffic. The length of the roads, which must be served doesn't change as the car has to drive all streets of the area, and this is why the optimization will be based on minimization of dead runs, mean driving the roads where the waste isn't collected, driving between separate streets and driving to the landfill. The result would be optimal, if a sum of empty runs and drives to landfill is minimum.

In the article, it is shown a solution of a key element of such optimization, which means planning one cycle of truck's work from entering the area, the filling the truck by collecting waste from every house and returning to the landfill.

Describing issue belong to problems called arc routing problem (ARP), where a vehicle must drive demanding network and transport definite load. Snow removal is a similar problem [9]. In literature, it is called also a Chinese postman problem (CPP).

2. MATHEMATICAL MODEL

In the concerned area, there live over 2700 people in about 700 properties; an amount of generated waste is about 1080 [m^3/year]. There are only two-way streets. The waste is collected once a month. Picture 1a shows outline of concerned area.

From the mathematical point of view, area is presented using an undirected graph G=(V,E), where V is a set of vertices, and E is a set of edges of the graph [1, 2]. Vertices of the graph correspond to the selected crossroads. Edges of the graph correspond to area's streets, which connect the vertices. Figure 1b shows a graph, which maps analysing an area. In the picture, the numbers of vertices are shown in circles, and edges are shown in rectangles. Scales are attributed to edges. They correspond to the length of the streets that are represented by given edge. Garbage truck must drive every edge once during collecting waste, but it could drive them as many times as necessary when it moves through the area. Those rides are called dead runs. As it was mentioned earlier, for optimal solve the sum of dead runs and drives to landfill should be reduced to the minimum, because the length of the distance that car must cover during collecting waste influences on the transports' costs and pollution from exhaust fumes [8].

The route of the car collecting waste from housing estate consists of a drive from base to housing estate, road from housing estate to the landfill and return, driving lines between successive parts of the route. Vertex 0 means the point of departure from the area and distances the point 0 from base and to base, also from and to landfill.

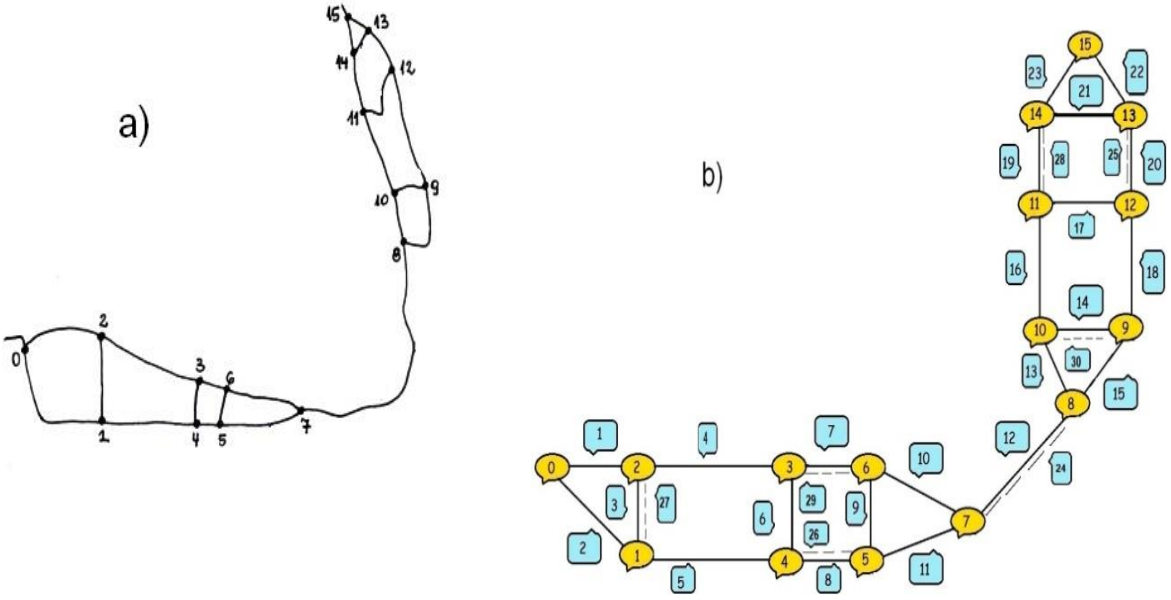

Figure1. Scheme of the area and the graph, which represents the area

Considering the problem can be shown by setting in the graph the roads that cross through every edge of the graph. That road is called Eulerian trail and Eulerian circuit is an Eulerian trail, which starts and ends on the same vertex. According to the Euler's theory, connected graph G has the Eulerian circuit if and only if every vertex has an even degree [2].

Graph in the fig. 1b doesn't fulfil this condition. In practice, it means, that it's impossible to drive every street of the housing estate without using some of them twice. In that situation, it should be pointed sections of roads with the smallest sum of lengths. So it is necessary to extend the graph G by edges that correspond to those sections of roads. In consequence of this extension, an Eulerian graph $\bar{G}$ will be given.

Table 1 includes list of edges of the graph$\bar{G}$. For every edge, there is given a number of initial vertex, number of final vertex and length of road's section represented by edge. Edges from 1 to 23 are originally from the graph G.

For solving that kind of the problems heuristic methods [3, 7] are used the most often, for example, a nearest neighbour algorithm, evolutionary algorithms [5], simulated annealing. This problem was solved using a method of artificial immune system [6, 10]. It is the method of artificial intelligence, which imitate human immune system. Organism, attacked by foreign bodies first defends itself mechanically and chemically (skin, tears, temperature). If, despite these barriers, pathogens enter the organism, the immune system starts to work.

Antibodies work more successfully if they fix to antigens, which attack organism. The better-fitted antibodies are cloned and mutated. They become more effective. After the successful defence follows suppression, it means an act of stopping the antibodies' activity. Part of the antibodies is retained, and they create a base from which organism will take in the event of another antigens' attack. Model of selection the best antibody is called clonal selection.

Table 1.List of edges of the graph

Number of edge	Initial vertex	Final vertex	Scale (length in kilometres)	Number of edge	Initial vertex	Final vertex	Scale (length in kilometres)
1	0	2	0,8	16	10	11	0,6
2	0	1	1,2	17	12	11	0,7
3	1	2	0,9	18	9	12	1
4	2	3	1	19	11	14	0,5
5	1	4	0,9	20	12	13	0,4
6	3	4	0,4	21	14	13	0,3
7	3	6	0,3	22	13	15	0,3
8	4	5	0,3	23	14	15	0,4
9	6	5	0,3	**24**	**8**	**7**	**2,3**
10	6	7	0,8	**25**	**13**	**12**	**0,4**
11	5	7	0,9	**26**	**4**	**5**	**0,3**
12	7	8	2,3	**27**	**1**	**2**	**0,9**
13	8	10	0,5	**28**	**11**	**14**	**0,5**
14	10	9	0,3	**29**	**3**	**6**	**0,3**
15	8	9	0,8	**30**	**9**	**10**	**0,3**

3. NUMERICAL CALCULATIONS

Initially, there were designated distances between each vertex of the graph of each. The Dijkstra's algorithm was used [2]. Results are in table 2.

The first stage of calculations was bringing graph that represents the area to the Eulerian graph. Paradigm of clonal selection was used. In the area's graph was separated set of vertices with odd degrees. So, it was created set of 16 vertices with a third degree. Every antibody consists of finite sequence of those vertices numbers. Two other numbers they are numbers of vertices, between which is going to be created as short path as possible. Fitness function value is the sum of the shortest distances those paths for every occurring alternately in antibody pairs of those vertices.

As a result of calculations was given the Eulerian graph, which is shown in the fig. 1b. Additional edges between graphs are marked with dotted lines. In the table 1 they are numbered from 24 to 30. Those edges present roads where car-collecting waste from the area will have to drive the second time, without collecting waste. According to criterion of optimisation, given solution proposes the shortest way.

Another step is to designate a drive plan through the area's streets. It isn't the difficult task for the Eulerian graph using Fleury's algorithm [1] or Hierholzer's algorithm [4]. Here was used the second algorithm. The passing edges of the graph is following (according to vertices' numbering): 0 – 2 – 1 – 2 – 3 – 6 – 3 – 4 – 5 – 6 – 7 – 8 – 10 – 9 – 10 – 11 – 14 – 11 – 12 – 13 – 14 – 15 – 13 – 12 – 9 – 8 – 7 – 5 – 4 – 1 – 0. It is one of the optimal solve.

4. CONCLUSIONS

In the article was shown the method of extension the graph G that represents the area's streets to the Eulerian graph and designation streets, through which the car must drive the second time and which sum is minimal. To this end was used paradigm of clonal selection.

The following step while planning routes for the cars, which are intended for selective collection of waste, is to point the order of a drive through the streets. According to Euler's theorem, those solutions exist. They were given by using the Hierholzer's algorithm. It is extremely important issue, considering the changes in collecting waste that refer to a new act, which currently enters into force in Poland.

Table 2.The shortest paths in metres between vertices of Eulerian graph

Number of edge	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	1,2	0,8	1,8	2,1	2,4	2,1	2,9	5,2	6	5,7	6,3	7	7,1	6,8	7,2
1	1,2	0	0,9	1,9	0,9	1,2	1,5	2,1	4,4	5,2	4,9	5,5	6,2	6,3	6	6,4
2	0,8	0,9	0	1	1,8	1,6	1,3	2,1	4,4	5,2	4,9	5,5	6,2	6,3	6	6,4
3	1,8	1,3	1	0	0,4	0,6	0,3	1,1	3,4	4,2	3,9	4,5	5,2	5,3	5	5,4
4	2,1	0,9	1,4	0,4	0	0,3	0,6	1,2	3,5	4,3	4	4,6	5,3	5,4	5,1	5,5
5	2,4	1,2	1,7	0,7	0,3	0	0,3	0,9	3,2	4	3,7	4,3	5	5,1	4,8	5,2
6	2,1	1,6	1,3	0,3	0,7	0,3	0	0,8	3,1	3,9	3,6	4,2	4,9	5	4,7	5,1
7	2,9	2,1	2,1	1,1	1,2	0,9	0,8	0	2,3	3,1	2,8	3,4	4,1	4,2	3,9	4,3
8	5,2	4,4	4,4	3,4	3,5	3,2	3,1	2,3	0	0,8	0,5	1,1	1,8	1,9	1,6	2
9	6	5,2	5,2	4,2	4,3	4	3,9	3,1	0,8	0	0,3	0,9	1	1,4	1,4	1,7
10	5,7	4,9	4,9	3,9	4	3,7	3,6	2,8	0,5	0,3	0	0,6	1,3	1,4	1,1	1,5
11	6,3	5,5	5,5	4,5	4,6	4,3	4,2	3,4	1,1	1,7	0,6	0	0,7	0,8	0,5	0,9
12	7	6,2	6,2	5,2	5,3	5	4,9	4,1	1,8	1	1,3	0,7	0	0,4	0,7	0,7
13	7,1	6,3	6,3	5,3	5,4	5,1	5	4,2	1,9	1,4	1,4	0,8	0,4	0	0,3	0,3
14	6,8	6	6	5	5,1	4,8	4,7	3,9	1,6	1,4	1,1	0,5	0,7	0,3	0	0,4
15	7,2	6,4	6,4	5,4	5,5	5,2	5,1	4,3	2	1,7	1,5	0,9	0,7	0,3	0,4	0

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