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T3 ________________	Problem Chosen	F3 ________________
T4 ________________	**A**	F4 ________________

2020
MCM/ICM
Summary Sheet

The Comprehensive Evacuation Planing Model in Case of Emergency

Summary

Keywords: VRP; optimal path; Tyson polygon; Time-varying curve; Time-varying curve

Contents

1 Introduction

1.1 Background

Changes in global ocean temperature will cause various marine lives to migrate. When the temperature varies too great, these animals can no longer survive and they will migrate to more suitable habitats.

herring and mackerel are very important pelagic fish in the Scottish fisheries. herring is widely distributed throughout the Northeast Atlantic, while mackerel is mostly distributed in the North and West Seas. They are located in the deep water during the day and move towards the surface at dusk and spread over a wide area.

It has been suggested that observed spatial variation in mackerel fisheries, extending over several hundreds of kilometers, is reflective of climate-driven changes in mackerel migration patterns.

In recent years, with the global ocean temperature rising, the distribution of these populations has changed dramatically. However, the geographic population shift may seriously affect the disrupt the livelihood of the smaller Scottish Fisheries companies who depend on these ocean-dwelling species.

1.2 Problem Restatement

In order to develop the Scottish fishing industries steadily, we need to analyze the characteristics, requirements, and interactions of herring and mackerel

1. How does the location of herring and mackerel change according to temperature

2. What are the best case, worse case and most likely time about small fishing companies based on the rate

3. Whether these small fishing companies should change the way they operate, what is the best way to run a small fishing company

4. What will happen if a certain percentage of fishery enters the territorial seas of another country

5. What solutions will improve the future business prospects of fishermen

1.3 Our Work

2 Assumptions

To simplify our problems, we make the following basic assumptions, each of which is properly justified.

- Assumed that the fishing time of Scottish vessels negligible
- Assumed that the ship travels in a straight line and its sailing route is from the port to the center of the position of fish.
- Supposed that the salaries of crews in Scotland are equal to the average wage of the British people, at 7 pounds per hour.
- Supposed that large size ferries in Scotland generally have 20 crew members and small Scottish ships generally have 8 crew members.
- Assumed that the maximum catch per vessel of a small Scottish company is 10 percent of its own weight
-

3 List of Notation

Table 1: The List of Notation

Symbol	Meaning
L	The length of the Scottish vessels
B	The width of the Scottish vessels
D	The height of the Scottish vessels
W	The weight of the Scottish vessels
d	The waterline length of the Scottish vessels
l	Length between perpendiculars
v	The average velocity of the Scottish vessels
P	The average power of the Scottish vessels
P_0	The average power of small Scottish vessels
V	The displacement of the Scottish vessels
V_o	The volume of the fuel consumption
A_1	Total purchase cost of a Scottish vessel
A_2	Total salary of a crew member
A_3	Total fuel cost of a Scottish vessel
A	total cost of a Scottish vessel
A_e	Extra cost for one voyage.
c_1	The purchase cost of a Scottish vessel per hour

c_2	The salary of a crew member per hour
c_3	The fuel cost of a Scottish vessel per hour
T_1	The time spent in fishing of a Scottish vessel
T_2	Fish preservation time at ambient temperature
S	The distance sailed of a Scottish vessel
a	Fish density ratio
a_o	Oil density
k	Unit fixed cost of the ship
r_o	Fuel consumption ratio
E	The earnings of herrings and mackerels
E_0	The small Scottish vessel's earnings of herrings and mackerels
E_1	The earnings of herrings
E_2	The earnings of mackerels
p_1	The price of herrings
p_2	The price of mackerels
p_o	The price of oil
n_1	The number of crew in large size ferries
n_2	The number of crew in small size ferries

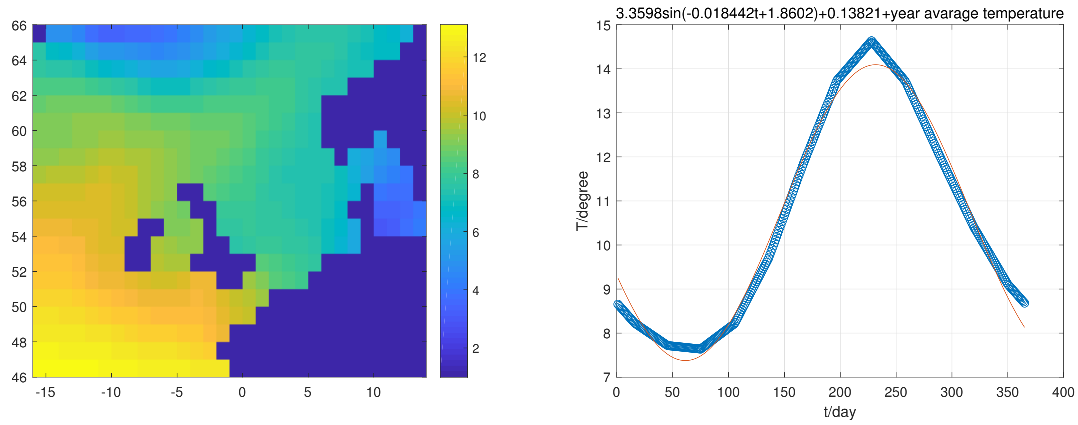
4 The fish accumutation model

4.1 The varying temperature model

[4]

4.1.1 basic idea

There are many factors can affect the temperature of the oscan, and the changing of the sea surface temperature(SST) can be regarded as short monthly average temperature change and long-term yearly average temperature change from a time perspective, and spatial distribution from geographical perspective. We separate those changing trend by analyzing the data from project ERSST which contains $1\deg$ resolution data from 1981 to 2010 and $2\deg$ data from 1854 to 2020. Specificly, we use the long-term data to predicte the yearly change, and use high resolution data to be the begining of long-term prediction as well as to analyze the spatial distribution and the monthly change. The area we analyze lies in W15.5 to E13.5 and N46.5 to 65.5.



(a) spatial temperature distribution

(b) monthly changing and fit

Figure 1:

4.1.2 monthly changing

In our model, we assume that the monthly change has a central value related to yearly avarage temperature. We also assume that the monthly change are determined by the seasonal change and not only independent of the factors affect the change of yrarly avachange temperature, but also much stronger than the change of yearly average temperature. A long-term monthly avarage are made based on SST data from 1981 to 2010. Since the seasonal change of temperature are mostly related to the rotation of the earth, it is convenience to suppose this change has a trigonometric form.

4.2 The fish-temperature model

As we known, fish need the proper habitat to service, and temperature play an important role in multiply of fish, such as the mackerel population is found further upstream in warmer waters as the current cools through winter[3]. In our previous predictions, the increase of SST because global warming is obvious, so we take fisheries data from The International Council for the Exploration of the Sea(ICES) and make a comparison.

According to the graph, we can tell that besides fisheries productivity growth and some statistical gaps, the density of fish is particularly relevant to SST. So we use Pearson correlation coefficient to correlation analysis.

Table 2: The result of correlation analysis

result	herring	mackerel
r	0.4637	0.5463

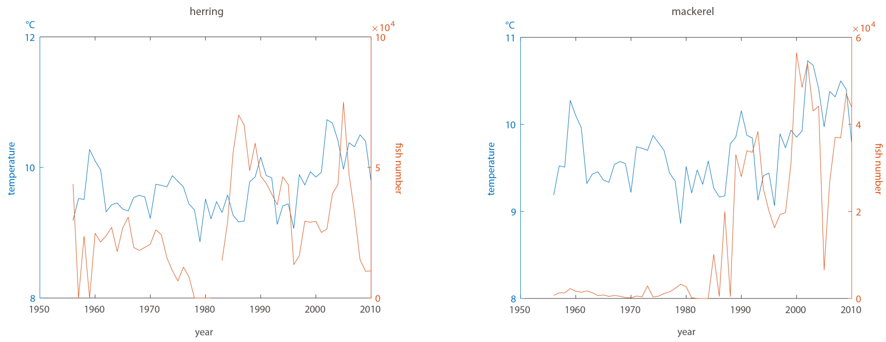


Figure 2: Comparison graph

So it's highly correlative. Then we use them to fitting the Gaussian distribution, and get the desired relationship between temperature and fish density.

4.3 The predicted fish accumutation distribution

5 The Demand Distribution Model

5.1 Cost and profit

Table 3: The range dimension ratios of trawlers

parameter	L/B	B/d	D/d
Range of steel materials	3.93-5.00	2.38-3.65	1.19-1.38
Range of wood materials	3.19-4.53	2.61-4.67	1.06-1.44

As can be seen from the 2016 Scottish Marine Statistics (Table 3), most of the Scottish vessels that capture herring and mackerel are larger than 40 meters in length. Figure 6 is the structural model of the ship. We simplified the structure of

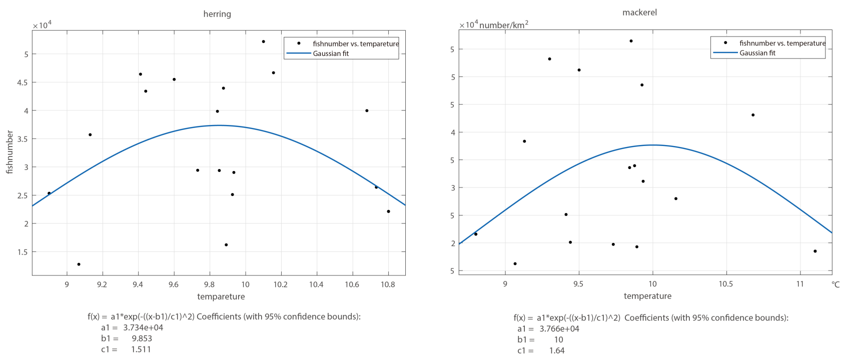


Figure 3: Fitting result

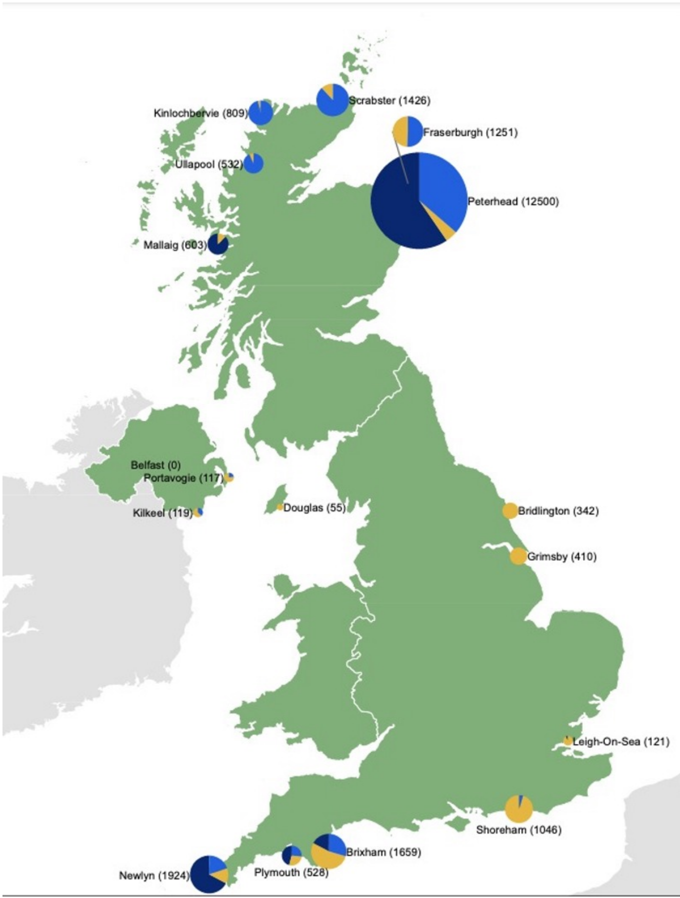


Figure 4: English Harbor Division

the ship to a cuboid, and the relationship between its length, width, and height is shown in Table 3. We assume that the length of the Scottish vessels in small company is about 40 meters, the width is one quarter of its length, the height of the waterline is one twelfth of the length, and the length between the perpendiculars is equal to the length of the boat.

From Table 4, it is estimated that the average power of a 40-meter-long Scottish vessel is 4000 kilowatt and. the average tonnage is about 1300 tonnes. The speed and flight time are calculated from the speed-related formula.

Table 4: The prices of two species : 2012 to 2016

Year	2012	2013	2014	2015	2016	average
Herring (pound per tonne)	565	408	308	369	665	463
Mackerel (pound per tonne)	1034	979	832	664	895	880.8

Table 5: The information about Scottish registered vessels

vessel length (metres)	<=10	10-12	12-15	15-24	24-40	>=40
Herring (tonnes)	0	0	0	7	1505	63031
Mackerel (tonnes)	811	0	0	42	3802	183831
Average tonnage (tonnes)	4	13	22	110	273	1748
Average age (year)	26	33	29	31	28	17
Average engine power (kW)	57	127	190	325	641	4327

$$\begin{cases} v = 1.84 \times \ (\frac{P}{V})^{0.237} \times \sqrt{l} \\ l = L \approx 40 \\ P = 4000 \\ V = L \times B \times \ d = \frac{1}{48 \times L^3} \end{cases} \tag{1}$$

$$T = \frac{S}{v} \tag{2}$$

$$A_1 = c_1 \times T_1 \tag{3}$$

$$A_2 = c_2 \times T_1 \times n_1 \tag{4}$$

$$A_3 = V_o \times p_o \tag{5}$$

$$\begin{cases} V_o = r_o \times P \times T_1 \times a_o \\ a_o = 0.8 \\ p_o = 0.5 \\ A_3 = V_o \times p_o \end{cases} \tag{6}$$

$$A = A_1 + A_2 + A_3 + A_e \tag{7}$$

Where:

A_1 represents the average working cost per hour of the large Scottish vessel.As a Scottish vessel with a length of 40 meters, the purchase price is approximately 44,000 pounds, the number of days of operation is 180 days per year, and the daily working time is 13 hours.

A_2 is the cost that the small company need to pay about 20 crew members during a voyage

A_e is a fixed cost of about 20,000 pounds for a small sailing company in Scotland, including depreciation fees for fishing boats, fishing nets, hook fees, port fees, and loss costs during the off-season.

$$\begin{cases} E_1 = 1300 \times 10\% \times a_1 \times p_1 \\ E_2 = 1300 \times 10\% \times a_2 \times p_2 \\ E = \frac{a_1 \times p_1}{a_1 \times p_1 + a_2 \times p_2} \times E_1 + \frac{a_2 \times p_2}{a_1 \times p_1 + a_2 \times p_2} \times E_2 \end{cases} \tag{8}$$

The weighted average prices and the proportion of density in different regions of herring and mackerel is used to calculate the earnings of small Scottish companies during a voyage.

Since no refrigerant fishing, in order to ensure fresh fish, the return time of Scottish vessel must be shorter than the fresh-keeping period of the fish

$$\frac{T_1}{2} \leq T_2 \tag{9}$$

5.2 the spatial profit distribution model

We have obtained the predicted fish density distribution in last section, and after the work above we can caulate the net profit by the sailing cost, the gross profit from fishing, and a constant cost appears on every yoyage.

It can be seen from the figure(a) and (b) that there is no obvious change in the income of fishing in 10 years, which is because the slow increase of sea temperature has a time lag to the migration of fish. After 25 years (c), the largest income gradually migrates northward. Fifty years later, the school of fish is obviously moving north. At this time, the port is far from the school of fish, and the fishing cost will increase significantly (d)

Due to the limitation of fish preservation time, Scotland small company can make a large profit offshore. From the comparison about the offshore distance and income (e), it can be concluded that when the distance is less than 200 kilo-

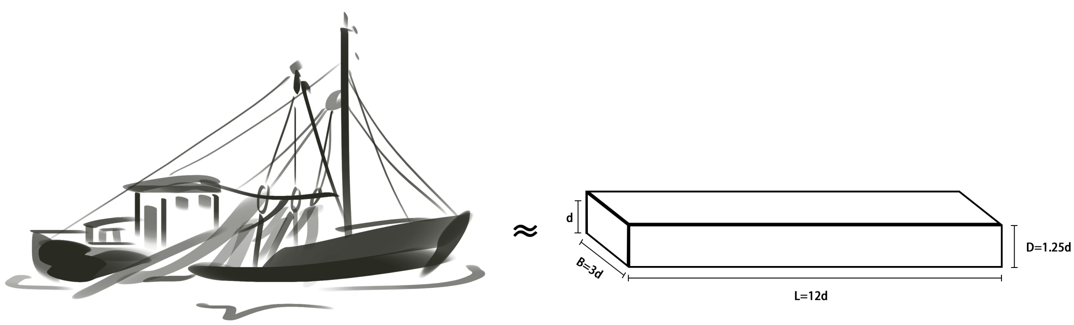
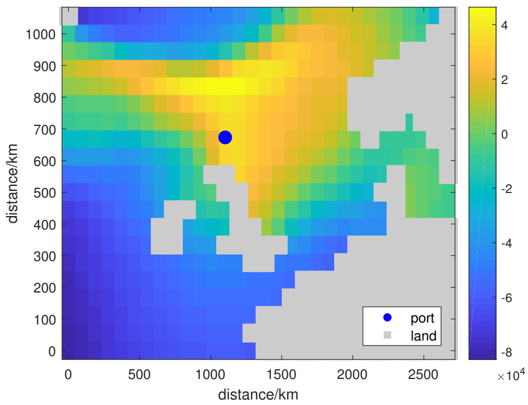


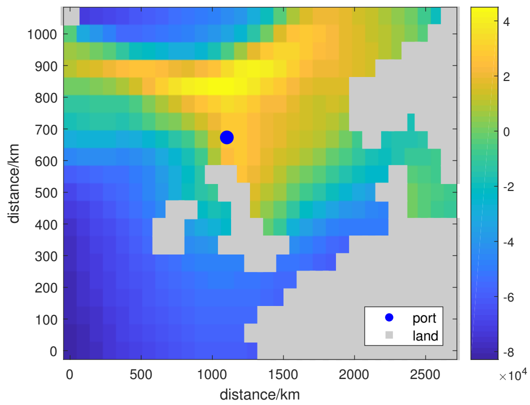
Figure 5: The model of a ship

meters, the company's profit is positively related to the density of the local fish school. There are obvious differences in various years, because the fish school moves northward with the change in temperature. As can be seen from the figure (f) that after about 40 years, the net profit will drop to 0. Therefore, these small companies should take measures in advance to deal with changes in fish stocks.

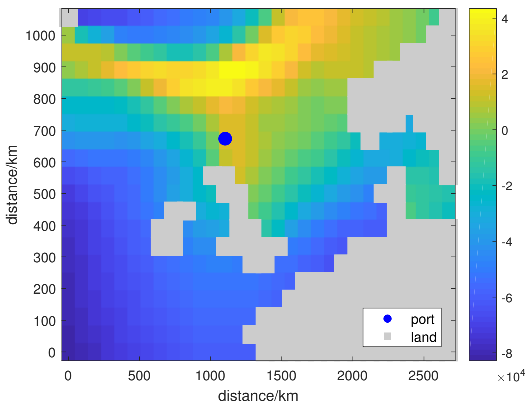
However, when the distance is more than 200 kilometers, due to the higher inherent cost of navigation, the fishing income will decline rapidly, showing a consistent downward trend among different years. At the same time, the 50-year net profit curve fluctuated slightly compared to others due to the change in the position of fish density.



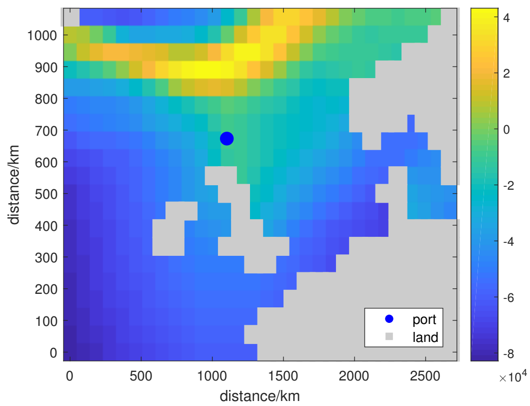
(a) spatial net profit distribution after 0 years



(b) spatial net profit distribution after 10 years



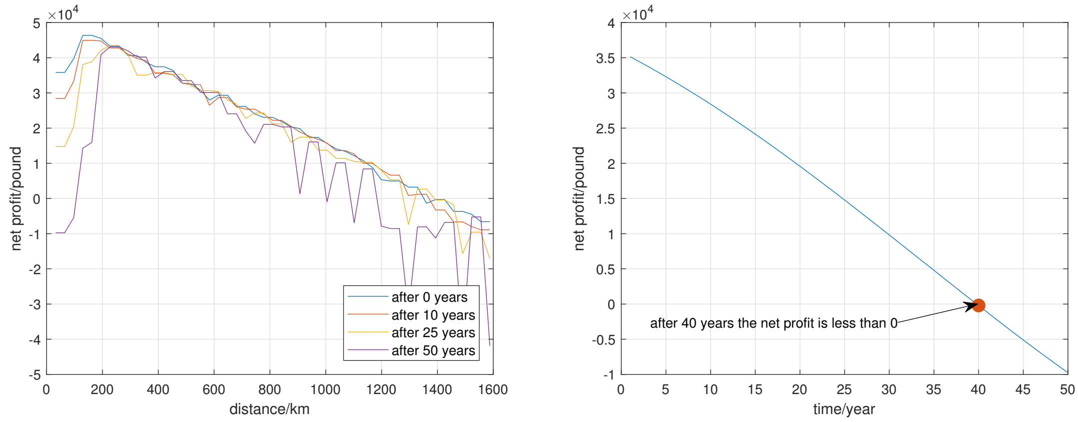
(c) spatial net profit distribution after 25 years



(d) spatial net profit distribution after 50 years

6 The third question

Assume that the fishing boat is a cuboid with a length of L, and its width and height are consistent with the previous assumptions.



(e) the realationship between distance and net profit

(f) the elapsed time

Figure 6:

Based on the data in Table 5, the power and mass corresponding to the different lengths of small fishing boats in Scotland are fitted to the relevant functional relations.The speed and flight time are calculated from the speed-related formula.

$$v = 1.84 \times (\frac{P_0}{V})^{0.237} \times \sqrt{l} \tag{10}$$

$$\begin{cases} P_0 = P \times (1 - 0.2) \\ P = 0.3358 \times L^2 - 9.4446 \times L - 3.6361 \end{cases} \tag{11}$$

$$V = L \times B \times d = \frac{1}{48 \times L^3} \tag{12}$$

$$l = L \approx 40 \tag{13}$$

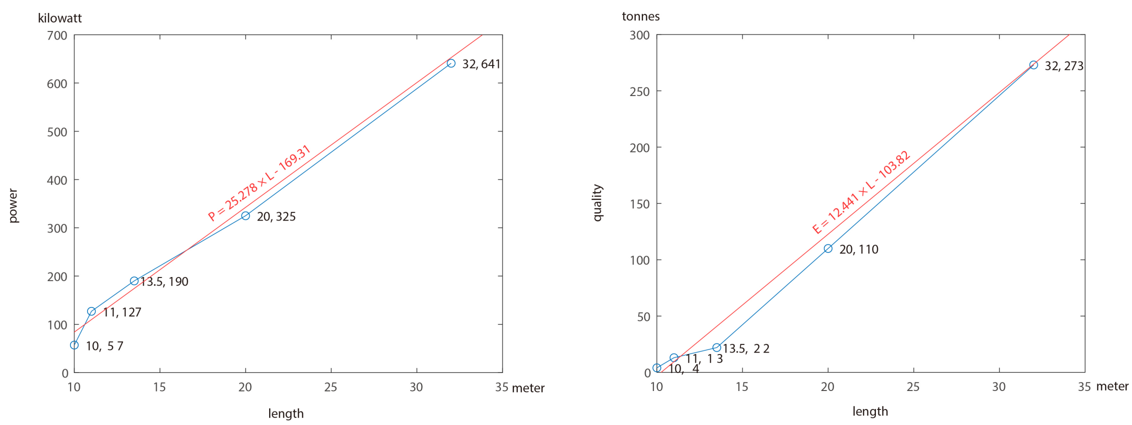


Figure 7: The model of a ship

$$T_1 = \frac{S}{v} \tag{14}$$

$$\begin{cases} V_o = r_o \times P \times T_1 \times a_o \\ a_o = 0.8 \\ p_o = 0.5 \\ A_3 = V_o \times p_o \end{cases} \tag{15}$$

$$\begin{cases} A_1 = k_1 \times T_1 \times L \\ A_2 = c_4 \times T_1 \times n_2 \\ A_3 = V_o \times P_o \\ A = A_1 + A_2 + A_3 + A_e \end{cases} \tag{16}$$

$$\begin{cases} E = 0.3203 \times L^2 - 1.5264 \times L - 2.973 \\ E_1 = E \times 10\% \times a_1 \times p_1 \\ E_2 = E \times 10\% \times a_2 \times p_2 \\ E = \frac{a_1 \times p_1}{a_1 \times p_1 + a_2 \times p_2} \times E_1 + \frac{a_2 \times p_2}{a_1 \times p_1 + a_2 \times p_2} \times E_2 \end{cases} \tag{17}$$

7 The Comprehensive Evacuation Planning Model

7.1 Model Preparation

VRP [1, 2] generally

Based on the traditional VRP, a comprehensive evacuation planning model is established to satisfy the constraint conditions:

- Time constraint: the total withdrawal time is the shortest in the case of meeting all the evacuees' needs and not violating the constraints;

7.2 Modeling

-
-

time is crucial [8, 9].

as is shown in Figure 6.

ve Evacuation Problem (CEP)[5–7]

In this mixed integer program we use the following variables: δ_{ij} denotes traversal of arc (i,j) $\in$ A. x_{ij}^t denotes the spend time passing arc (i,j). r_{ij}^t denotes the risk factor passing arc (i,j) at time t. f_{ij}^t denotes the number of evacuees using cars passing arc (i,j) at time t. In contrast, g_{ij}^t denotes the number of evacuees using bus b to go from node i to node j at time t. η represents the jam factor, which depends on the magnitude of the hurricane, the location of the landing, and the average number of evacuees passing arc (i,j) at time t. B_{ij}^t denotes the number of bus driving on arc (i,j) at time t.In the same way, C_{ij}^t denotes the number of car driving on arc (i,j) at time t. P_j^t denotes the number of people in the j shelter at time t. r denotes the capacity factor.

7.3 Model Solution

Based on the above model and the parameters involved in the model, the final evacuation time is obtained by programming, and the result is shown in the table below:

8 Strengths and Weaknesses

8.1 Strengths

- The comprehensive evacuation planning model takes the shortest time and lowest risk and low economic losses as the total constraint conditions to get the optimal solution;

8.2 Weaknesses and Extensions

- Without considering the evacuation of the county itself;
- Without considering the refueling problem of cars and buses;
- Without considering the risk caused by large numbers of people in station nodes;
- Without considering other means of transportation, such as aircraft, railway, etc.;
- Without considering the subsequent material problems of the shelter.

Optimization method: When the forecast hat hurricane level is high, we can arrange inland evacuation ahead, in the case of ensure the overall time is enough for the coastal areas to evacuate to the site of the corresponding time calculation.

Advantage: Inland remove first can reduce the road pressure; Coastal remove later can increase the economic benefit. Compare the results again and get the final optimization plan.

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Appendices

Appendix A First appendix

Aliquam lectus. Vivamus leo. Quisque ornare tellus ullamcorper nulla. Mauris porttitor pharetra tortor. Sed fringilla justo sed mauris. Mauris tellus. Sed non leo. Nullam elementum, magna in cursus sodales, augue est scelerisque sapien, venenatis congue nulla arcu et pede. Ut suscipit enim vel sapien. Donec congue. Maecenas urna mi, suscipit in, placerat ut, vestibulum ut, massa. Fusce ultrices nulla et nisl.

Here are simulation programmes we used in our model as follow.

Input matlab source:

Appendix B Second appendix

some more text **Input C++ source:**