Optimization of Multi-objective Road Snow Removing Based on Greedy Algorithm

Summary Sheet

Road congestion caused by snowfall exceeding 20 cm, in some cities in northern China has seriously affected the daily life of residents. This paper will optimize the road snow removal from two aspects, one is the number of snow removal equipment, the other is the path planning of each snow removal equipment.

For problem one, the snow can be stacked on the green belt, only the snow removal machine can complete the task of clearing snow, divide the city according to the main road, consider the local optimal solution to different partitions, and thus reach the global optimal solution. Two optimization objectives of equipment and snow removal time are considered for each partition, and a multi-objective nonlinear programming is established with the snow removal time less than the specified value and the snow removal area larger than the snow cover area as the constraint conditions. fluery algorithm is used to group the paths in the partition, and the optimal path is obtained by greedy algorithm. First, the optimal solution is 38 snow sweepers, the snow removal time is 2.9801 h.

For question two, the snow needs to be transported to the snow point. The snow sweeper, the worker and the transport vehicle need to work at the same time. Considering that the truck can not drive on the uncleaned road, the truck should always lag behind the snow sweeper.Considering the two optimization objectives of equipment and snow removal time, and taking the snow removal time less than the specified value and the snow removal area larger than the snow cover area, the snow cover volume at the snow point is less than the volume that can be stacked at the snow point as the constraint condition, the multi-objective nonlinear programming is established.Taking the distance from the node to the snow point and the volume of the snow point as the constraint, the partition is grouped, and the optimal partition scheme is obtained by greedy algorithm, and the global optimal solution is obtained.

For question 3, in order to make the parking space resume as soon as possible, the time of complete cleaning of each street is as small as possible, and the time scale is increased, and the end time of street cleaning minus the start time is taken as the optimization goal. Considering that the snow can be stacked in the green belt and can not be stacked, a constraint condition is added on the basis of question 1 and question 2, respectively. In the case of the optimal equipment route obtained from the first two questions, the invalid driving edge is added. Give priority to completely cleaning a street.

For problem 4, considering the problem of road priority, a multi-objective nonlinear programming model is established in order to clean up the high priority path first and increase the end time of street snow clearing. According to the grouping of the second question, the high priority path is searched from the snow point, and the cleaning path from high to low is obtained by greedy algorithm.

Key word: greedy algorithm fluery multi-objective nonlinear programming

Content

1.Introduction

1.1 Background

Recently, there was heavy snow in northern China.In some areas, snowfall exceeds 20 cm. Large-scale heavy snow has caused a lot of inconvenience, especially for China's more urbanized areas. Road congestion caused by snow removal delays has seriously affected the daily life of residents. To ensure the smooth passage of citizens, sanitation workers tried to clear and transport snow on the road. In order to realize the goal of making the road smooth after snowfall, scientific and reasonable road snow removal scheme is needed.

1.2 Work

Tixt (snow removal method varies with snow depth. When the snow depth is small, just sweep the middle of the road to the green belt or leisure area. However, when the depth of the snow increases to the point where it is difficult to temporarily store the green belt, it is necessary to use a snow sweeper to collect the snow and pour it into large trucks and transport it to large open spaces inside and outside the city.

Annex 1 provides road information for a city, including the latitude and longitude of the intersection, the connection point of the intersection, the width of the intersection and the location of potential snow. Please try to solve the following four problems by mathematical modeling:

Question one： give the optimal number, model configuration, and the driving path of each shovel, so that in the case of Lesser Snow, a reasonable cleaning plan is given

Question tow： when the green belt can not pile up snow, increase transport vehicles and sanitation workers to transport snow to the snow point, please provide the number of snow sweepers, workers, transport vehicles and reasonable snow removal plan to make the snow removal time as small as possible.

A parking space is available in the Question three： lane to remove the vehicle in advance. Please provide a snow removal plan so that the street has the shortest snow removal time

Question four： please make snow removal plan according to different priority.

2.Problem analysis

2.1 Data analysis

Annex 1 Road width 2 means two-way single lane 4 means two-way two lane 6 means two-way three lane 8 means two-way four lane, one lane width is 3.75 m. During snow removal, the snow sweeper clears the snow in one lane at a time, that is, the road between the starting point and the end point is cleared at a time. The potential snow point indicates the place where the snow can be piled up. Each snow point has a corresponding area. When the snow is difficult to pile in the green belt, the snow needs to be transported to the snow point.

According to the relevant regulations given by the Meteorological Bureau, the snowfall standard can be obtained as shown in Table 1:

Criteria for Table 1 snowfall

Name of snowfall	24 hours snowfall (mm)
Lesser Snow	1.25
Lesser Snow	2.50
Middle Snow	3.70
Heavy snow	5.60
Heavy snow	7.45
Blizzard	10.0

Each point and street in Annex 1 are represented in the two-dimensional plane. Because the latitude and longitude given in this paper are the same as the coordinates of Hohhot city, this paper takes the snow removal regulations of Hohhot city as an example.

1. when the snow thickness is less than 10 cm, the snow on the road can be swept into the roadside green belt.
2. for Lesser Snow, snow stop is clear, must complete the snow task within 3 hours.For the green belt can not be stacked in the case of 12 hours to complete the task.

Suppose the compression coefficient of snow is 0.05, the parameter of truck is 4.2 m*2m*2m, that is, the capacity of truck is 16.8 cubic meters, and the height of snow can be 1.2 m. at snow point

2.2 Analysis of question one

To question one, draw the scattered points in the table in Annex 1 nodes according to latitude and longitude; draw each street according to the table links, mark the width of the street, and calculate the length of each street; according to the location table, mark the snow point above; Divide the city into 8 districts according to the main road. Assuming that each partition does not interfere with each other, the snow removal plan is carried out at the same time, that is, the snow removal equipment in a certain area will not go to the next partition to remove snow.

Each partition needs to set up the optimal cleaning scheme, and its optimization aspect distributes the quantity for each partition snow sweeper, and the driving path of each snow sweeper during snow removal.

A multi-objective nonlinear optimization problem is established, in which the snow removal time is as small as possible and the number of snow sweeps is as small as possible. As the optimization goal, the snow removal time is less than 3 h, and the snow removal area is larger than the possible snow point as the constraint condition. Taking a partition as an example, assuming that each snow sweeper works at the same time until the last snow scraper stops working, the longest working time is the snow removal time in the area. The driving time of snow sweeper in snow removal time is working time, and the time of snow sweeper in snow removal work is effective working time. The snow removal efficiency in this area can be expressed by total effective working time. In the constraint condition, the effective working time of each snow sweeper is multiplied by the speed and the working width of the snow sweeper, and the actual cleaning area of the snow sweeper can be obtained, which is larger than the area of snow in the district.

For the solution of this problem, considering the number of fixed snow sweeps, the driving path of each vehicle forms a closed Euler graph, which minimizes the invalid path and calculates the time required for snow removal. By increasing the number of snow sweeping vehicles, the snow removal time is gradually reduced. The optimal value of the vehicle is obtained by considering the snow sweeping machine and the path. Because the path of this paper is a two-way even-numbered highway, the three-lane route that may appear on the boundary is considered invalid, so it can traverse all the roads that need to be cleaned up in the partition, and there will be no invalid driving except the odd path of the boundary. Snow removal time in this area is the maximum time required for snow sweeper to clean up the planned route. In order to minimize the snow removal time, the cleaning path of each vehicle should be the same as possible, so the path arrangement of each vehicle can be obtained by fluery algorithm.

2.3 Analysis of question two

For question two, considering that snow can not accumulate in the green belt, increase sanitation workers and transport vehicles on the basis of question one. a snow sweeper, a transport vehicle, two sanitation workers to form a group, assuming that the snow sweeper can not sweep the snow into the green belt when the snow thickness is more than 10 cm. the snow sweeper acts as a snow sweeper that heaps every 200 meters of snow on the road surface, and the sanitation worker loads the accumulated snow into the transport vehicle, and the truck is filled to the snow point. Because the truck can not drive on the road without clearing the snow, it can only clear the snow from the snow point and give priority to the path between the snow points, so the number of groups and the driving path need to be replanned. Therefore, the optimization goal of the second question is that the snow removal time is the smallest and the number of groups is the least. The maximum time for each group of snow removal teams to start working at the same time is the snow removal time, and the snow removal time is less than 3 h, the snow removal area is larger than the snow area.

In order to minimize the snow removal time, the cleaning area of each group is roughly the same, and the volume of snow compression is smaller than that of snow point. Arrange each group of snow sweeper from the snow point, the transport vehicle runs behind the snow sweeper, so the transport vehicle will return the snow to the group of snow point is the nearest distance, and the back of the road has been cleared. According to the idea of the first question, a closed loop is formed in the group to find the optimal route.

2.3 Analysis of question three

For question 3, the snow removal schedule is given, considering the two cases where the snow can be stored in the green belt and can not be stored, the cleaning time of each street is given, and no parking is required on the roadside when the snow sweeper cleans the street. Because the road surface of two-way two-lane is narrow, the parking space on the roadside is not considered, and each highway occupies a maximum of two-way single lane as parking space, that is, only one lane can be used as parking space in each direction.

On the basis of questions 1 and 2, the optimization goal should be added, that is, to finish cleaning a street as quickly as possible. Assuming that the street is cleaned from 8:00, the start time and end time of each street cleaning can be obtained. In order for the vehicle to return to the original parking point in a short period of time, the complete cleaning time of the road width 4/6/8 should be as fast as possible. Therefore, when the green belt can store snow, the optimization goal is to increase the shortest total snow removal time of the street on the model of question 1; when the green belt can not store snow, when the snow sweeper clears the snow, there can be no parking on the roadside.

2.4 Analysis of question four

For question 4, planning the snow clearing path according to the priority, marking the weight of each street on the original map, we can find that the edges with larger weights are near the snow point, so consider the grouping method of the second question. Clean up the streets in each group according to the weight.The optimization index time-first ratio is introduced, that is, the time of the street to complete the work is divided by the priority of the street. When the index is as small as possible, the street with high important level gives priority to the task of clearing snow.

3.Symbol and Assumptions

3.1 Symbol Description

Table 2 symbol description

Symbol	Note
x	Number of snow sweeper units in a district
$t_i\,(i=1,...,x)$	Working hours of each snow sweeper in a given division
$t_i'(i=1,...,x)$	Effective working hours of each snow sweeper in a given division
$v_i\,(i=1,2,3)$	Snow sweeper working speed and normal speed, truck speed
s	Total area of snow to be cleared in a zone
$h_i\,(1=1,...,m)$	There are m streets in a district, i street length
$d_i\,(i=1,...,m)$	There are m streets in a district, i street width
n	Number of snow cover points in a zone
$c_i\,(i=1,...,n)$	Area of snowfall at the i snow point in a given zone
$k_{ij}\,(i=1,...,x,\ j=1,...,n)$	Volume of snow transported by i transport vehicle to the j snow point in a given sector
b	The volume of snow that can be loaded into a transport vehicle

	at a time
a_{ij}	An adjacency matrix of a district street, i-j the existence value of the street is 1, the non-existence value is 0
$a_{ij}y_{i-j}$	A certain district i-j the beginning of the street snow time
$a_{ij}y'_{i-j}$	End of snow clearing in a district i-j street

Note: the symbols in this table are mainly described in stationery.

3.2 Fundamental assumptions

1., it is assumed that the speed of each vehicle is the same, and the speed of the vehicle in the snow removal operation is the same as that in the ordinary section, and the snow removal speed is independent of the snow thickness.

2. assume that the snow sweeper can clean the road once to meet the cleaning standard, and the snow sweeper clean the same width each time.

3. all sub-area snow sweeper starts work at the same time, the snow sweeper does not rest until the snow sweeper plans the snow removal range.

4. suppose the snow thickness of each street is the same, the second question is that the snow thickness is more than 10 cm. on the ground

5. assume that the snow at the snow point is a standard column with a stacking height of 1.2 m..1

6. assume that the snow sweeper piles 100 m of snow together when the snow is thick, and the sanitation worker loads the truck to the snow point.

7. assume that two-way single lane can not stop, and other roads can only park one lane in one direction.

4.Model

4.1 Model establishment and solution of problem 1

4.1.1Analysis of model

The data of Annex 1 are processed ,141 points are drawn from latitude and longitude on the two-bit plane, and the connection of each street is obtained from the starting point and the end point of the street. The 8-lane highway in the figure is connected and the city is roughly divided into six areas. Because the streets in the left area are too dense, the city is divided into eight districts along the longitudinal 6 lanes. The streets used to divide the area are regarded as two parts. One-way distribution to the region. Urban zoning is shown in figure 1:

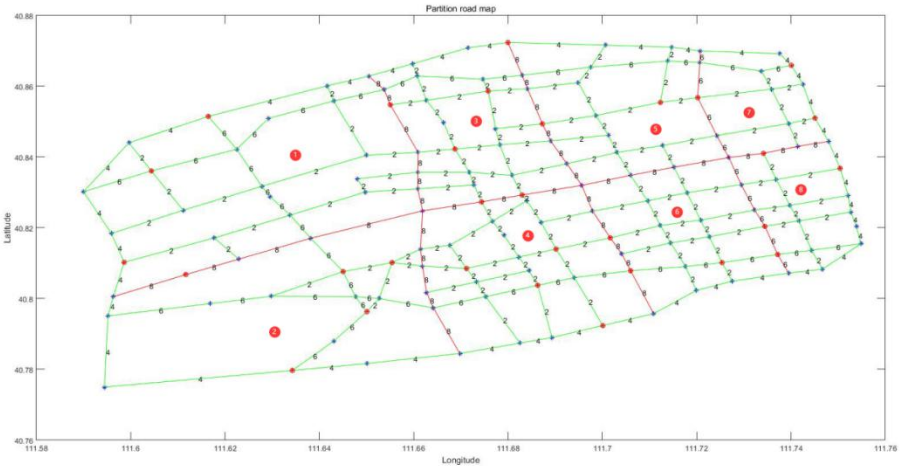

Figure 1 urban zoning

The optimal snow removal plan is to complete the snow sweeping plan as quickly as possible with as few snow sweeps as possible. This question needs to configure the number of snow sweepers in each district, and optimize the driving path of each snow sweep machine, so that the number of snow sweepers is the least, and the snow removal time is as small as possible. According to the relevant regulations of Hohhot city, it is required to clear the snow on the road within 4 h after the snow stops. This question assumes that the snow begins to clean up after the snow stops, and there will be no snowfall during the snow removal period. After the snow sweeper works on the snow pavement once, the road surface reaches the cleaning standard, and a snow sweeper can clean up the snow in one lane at a time. The actual snow removal time of the snow sweeper in this snow removal task is the effective working time, and the effective working time plus the driving time of the snow sweeper road surface is the total working time.

4.1.2E stablish of model

Taking partition 8 as an example, the distribution and scheduling process of snow sweeper is described in detail.

Subarea 8 The number of snow sweeps purchased is x ; Subarea 8 The working time of each snow sweeper is $t_i(i=1,...,x)$; Subarea 8 The effective working time of each snow sweeper is $t_i'(i=1,...,x)$; The working speed and normal driving speed of the snow sweeper is $v_i(i=1,2)$; The snow sweeper can clean up one lane of snow at a time; The total area of snow required for Subarea 8 is s; Subarea 8 has m streets, of which the length of the i street is $h_i(1=1,...,m)$; Subarea 8 has m streets, of which the width of the street is $d_i(i=1,...,m)$, where the width of the street refers to several lanes.

Since each snow sweeper in the partition starts to work at the same time, and the snow sweeper does not rest before completing the prescribed snow removal route, the time required for snow removal in partition 8 is: $\max t_i$.

Because the length of the district street and the working speed of the snow sweeper are known, each street in the district needs to clean up the snow, so the effective working time required for snow removal in the district is the length of each street multiplied by the number of street lanes. That is $\sum_{i=1}^{m} h_i d_i$. The effective working time of the snow sweeper is multiplied by the speed, which is the length of the snow sweeper. $\sum_{i=1}^{m} h_i d_i$

Because the snow removal time and the number of snow sweepers are the optimization objectives, the snow removal time is less than 3 h, and the effective snow removal length is equal to the effective snow removal length of the partition.

Objective function:

$$\min \quad \max t_i (i = 1, ..., x)$$

$$\min \quad x$$

Constraints:

$$\begin{cases} \max t_i (i = 1, ..., x) \le 3 \\ \sum_{i=1}^{x} v_1 t_i' = \sum_{i=1}^{m} h_i d_i \end{cases}$$

4.1.3Solution of model

The operating speed of the snow sweeper is set to 3 m/s, the common speed is set to 6 m/s.

In this paper, the number of snow sweeper in each partition and the driving path of snow sweeper are planned, and the optimal solution of the partition is obtained, and the optimal planning of snow removal in the whole city is obtained. Because there are two optimization objectives, the number of snow sweeper and snow removal time, when the number of snow sweeper increases, the snow removal time decreases, and the number of a snow sweeper is fixed, and the minimum value of snow removal time is obtained under this condition. Considering the limit of snow removal time, the optimal solution of snow sweeper number and snow removal time is obtained.

To determine whether the subdistrict street constitutes Eulerian, due to the possible 3-lane situation at the boundary, an invalid driving can be added, so that the subdistrict street forms a closed Eulerian, and the snow sweeper works back to the starting point. Because the snow sweeper works at the same speed, the snow removal time is the longest snow removal time. In order to make the snow removal time as small as possible, the working time of the snow sweeper can be as same as possible.

First, it is determined whether the partition path is Eulerian. If the invalid driving edge is not added to form Eulerian, the fluery algorithm can form a closed Eulerian loop for the given point.

The pseudo code is as follows:

fluery algorithm
Input: any number of specified points in a connected graph G and G u
u Output: Multiple Euler loops from the starting G
W：=u,x：=u,F：=G 1. Order
2.while $\partial F \neq \varnothing do$
$\partial F(x)$ 3. choose one of the edges e, e of which is not a cut edge; if the edges are all cut edges, choose one edge e $\partial F(x)$
$uWxey$ uWx 4. replacement, y replacement x, replacement $F \setminus e$
5.end while
6. Return W

The solution is demonstrated by partition 8, which is shown in figure 2:

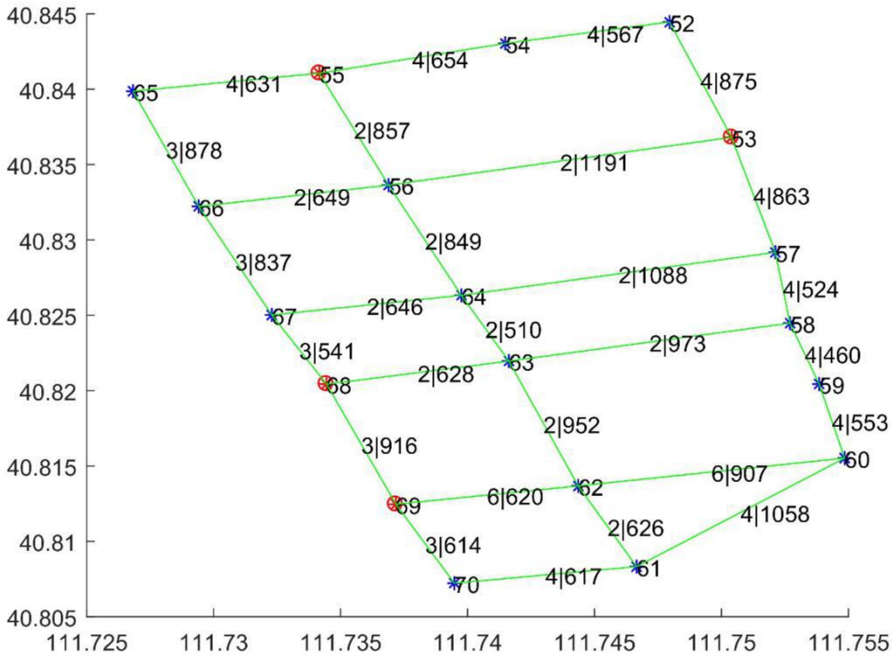

figure 2Map of division 8

Sept1： when the number of snow sweeps is 1

The Euler loop is composed of fluery algorithm traversing nodes. The total distance divided by the working speed of the snow sweeper is 6.0802 h, and the snow removal time is more than 3 h which does not satisfy the constraint.

Sept2： when the number of snow sweeps is 2

The fluery algorithm is used to form the Euler loop, and two vehicles are allocated to reverse driving from the starting point. The difference between the driving paths of the two snow sweeps is the smallest, and the snow removal time is 3.1401 h, and the snow removal time is more than 3 h which does not meet the constraints.

Sept3： when the number of snow sweeps is 3

Pre-process the map and divide the street into three groups according to the number of lanes:

6 lanes :(65-66,66-67,67-68,68-69,69-70,69-62,62-60 m length 20520

4 lanes :(65-55,55-54,54-52,52-53,53-57,57-58,58-59,59-60,50-61,61-70 m length 27208

2 lanes :(61-62,62-63,63-68,63-58,63-64,64-67,64-57,64-56,56-66,56-53,56-55) length 17938 m

The difference between the two lanes and the four lanes is the largest, so the road at the end of the four lanes (65-5555-54) is divided into two lanes, so that the three groups are as equal as possible. Each group arranges a snow sweeper to fluery the algorithm to traverse each group of roads to form an Euler loop. As shown in the diagram, the working time and path of the three snow sweepers are shown in the table, and the snow removal time is h.2.14

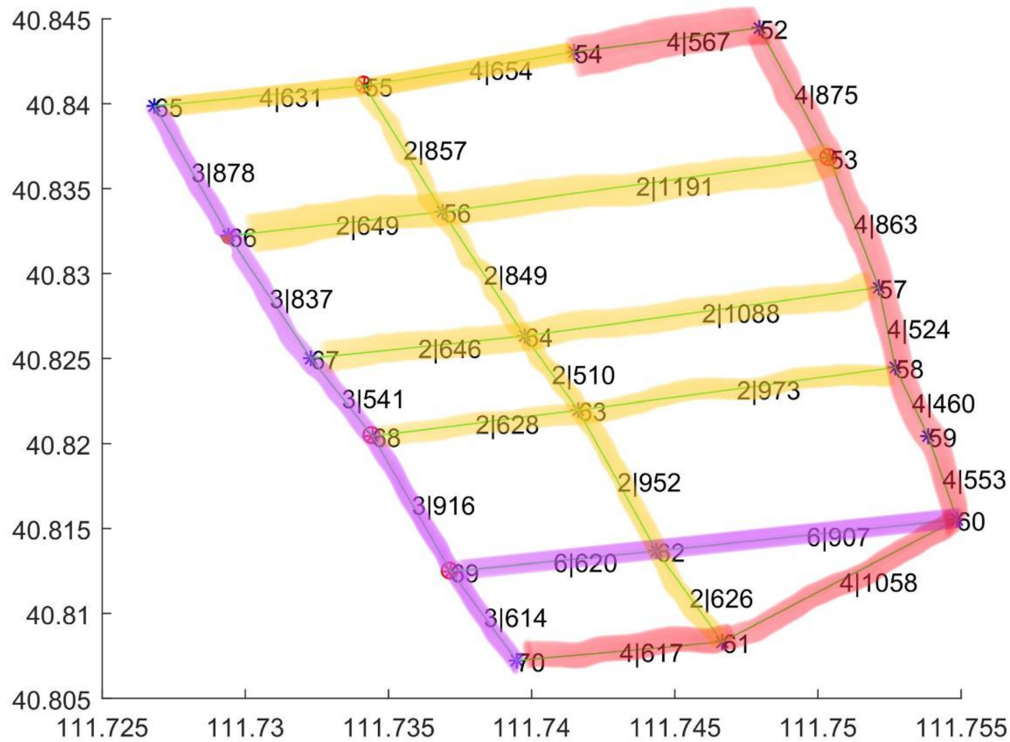

figure 3Grouping of partition 8

Table 3Working time and path of Three Snow sweepers

Partition	Vehicles	Street Street	Length	Working hours	Effective time	Path scheduling
8	3	2 lanes	m 23078	2.14 h	2.14 h	61-62-63-68-63-58-63-64-67-64-57-64-56-66-56-53-56-55-65-55-65-55-54-55-54-55-56-64-63-62-61
		4 lanes	m 22068	2.04 h	2.04 h	70-61-60-59-58-57-53-52-54-52-53-57-58-59-60-61-70-61-60-59-58-57-53-52-54-52-53-57-58-59-60-61-70

		6 lanes	m 20520	h 1.90	h 1.90	65-66-67-68-69-70-69-68-67-66-65-66-67-68-69-62-60-62-69-62-60-62-69-62-60-62-69-70

Sept4: when the number of snow sweeps is 4

2 lanes arrange a snow sweeper ,4 lanes arrange two snow sweeper ,6 lanes arrange a snow sweeper, because the total length of the district highway is divided into four or two snow sweeps, each length is 16416.5 m, so the 4 lanes are divided into two groups, the new grouping is:

6 lanes :(65-66,66-67,67-68,68-69,69-70,69-62,62-60 m length 20520

4 lanes :1.(65-55,55-54,54-52,52-53-57,57-58) Length 16456 m

2.(58-59 59-60 50-61 61-70) length 10752 m

2 lanes :(61-62,62-63,63-68,63-58,63-64,64-67,64-57,64-56,56-66,56-53,56-55) length 17938 m

Four lanes 2 and 6 lanes are quite different, the (62-60) highway is divided into 4 lanes 2. Euler loop is composed of fluery algorithm traversal nodes. The 4 lanes arrange two vehicles traversing in the opposite direction from the unified starting point. The route is shown in the figure. The working time and path of the four snow sweeping machines are shown in the table, and the snow removal time is 1.66 hours.

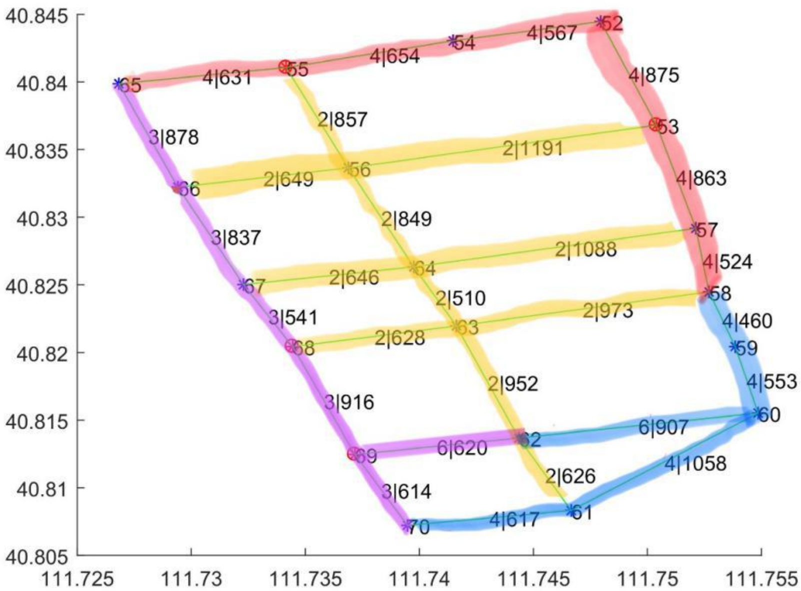

figure 4Grouping of partition 8

Table 4Working time and path of Four Snow sweepers

Partition	Vehicles	Street Street	Length	Working hours	Effective time	Path scheduling
8	4	2lanes	17938m	1.66 h	1.66 h	61-62-63-68-63-58-63-64-67-64-57-64-56-66-56-53-56-64-63-62-61
		4lanes1	16456m	1.52 h	1.52 h	65-55-54-52-53-57-58-57-53-52-54-55-65-55-54-52-53-57-58-57-53-52-54-55-65
		4lanes2	16194m	1.50 h	1.50 h	70-61-60-62-60-62-60-62-60-59-58-59-60-61-70-61-60-59-58-59-60-61-70
		6 lanes	15078m	1.40 h	1.40 h	65-66-67-68-69-70-69-68-67-66-65-66-67-68-69-62-69-62-69-62-69-70

By synthetically judging the time required for three vehicles and four vehicles, the three vehicles are the optimal solution. Therefore, the scheme given by partition 8 is as follows: three vehicles are configured, the starting point is 61/70/56, and the snow removal time is 2.14 hours. The results of the remaining partitions will be shown as attachments.

4.2 Model establishment and solution of problem 2

4.2.1Analysis of model

Tixt for the snow points on the boundary, the accumulated area is divided equally into adjacent zones, and the snow in each zone is only transported to the snow points in this area. According to the preliminary calculation, the area of snow to be cleared in each zone can be obtained, the snow thickness is 10 cm, the snow compression coefficient is 0.05, and the volume of snow after compression in each zone can be obtained. By calculating the total area of the snow point in the partition, the maximum snow can be piled up to 1.2 m, and the snow is piled into a standard column. It is found that the snow can be located at the snow point.

Because the second question on the basis of the first question to increase the need to transport snow conditions. Therefore, this paper takes a snow sweeper, a transport vehicle and two environmental protection workers as a group. Because the transport vehicle can not drive on the road without clearing the snow, each group of snow sweeping equipment should start from the snow point to clear the snow, and the path and the number of groups need to be replanned. Because the snow on the road is too thick to be stored in the green belt, the snow sweeper piles up the snow every 100 m, and the sanitation workers load the snow into the transport vehicle and transport it to the snow point.

Each group of snow removal settings work at the same time until all snow accumulation in the snow point snow removal task completed, the maximum working time of each group immediately snow removal time. For the optimization goal, the snow removal time is as little as possible, the snow removal equipment is as small as possible, the constraint condition is that the snow removal time is less than 3 h, the snow removal area is larger than the snow cover area, and the snow volume of each snow point in the partition is less than the snow volume. A nonlinear optimization model is established.

4.2.2E stablish of model

Tixt take partition 8 as an example, detail the allocation scheduling process.

The number of snow sweepers in Zone 8 is x ;The working hours of each group of snow sweeping equipment are as follows: $t_i(i=1,\ldots,x)$ the working speed of the snow sweeping machine and the normal driving speed of the transport vehicle are as follows: $v_i(i=1,2)$ the speed of the transport vehicle is v_3 , the speed of the workers loading the snow into the transport vehicle is v_4 ; the number of snow points is n, i snow point the area of snow is $c_j(j=1,\ldots,n)$ can be piled up is 1.2 m.

Since each group of snow sweeping equipment in the partition starts work at the same time and does not rest before completing the prescribed snow removal route, the time required for snow removal in partition 8 is: $\max t_i$.

Since the number of transport vehicles is the same as the number of snow sweeps, the snow volume of the i vehicle to the j snow point is $k_{ij}(i=1,\ldots,x,j=1,\ldots,n)$ the same as that of each truck. The snow volume can be loaded into b cubic meters, and the truck is filled and transported to the snow point. Assuming the snow sweeper has compressed the snow every 100 m and piled it on the road.

Because the snow removal time is the optimization goal and the snow removal time is less than 3 h, the effective snow removal length is equal to the effective snow removal length of the partition.

Objective function:

$$\min \quad \max t_i(i=1,\ldots,x)$$

$$\min \quad x$$

Constraints:

$$\begin{cases} \max t_i(i=1,\ldots,x)\le 12 \\ \sum_{i=1}^{x} v_1 t_i' = \sum_{i=1}^{m} h_i d_i \\ \sum_{i=1}^{x} k_{ij} \le 1.2c_j(j=1,\ldots,n) \end{cases}$$

4.2.3Solution of model

Tixt for convenience, it is assumed that the road snow is 10 cm, the snow compression coefficient is 0.05, the transport vehicle can run 15 cubic meters of compressed snow at a time, The speed of the transport vehicle is 10 m/s, the speed of the snow sweeper is 3 m/s,6.

In this question, the streets of partition 8 are regrouped, taking the snow point as the center, the maximum volume of the snow point can be stacked as the constraint, and the distance from any node in the group to the snow point is the closest to the other snow points.

Each group of snow was cleared, the snow was compressed and accumulated every 200 m by the snow sweeper, then the workers loaded the snow into the transport vehicle, which transported the snow to the snow point. In the process, the transport vehicle can drive on the cleared road, and dumping snow at the snow point in the group is the nearest path. The working time of each group of snow sweeper and transport vehicle is calculated. For the first group of partition 8, considering four snow removal equipment, the time of clearing the road surface is 1.21 h; Assuming that the snow sweeper cleans the road before the transport begins to work, the transporter takes 4.41 h; It can be seen that the speed of the snow sweeper is significantly higher than that of the transport vehicle. Therefore, each group of snow removal time for the truck from the start to the end of the work time. From the first question, it can be seen that when the number of snow sweeps is 1 and 2, the constraint conditions are not satisfied, so this question begins with the number of snow sweeps is 3, and the search method of each group of optimal routes is shown in the first question.

Sept1： snow sweeper number is 3.00

The three snow points are traversed in breadth, and the distance between the nodes in this group and the snow points is the smallest. The partition 8 is grouped, as shown in the figure:

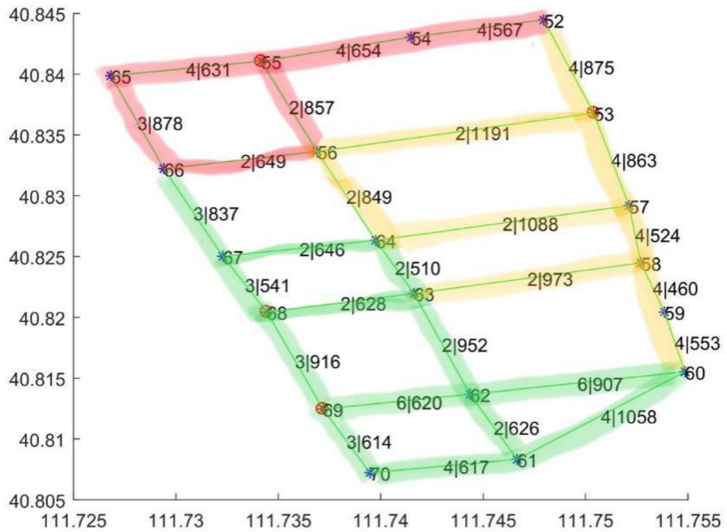

figure 5Grouping of partition 8

55 points :(55-65,65-66,66-56,55-56,55-54,54-52) length 13054 m

53 points :(52-53,53-56,56-64,53-57,64-57,63-58,57-68,58-59,59-60) m 21230

68
points :(66-67,67-64,64-63,63-62,62-60,60-61,61-62,61-70,70-69,69-62,69-68,68-67) length m 31310

If the length of 68 points is too large, if it takes too much time to clear snow with a snow removal equipment, it is necessary to add a group of snow removal equipment, which is considered to be divided into four groups.

Sept2: snow sweeper 4.00 hours

The four snow points are traversed in breadth first, and the distance between the nodes of the group and the snow points is the smallest. Among them ,556869 three snow points are at the boundary, and the snow transported there is less than half of the area that can be accumulated here. The grouping is shown in the figure:

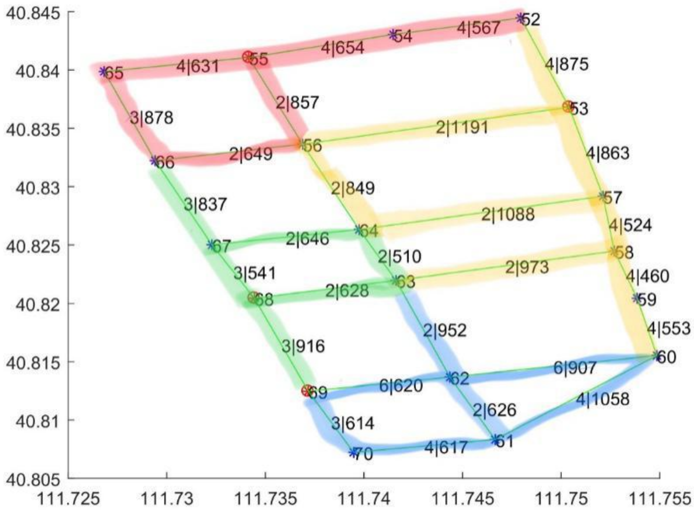

figure 6Grouping of partition 8

55 points :(55-65,65-66,66-56,55-56,55-54,54-52) length 13054 m

53 points :(52-53,53-56,56-64,53-57,64-57,63-58,57-68,58-59,59-60)
m 21230

68 points :(66-67,68-67,67-64,64-63,63-68,69-68) length 10450 m

69 points :(63-62,62-60,60-61,61-62,61-70,70-69,69-62) length 20860 m

fluery algorithm is used to find the optimal route for each group, and the truck working time is used as the snow removal time to obtain the working time and path table of each group, as shown below

Table 5Working time and path of Four Snow sweepers

Partition	Vehicles	Street	Length	Working hours	Effective time	Truck time	Path scheduling
8	4	55 points	13054 m	1.21 h	1.21 h	4.4172h	55-54-52-54-55-54-52-54-55-56-66-56-55-65-55-65-55-65-66-65-66

		53 points	21230 m	1.96 h	1.96 h	7.146 h	53-52-53-52-53-56-53-57-64-56-64-57-58-63-58-59-60-59-58-57-53-57-58-59-60-59-58-57-
		68 points	10450 m	0.97 h	0.97 h	3.4455h	69-68-63-64-67-64-63-68-67-66-67-68-69-68-67-66
		69 points	m 20860	193 h	193 h	6.1713h	69-62-63-62-61-62-60-61-70-61-60-61-70-61-60-62-69-62-60-62-69-70-69-70

The snow volume stored at each snow point is shown in the table below

Table 6Snow spot area

	53	55	68	69
Deposited	315	210	255	375
Total volume	648	480	504	450

Because of the optimal solution when the snow removal equipment is 4, the cleaning time of partition 8 is 7.1646 h, and the route planning and time of the other partitions are shown in the appendix.

4.3 Model establishment and solution of problem 3

4.3.1Analysis of model

Tixt for question three, determine the snow clearing plan, so that car owners remove roadside parking before snow removal, and clean up the streets as soon as possible, so that the parking space to resume use. Here, it is assumed that the parking space occupies one lane. In order to prevent traffic from being blocked, only 4/6/8 lanes have parking spaces on the highway and only one lane is occupied. Only when a street is completely cleared by a snow sweeper can the parking space be restored to use, so it takes as little time as possible to clean each street completely.

Considering that snow can be stacked in the green belt and can not be stacked in the green belt, the constraints of minimum street cleaning time can be added on the basis of the first question, and when the snow can not be stacked, On the basis of the second question, add the minimum constraints for street cleaning.

4.3.2E stablish of model

a_{ij} The adjacent matrix of the remaining street is obtained after removing the two-way 2 lanes. i-j the street exists, the value is 1 and the non-existence value is 0; the time when the street i-j begins to clear snow and the time when the street i-j ends the snow clearing. $a_{ij}y_{i-j}$ $a_{ij}y'_{i-j}$

Sept1： green belts can be stacked

Objective function:

$$\min \quad \max t_i (i=1,...,x)$$
$$\min \quad x$$
$$\min \quad \frac{1}{2}\sum_{i,j}(a_{ij}y_{i-j}-a_{ij}y'_{i-j})$$

Constraints:

$$\begin{cases} \max t_i (i=1,...,x) \le 3 \\ \sum_{i=1}^{x} v_1 t'_i = \sum_{i=1}^{m} h_i d_i \end{cases}$$

Sept2： the green belt can not be stacked

Objective function:

$$\min \quad \max t_i (i=1,...,x)$$
$$\min \quad x$$
$$\min \quad \frac{1}{2}\sum_{i,j}(a_{ij}y_{i-j}-a_{ij}y'_{i-j})$$

Constraints:

$$\begin{cases} \max t_i (i=1,...,x) \le 12 \\ \sum_{i=1}^{x} v_1 t'_i = \sum_{i=1}^{m} h_i d_i \\ \sum_{i=1}^{x} k_{ij} \le 1.2 c_j (j=1,...,n) \end{cases}$$

4.3.3Solution of model

Suppose the snow is cleared from 8:00.

Ti Sept1: green belts can be stacked

Since the use of three snow removal machines in question 1 is the optimal solution, and each path is given, for this question, an invalid road is added to each even lane. Let the snow sweeper clean up one road and pass an invalid road to the next node to start clearing the snow on the second road. So the snow removal time of each street is shown in the table:

Table 7Snow removal schedule

Street Street	Start	Conclusion	Street Street	Start	Conclusion
70-61	8:00	10:24	65-66	8:00	8:42
61-60	8:04	10:20	66-67	8:05	8:52
60-59	8:09	10:15	67-68	8:08	8:53
59-58	8:12	10:12	68-69	8:13	9:51
58-57	8:14	10:10	69-70	8:16	9:52
57-53	8:17	10:07	69-62	8:20	9:11

53-52	8:22	10:02	62-60	8:24	9:08
52-54	8:27	9:57			

Ti Sept2: the green belt can not be stacked

Because the four snow removal devices used in problem 2 are the optimal solution, and each path is given, according to the solution method step1 above, the snow removal time of each street is obtained as shown in the table:

Table 8Snow removal schedule

Street Street	Start	Conclusion	Street Street	Start	Conclusion
69-70	8:00	8:14	55-65	8:00	8:14
69-62	8:14	9:40	55-54	8:14	10:17
62-60	8:17	9:01	54-52	8:18	10:22
69-68	9:04	9:44	52-53	8:21	10:33
68-67	9:09	9:47	53-57	8:26	10:06
67-66	9:12	9:52	57-58	8:31	10:01
66-65	9:17	9:57	58-59	8:34	9:36
			59-60	8:37	9:57
			60-61	8:40	9:53

4.4 Model establishment and solution of problem 4

4.4.1Analysis of model

Tixt for question 4, considering the priority of the street, the high priority street needs to be cleaned up as soon as possible, so this question increases the target time-priority, that is, the end of the street cleaning time / the street priority as the optimization goal. Make the priority street clean as soon as possible. It can be seen from the diagram that most of the streets with higher priority are distributed around the snow points, so this question uses the grouping method of question 2 to clean up the streets with higher priority in each group. For simple operation, only the snow can be stacked in the green belt.

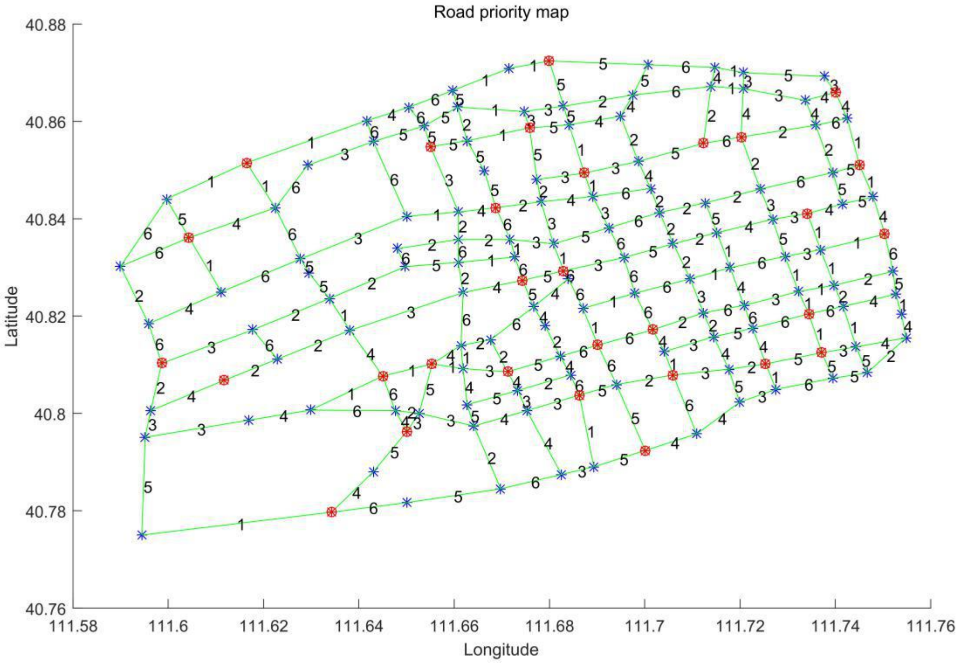

figure 7

4.4.2Analysis of model

Tixt priority of i-j street is $a_{ij}w_{i-j}$ 。 In this paper, we increase the time-priority as the optimization objective to obtain multi-objective nonlinear optimization:

Objective function:

$$\min \quad \max t_i (i = 1, \ldots, x)$$

$$\min \quad x$$

$$\min \quad \sum_{i,j} \frac{a_{ij} y'_{i-j}}{a_{ij} w_{i-j}}$$

Constraints:

$$\begin{cases} \max t_i (i = 1, \ldots, x) \le 3 \\ \sum_{i=1}^{x} v_1 t'_i = \sum_{i=1}^{m} h_i d_i \end{cases}$$

4.4.3Solution of model

In order to solve this problem, this question uses the grouping method of problem 2, and regards priority 4,5,6 as high priority, so the edge with priority 1,2,3 is removed from the adjacency matrix, and only the streets with high priority are completely cleaned.

Table 9Route

	Snow spots	Time	Route
8	53	1.2929	53-57-53-57-53-52-53-52-53-57-58-59-60-59-58-57-58-59-60-59-58-57
	55	0.8358	55-54-52-54-55-54-52-54-55-65-66-65-66-65

68	0.2965	68-63-58-63-68
69	1.0189	69-70-69-70-61-70-61-62-60-62-60-62-60-62-61-70

5.Strengths and Weakne s s

5.1 Strengths of model

Tixt, the city is partitioned according to the main road, the multi-objective nonlinear programming model is considered, and the greedy algorithm is used to solve the problem, and the local optimal solution of each region is obtained, and the global optimal solution is obtained.

The streets in the partition are grouped, and different problems are grouped flexibly to obtain better results.

In this paper, the specific numerical value is given, and the idea of solving the problem is described intuitively.

Weakness of model 5.2

Tixt in the third question, only consider the shortest time to clean up all streets, not to optimize the cleaning time of each street.In the fourth question, only the snow can be stacked in the green belt, not in the green belt.

References

[1] Yin Jie. Analysis on Snow Removing Operation and Maintenance Strategy of Expressway in Winter [J].] and Mass Standardization 2020(05):30-31.

[2] Wang Shi. Intelligent Design [J].] of Snow Removing Equipment Industrial Design ,2020(02):68-69.

[3] Xu Hongfei, Zhao Xueling. A Study on the Key Influencing Factors of the Operation Efficiency of Steam Snow Removing Vehicle [J].]1 Special purpose vehicle ,2019(09):84-88.

Appendix

Results of the first question:

Partition	Vehicles	Working hours	Effective time	
1	8	2.6097	2.6097	1-2-5-4-5-7-12-10-11-10-12-16-15-16-15-16-107-16-107-108-107-108-107-127-126-108
		2.6097	2.6097	108-126-129-130-131-4-131-4-131-130-132-130-129-126-127-107-16-12-7-5-2-1
		2.2006	2.2006	1-3-1-3-4-3-4-131-4-131-134-131-134-133-132-125-109-108-109
		2.3168	2.3168	109-108-109-125-109-125-132-125-132-133-132-133-134-133-134-131-4-3
		2.2956	2.2956	3-1-8-1-8-11-8-11-13-11-13-14-13-14-15-14-15-14-13-11-8-1
		2.2144	2.2144	2-3-2-3-2-3-2-6-2-6-2-6-7-6-7-6-7-128-7
		1.7197	1.7197	7-128-7-128-129-125-129-125-129-125-129-128-129-128-129-128-7-6-8-6-8-6-8
		2.1384	2.1384	8-6-9-6-9-6-9-10-9-10-9-10-14-10-14-10-14-10-9-6-2
2	7	2.1104	2.1104	109-119-109-119-118-117-116-117-116-117-118-117-118-119-118-119-120-118-120-121-122-121-120-124-137-124-120-119-109
		2.2939	2.2939	109-125-109-125-132-125-132-133-132-133-134-133-134-135-134-135-139
		2.1984	2.1984	139-135-139-138-139-138-140-115-116-115-116
		2.1321	2.1321	116-115-140-115-140-138-140-138-139-135-134-133-132-125-109
		2.0711	2.0711	116-121-116-121-116-121-123-121-123-121-123-122-123-122-123-122-141-122-141-122-141-138-141-138-141-138
		2.1766	2.1766	138-141-122-123-124-123-124-123-124-125-124-125-124-125-124-123-137-123-137-123-137
		1.9294	1.9294	137-136-135-136-135-136-135-136-137-136-137-136-137-123-121-116
3	4	2.7659	2.7659	15-19-24-23-24-25-26-21-16-21-26-31-26-91-90-91-92-91-106-21-106-105-104-105-108-105-106-107-106-91-26-25-30-25-24-29-24-19-15
		2.764	2.764	13-14-13-14-13-17-13-17-22-17-22-27-22-27-28-27-28-29-28-29-30-29-30-31-30-31-90-31-90-89-90-89-92-89-92-104-92
		2.778	2.778	92-104-109-104-109-108-107-16-15-14-15-14-15-16-15-16-107-16-107-108-107-108-109-108-109-104-92-89-90-31-30-29-28-27-22-17-13
		1.971	1.9712	14-18-14-18-14-18-17-18-19-20-21-20-19-18-23-18-23-18-23-28-23-28-23-28-23-18-14
4	5	2.0347	2.0347	87-95-94-88-94-93-92-93-94-95-96-97-96-95-101-100-99-98-99-100-101-102-101-111-110
		1.9743	1.9743	110-103-93-103-102-103-104-103-110-119-110-111-112-100-112-113-114-113-112-117-112-111-118-111-101-95-87

		2.9801	2.9801	84-85-84-85-84-97-84-97-98-97-98-114-98-114-115-114-115-116-115-116-117-116-117-118-117-118-119-109-104-92-89-88-87
		2.7946	2.7946	87-86-85-86-85-86-87-86-87-88-87-88-89-88-89-92-89-92-104-92-104-109-104-109-119-109-119-118-119-118-117-116-115-114-98-97-84
		2.0667	2.0667	85-96-85-96-85-96-99-96-99-96-99-113-99-113-99-113-116-113-116-113-116-113-99-96-85
5	4	2.68	2.68	42-39-38-37-38-39-33-34-29-34-35-36-35-34-33-30-33-32-31-32-77-90-77-78-77-40-76-40-41-40-77-32-33-39-42
		2.02	2.02	65-76-78-89-90-31-30-29-28-27-36-37-44-37-36-27-28-29-30-31-90-89-78-76-65
		2.02	2.02	65-76-78-89-90-31-30-29-28-27-36-37-44-37-36-27-28-29-30-31-90-89-78-76-65
		2.73	2.73	44-43-42-41-65-41-42-43-44-43-38-35-28-35-38-42-38-35-28-35-38-43-38-35-28-35-38-43-42-41-65
6	3	2.27	2.27	78-79-88-79-80-87-80-74-67-74-80-81-66-81-73-68-73-72-71-72-73-81-82-83-82-81-80-89-78
		2.31	2.31	70-71-83-84-85-86-87-88-89-78-76-65-66-75-79-75-66-65-76-78-89-88-87-86-85-84-83-71-70
		2.13	2.13	70-71-83-84-85-86-87-88-89-78-76-65-76-75-74-75-76-78-89-88-87-86-85-84-83-71-70
		2.38	2.38	70-69-72-82-85-82-72-69-72-82-85-82-72-69-72-82-85-82-72-69-68-67-66-67-68-69-70-69-68-67-66-65
7	3	1.62	2.38	45-46-42-46-50-46-47-41-47-51-47-54-55-65-55-54-55-65-55-54-47-46-45
		1.81	1.81	54-52-51-50-49-48-44-48-49-50-51-52-54-52-51-50-49-48-44-48-49-50-51-52-54
		1.89	1.89	65-41-42-43-44-43-42-41-65-41-42-43-45-49-45-43-45-49-45-43-45-49-45-43-44
8	3	2.14	2.14	61-62-63-68-63-58-63-64-67-64-57-64-56-66-56-53-56-55-65-55-65-55-54-55-54-55-56-64-63-62-61
		2.04	2.04	70-61-60-59-58-57-53-52-54-52-53-57-58-59-60-61-70-61-60-59-58-57-53-52-54-52-53-57-58-59-60-61-70
		1.90	1.90	65-66-67-68-69-70-69-68-67-66-65-66-67-68-69-62-60-62-69-62-60-62-69-62-60-62-69-70

Results of the second question:

Partition	Vehicles	Working hours	Effective time	Transport time	Path
1	8	2.346	2.346	14.649	2-5-4-5-7-12-10-11-10-12-16-15-16-15-16-107-16-107-108-107-108-107-127

		2.540	2.540	14.321	2-1-2-5-7-12-16-107-127-126-129-130-132-130-131-4-131-4-131-130-129-126-108-126-127
		2.296	2.296	11.517	8-1-8-11-8-11-13-11-13-14-13-14-15-14-15-14-13-11-8-1-3-1
		2.301	2.301	8.482	131-4-3-4-3-4-131-134-133-134-133-132-133-132-125-132-125-109
		1.306	1.306	5.492	131-4-131-134-131-134-133-132-125-109-108-109-108-109
		2.214	2.214	11.302	2-3-2-3-2-3-2-6-2-6-2-6-7-6-7-6-7-128-7
		1.720	1.720	8.690	8-6-8-6-8-6-7-128-129-128-129-128-129-125-129-125-129-125-129-128-7-128-7
		2.138	2.138	10.069	8-6-9-6-9-6-9-10-9-10-9-10-14-10-14-10-14-10-9-6-2
		2.110	2.110	10.046	120-121-122-121-120-124-137-124-120-119-109-119-109-119-118-117-116-117-116-117-118-117-118-119-118-119-120-118
		2.006	2.006	8.892	133-132-125-109-125-109-125-132-125-132-133-132-133-134-133
		2.006	2.006	8.892	133-132-125-109-125-109-125-132-125-132-133-132-133-134-133
2	7	1.699	1.699	6.529	133-134-135-139-138-140-138-140-115-140-115-116
		2.071	2.071	8.191	138-141-138-141-138-141-122-141-122-141-122-123-122-123-122-123-121-123-121-123-121-116-121-116-121-116
		1.303	1.303	4.062	138-141-122-123-124-123-124-123-124-125-124-125-124-125-124
		2.700	2.700	15.761	124-123-137-123-137-123-137-136-135-136-135-136-135-136-137-136-137-136-137-123-121-116
3	4	2.661	2.661	9.783	24-23-24-25-26-21-16-21-26-31-26-91-90-91-92-91-106-21-106-105-104-105-108-105-106-107-106-91-26-25-30-25-24-29-24-19-15-19

		2.778	2.778	11.622	92-104-109-104-109-108-107-16-15-14-15-14-15-16-15-16-107-16-107-108-107-108-109-108-109-104-92-89-90-31-30-29-28-27-22-17-13
		2.764	2.764	10.905	92-104-92-89-92-89-90-89-90-31-90-31-30-31-30-29-30-29-28-29-28-27-28-27-22-27-22-17-22-17-13-17-13-14-13-14-13
		1.971	1.971	7.918	21-20-19-18-23-18-23-18-23-28-23-28-23-28-23-18-14-18-14-18-14-18-17-18-19-20
		2.035	2.035	7.229	87-95-94-88-94-93-92-93-94-95-96-97-96-95-101-100-99-98-99-100-101-102-101-111-110
		1.974	1.974	7.759	87-95-101-111-118-111-112-117-112-113-114-113-112-100-112-111-110-119-110-103-104-103-102-103-93-103-110
4	5	2.980	2.980	12.507	87-88-89-92-104-109-119-118-117-118-117-116-117-116-115-116-115-114-115-114-98-114-98-97-98-97-84-97-84-85-84-85-84
		2.795	2.795	11.794	87-86-85-86-85-86-87-86-87-88-87-88-89-88-89-92-89-92-104-92-104-109-104-109-119-109-119-118-119-118-117-116-115-114-98-97-84
		2.067	2.067	7.645	85-96-85-96-85-96-99-96-99-96-99-113-99-113-99-113-116-113-116-113-116-113-99-96-85
		2.680	2.680	13.384	42-39-38-37-38-39-33-34-29-34-35-36-35-34-33-30-33-32-31-32-77-90-77-78-77-40-76-40-41-40-77-32-33-39-42
5	4	2.020	2.020	8.7279	30-31-90-89-78-76-65-76-78-89-90-31-30-29-28-27-36-37-44-37-36-27-28-29-30
		2.020	2.020	8.7279	30-31-90-89-78-76-65-76-78-89-90-31-30-29-28-27-36-37-44-37-36-27-28-29-30
		2.810	2.730	13.878	42-41-65-41-42-43-44-43-38-35-28-35-38-42-38-35-28-35-38-43-38-35-28-35-38-43-42-43-44-43-42-41-65

		2.270	2.270	9.109	72-71-72-73-68-73-81-82-83-82-81-86-81-80-81-73-74-80-87-80-79-78-79-88-79-80-74-73-72
		2.270	2.310	11.565	87-86-85-84-83-71-70-71-83-84-85-86-87-88-89-78-76-65-66-75-79-75-66-65-76-78-89-88-87
6	3	2.270	2.130	10.899	85-84-83-71-70-71-83-84-85-86-87-88-89-78-76-65-76-75-74-75-76-78-89-88-87-86-85
		2.410	2.380	8.594	69-72-82-85-82-72-69-72-82-85-82-72-69-72-82-85-82-72-69-70-69-70-69-68-67-66-67-68-69-68-67-66-65
		1.620	1.620	5.644	42-46-45-46-50-46-47-41-47-51-47-54-55-65-55-54-55-65-55-54-47-46-42
7	3	1.810	1.620	6.940	49-48-44-48-49-48-44-48-49-50-51-52-54-52-51-50-49-50-51-52-54-52-51-50-49
		1.960	1.890	7.342	42-43-44-43-42-43-44-43-45-49-45-43-45-49-45-43-45-49-45-43-42-41-65-41-42-41-65
		1.890	1.890	4.4172	55-54-52-54-55-54-52-54-55-56-66-56-55-65-55-65-55-65-66-65-66
8	3	2.290	2.290	7.1646	53-52-53-52-53-56-53-57-64-56-64-57-58-63-58-59-60-59-58-57-53-57-58-59-60-59-58-57-53
		1.930	1.900	3.4455	69-68-63-64-67-64-63-68-67-66-67-68-69-68-67-66
				6.1713	69-62-63-62-61-62-60-61-70-61-60-61-70-61-60-62-69-62-60-62-69-70-69-70

code

All code test pass(MATLAB R2017a)

eulerGraph.m

```
% Euler circuit class
% The constructor input adjacency matrix a, a(i,j) represents the number of paths i to j
classdef eulerGraph < handle
    properties
        graphInp, nVertices, oddVertex , eulerIncludedEdges, eulerAnsArray , visited ;
    end
    methods
        function obj = eulerGraph(edges)
            obj.graphInp=edges;
```

```
        obj.nVertices = size(obj.graphInp,1);
    end
    function isIt = isEuler(obj)
        oddVertexCount=0;
        %returns 1 if Euler's Path , 2 if Euler's Circuit , 0 if NONE.
        %Function Assumes that graph is connected.If not, a simple dfs will do.
        for i=1:1:obj.nVertices
            sumRow = sum(obj.graphInp(i,:));
            if mod(sumRow,2)~=0
                oddVertexCount = oddVertexCount+ 1;
                obj.oddVertex = i ;
            end
        end
        if oddVertexCount==0
            obj.oddVertex = 1;
        end
        if oddVertexCount==0 || oddVertexCount == 2
            isIt=1;
        else
            isIt=0;
        end
    end
    function ansArray = startEuler(obj)
        if ~obj.isEuler()
            fprintf('The Graph Matrix Input Does not have a valid Euler Path/Circuit\n');
        end
        obj.eulerIncludedEdges = 0;
        obj.eulerAnsArray= {};
        u=obj.oddVertex;
        obj.storeEuler(u);
        ansArray = obj.eulerAnsArray;
    end
    function storeEuler(obj,vertex)
        %fprintf('here at %d\n',vertex);
        for i=1:1:obj.nVertices
            adj = obj.graphInp(vertex,i);
            %fprintf('at edge %d-%d\n',vertex,i);
            if adj~=0 && obj.isValidNextEdge(vertex,i)
                obj.eulerIncludedEdges = obj.eulerIncludedEdges +1;
                obj.eulerAnsArray{obj.eulerIncludedEdges,1} = vertex;
                obj.eulerAnsArray{obj.eulerIncludedEdges,2} = i;
                obj.rmvNormalEdge(vertex,i);
                obj.storeEuler(i);
            end
```

```
            end
        end
        function rmvNormalEdge(obj,u,v)
            obj.graphInp(v,u) = obj.graphInp(v,u) -1;
            obj.graphInp(u,v) = obj.graphInp(u,v) -1;
        end
        function addNormalEdge(obj,u,v)
            obj.graphInp(u,v) = obj.graphInp(u,v)+ 1;
            obj.graphInp(v,u) = obj.graphInp(v,u)+ 1;
        end
        function isValid= isValidNextEdge(obj,u,v)
            %fprintf('at edge checking if valid %d-%d\n',u,v);
            remVertices=0;
            for i= 1:1:obj.nVertices
                if obj.graphInp(u,i)~=0
                    remVertices = remVertices+ 1;
                end
            end
            obj.visited = zeros(1,obj.nVertices);
            countWithEdge = obj.dfsCount(u);
            obj.rmvNormalEdge(u,v);
            obj.visited = zeros(1,obj.nVertices);
            countWithoutEdge = obj.dfsCount(u);
            obj.addNormalEdge(u,v);
            isValid = (remVertices==1 || countWithEdge==countWithoutEdge);
        end
        function countVisited = dfsCount(obj,u)
            obj.visited(u)=1;
            countVisited=1;
            %fprintf('Visited %d\n',u);
            for i= 1:1:obj.nVertices
                if obj.graphInp(u,i)~=0 && ~obj.visited(i)
                    countVisited = countVisited + obj.dfsCount(i);
                    %fprintf('Increased count for %d->%d',u,i);
                end
            end
        end
    end
end
```

test.m

```
clear;clc;
load('date5.mat')%Import different data according to different partitions
% p=[1 2 4 5 7 10 11 12 15 16 107 108 126 127 129 130 131 132];% 1part--2
```

```
% p=[1 3 4 8 11 13 14 15 108 109 125 131 132 133 134];% 1part--4
% p=[2 3 6 7 8 9 10 14 125 128 129];% 1part--6
% p=[109 116 117 118 119 120 121 122 124 137];% 2part--2
% p=[109 115 116 125 132 133 134 135 138 139 140];% 2part--4
% p=[116 121 122 123 124 125 135 136 137 138 141];% 2part--6
% p=[15 16 19 21 23 24 25 26 29 30 31 90 91 92 104 105 106 107 108];% 3part--2
% p=[13 14 15 16 17 22 27 28 29 30 31 89 90 92 104 107 108 109];% 3part--4
% p=[14 17 18 19 20 21 23 28];% 3part--6
% p=[87 88 92 93 94 95 96 97 98 99 100 101 102 103 104 110 111 112 113 114 117 118 119];% 4part--2
% p=[84 85 86 87 88 89 92 97 98 104 109 114 115 116 117 118 119];% 4part--4
p=[85 96 99 113 116];% 4part--6
h=[];
for i=1:length(p)
     h=[h find(load1==p(i))];
end
% h=sort(h);
inp=[];
for i=1:length(h)
   inp(i,:)=A1(h(i),h);
end
% inp=hj(inp);

%% The upper and lower parts run separately
% inp = [
%       0 2 0 0 0;
%       2 0 2 0 0;
%       0 2 0 2 2;
%       0 0 2 0 0;
%       0 0 2 0 0
%       ];
a = eulerGraph(inp);
c=a.startEuler();

% bg=biograph(inp);
% view(bg)

flag=[];
for i=1:length(c)
     flag=[flag p(c{i,1})];
end
flag=[flag p(c{end,end})];%Get the full path


t=0;
```

```
s=0;
time=0;
for i=1:length(flag)-1
    start=flag(i);
    finish=flag(i+1);
    x=find(load1==start);
    y=find(load1==finish);
    if A1(x,y)>0
        t=t+distance1(x,y)/3;
        s=s+distance1(x,y);
        A1(x,y)=A1(x,y)-1;
        A1(y,x)=A1(y,x)-1;
    else
        t=t+distance1(x,y)/6;
        s=s+distance1(x,y);
        A1(x,y)=A1(x,y)-1;
        A1(y,x)=A1(y,x)-1;
        time=time+1;
    end
end

time
t=t/3600
s
```

rt.m

```
% First question
%
%%
n=length(a);
c1=0;
c2=0;
k=33;
for i=1:k
    c1=c1+distance(a(i),a(i+1));
    fprintf('%d-',a(i))
end
fprintf('\n')
t=c1/3/3600
for i=k:n-1
    c2=c2+distance(a(i),a(i+1));
    fprintf('%d-',a(i))
end
c2=c2+distance(a(i+1),a(1));
```

```
fprintf('%d',a(1))
t=c2/3/3600

%%
n=length(a);
c1=0;
c2=0;
c3=0;
k=26;
for i=1:k
    c1=c1+distance(a(i),a(i+1));
    fprintf('%d-',a(i))
end
fprintf('\n')
t=c1/3/3600

for i=k:k+20
    c2=c2+distance(a(i),a(i+1));
    fprintf('%d-',a(i))
end
k=i;
fprintf('\n')
t=c2/3/3600
for i=k:n-1
    c3=c3+distance(a(i),a(i+1));
    fprintf('%d-',a(i))
end
c3=c3+distance(a(i+1),a(1));
fprintf('%d',a(1))
t=c3/3/3600
```

fun.m

```
function [times,ji]=fun(distance,v,ji)
n=length(ji);
t=inf;
for i=1:n
    [distance1,path]=Dijk(distance,v,ji(1,i));
    if(t>distance1)
        t=distance1;
        path0=i;
    end
end
ji(2,path0)=ji(2,path0)+15;
times=t/(8*3600);
```

Dijk.m

```
function [distance1,path]=Dijk(w,st,e)
ind = find(w == 0);
w(ind) = inf;
for i=1:length(w)
    w(i,i)=0;
end
n=length(w);
d=w(st,:);
visit=ones(1,n);
visit(st)=0;
parent=zeros(1,n);

path=[];

for i=1:n-1
    temp=[];
    for j=1:n
        if visit(j)
            temp=[temp d(j)];
        else
            temp=[temp inf];
        end
    end
[value,index]=min(temp);
visit(index)=0;
for k=1:n
    if d(k)>d(index)+w(index,k)
        d(k)=d(index)+w(index,k);
        parent(k)=index;
    end
end
end

distance1=d(e);
t=e;
while t~=st&&t>0
    path=[t,path];
    p=parent(t);
    t=p;
end
path=[st,path];
```

```
end

test2.m
clear
clc
load('mat.mat')
load('width.mat')
load('distance.mat')
s=[2 5 4 5 7 12 10 11 10 12 16 15 16 15 16 107 16 107 108 107 108 107 127];
jxd(1,:)=[2 8 15 131 133];
jxd(2,:)=0;
n=length(s);
sum=0;
total=0;
t0=800/(10*3600)+0.2;
for i=2:n
    x=s(i-1);
    y=s(i);
    d=distance(x,y);
    sum=sum+d;
    if(sum>800)
        sum=sum-800;
        [tt,jxd]=fun(distance,s(i-1),jxd);
        time=abs(min(sum,d-sum))/(8*3600)+tt;
        total=total+t0+time*2;
    end
end
total
jxd
```