Problem Chosen	2021 MCM/ICM Summary Sheet	Team Control Number
A		**000000**

The Comprehensive Evacuation Planing Model in Case of Emergency

Summary

In the premise of guaranteeing the life safety of all the evacuees, we established the comprehensive evacuation planning model point of view from the shortest evacuation time, lowest evacuation risk, low economic losses angles to reduce the loss to minimum.

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

Contents

1 Introduction

1.1 Background

Natural disasters(such as hurricanes, floods, earthquakes, etc.) have always been a kind of obstacles that are difficult to overcome for mankind. Most area along the coast are often hit by hurricanes or typhoon, causing major economic losses and human casualties.

1.2 Problem Restatement

Build a model to advise MSEMA on an optimal strategy: which counties should be ordered to evacuate, when, and where to. The first page of your manuscript should be a one page non-technical, executive summary for the governor of Mississippi. It should describe your main recommendations, the criteria you used to evaluate their effectiveness, and any caveats you believe are important to mention.

1.3 Our Work

Originally topic asked us to review the current evacuation strategies of Mississippi. However, they did not give any current strategies, but just let us to establish a new personnel evacuation model, which is used to solve the question which counties should be ordered to evacuate, when, and where to. In addition, the size of the hurricane might seriously affect the driving conditions and the evacuation in Mississippi for its surrounding counties will also have to evacuate their constituents. On the one hand, if you order the evacuation later than the others, the population of your state end up stuck in traffic in affected areas. On the other hand, if you order the evacuation too early, this disruption carries a high economic cost : coastal areas generate much revenue for your state and early predictions about the expected hurricane strength/landfall time/location might be inaccurate.

2 Assumptions

- We consider individual car traffic and organized public bus transports. Most people will try to get to the safe places using their own car if possible. However, there are also people that do not have access to private transportation and rely on public transportation via buses.

3 List of Notation

Table 1: The List of Notation

Symbol	Meaning
N	Network nodes

4 The Sanctuary Selection Model

All hurricanes are assigned a category: from 1 (the weakest) to 5 (the strongest, like Katrina), and the corresponding potential damage can be seen in follows:

Table 2: The categories of hurricanes

Category	Maximum sustained winds	Potential damage
Category 1	119-153 km/h	No actual damage to the building, but damage to unfixed houses and cars, shrubs and trees. Some coasts will be flooded, and small docks will be damaged.
Category 5	$\geq$ 250 km/h	Most of the buildings and detached houses were completely destroyed, and some houses were blown away completely.Flood have devastated large areas, and all buildings near the coast have been flooded and settlers may need to evacuate.

5 The Demand Distribution Model

In the study, we determined the potential demand by using the Thiessen Polygon to determine the service area of the station node. Due to the evacuees in the evacuation process, the demand of the station nodes is uncertain, mainly manifested in the following two situations:

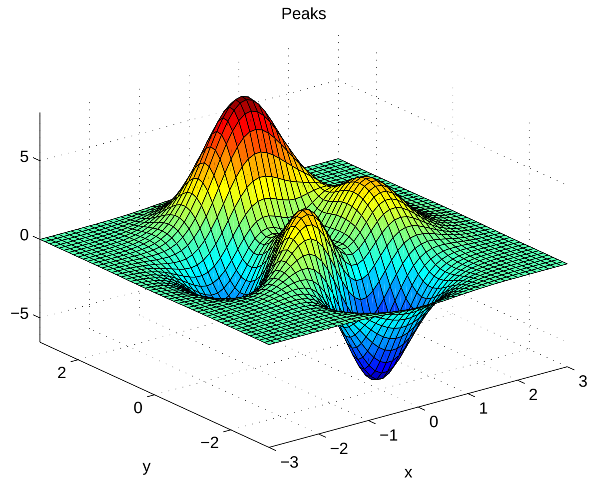

Figure 1: The Extent of the Hurricane in Mississippi

- Those who have been registered to evacuate will change their minds and evacuate by private cars or other means, reducing the need for evacuation;

$$C(t) = \frac{1}{(1 + e^{-\alpha(t-h)})} \tag{1}$$

$$C(0) = 0 \tag{2}$$

Where:

$C(t)$ is the cumulative percentage of withdrawal demands from time to time;

In the case of low loading rate, people gradually reach the station node within the time range of evacuation, but for the high loading rate, a large number of people rush to the station node during the final phase of evacuation,as is shown in Figure 2.

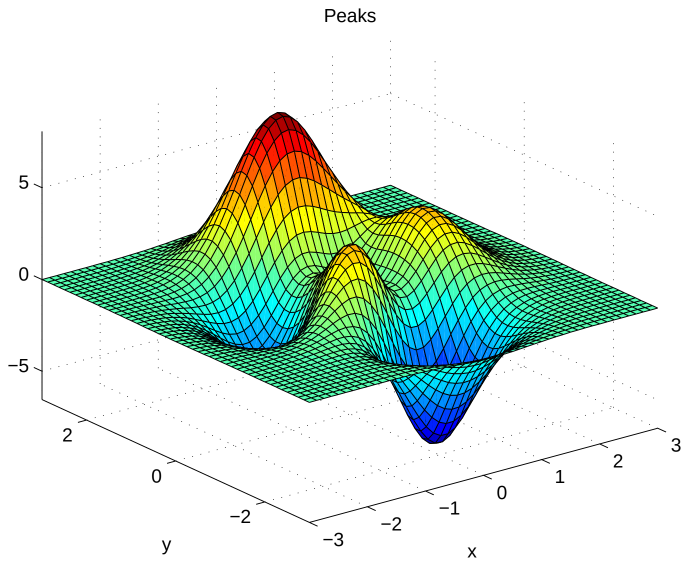

Figure 2: Behavioral Response Curves

6 The Comprehensive Evacuation Planning Model

6.1 Model Preparation

- Shelter: In this problem, there are several shelters whose location and capacity have been determined.

VRP [2, 5] generally defined as: on a range of clients point (location known or can be estimated) in satisfying certain constraints (such as the demand for goods, the delivery time of delivery, the vehicle capacity constraints, etc.), reasonably arrange the vehicle distribution route, making the vehicle through them in an orderly way to achieve a certain goal (such as the shortest mileage and least cost,

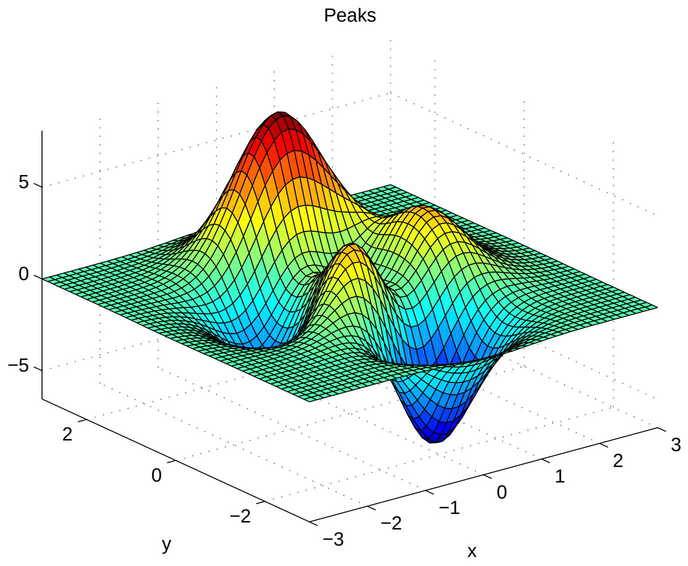

Figure 3: A Typical Vehicle Routing Problem

least time, use as little as possible and so on). The representation of VPR can be seen in Figure 3.

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;

6.2 Modeling

$$\Delta \min(\Delta, R) \tag{3}$$

$$\Delta \geq (2n-1) \times \max\Big(\sum_{(i,j)\in A} \sum_{t\in T} \delta_{ij}^t x_{ij}^t\Big) + \Delta t \tag{4}$$

The objective (1) is to minimize the evacuation time Δ and the risk R ,These objectives are computed using constraints (2)-(4). Constraints (2) ensure that Δ is the maximal evacuation time. The risk R depends on the number of people passing a link. This relation is expressed in constraint (3)and(4).

$$R = \sum_{(i,j)\in A} \sum_{t\in T} r_{ij}^t \Big(f_{ij}^t + \sum_{(i,j)\in A} \mathrm{g}_{ij}^t\Big) + W + V \tag{5}$$

$$\sum_{(i,j)\in A} \sum_{t\in T} f_{ij}^t = N_i \times a\% \tag{6}$$

$$n = \left[\frac{N_{\mathrm{i}} \times (1 - a\%)}{B_i \times N_0} \right] +1 \tag{7}$$

$$x_{ij}^t = \eta \frac{S_{ij}}{v_b} \tag{8}$$

$$\mathrm{g}_{ij}^t = N_0 \times B_{ij}^t \tag{9}$$

$$C_{ij}^t = \mathrm{p} \times \mathrm{C}_i \tag{10}$$

$$B_{ij}^t = \mathrm{p} \times \mathrm{B}_i \tag{11}$$

$$C_{ij}^t + B_{ij}^t \leq V_{ij} \tag{12}$$

$$C_j^t \leq C_j \tag{13}$$

$$P_j^t \leq rW_j \tag{14}$$

$$r = \frac{N_{\mathrm{i}}}{W_j} \tag{15}$$

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.

6.3 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:

Table 3: The Evacuation time

Hurricane level	1	2	3	4	5	6
Evacuation time	11.4	18.2	24.28	33.6	47.8	49.6

As shown in the figure above, it is necessary to calculate the time required for a category 1- 5 hurricane, including the withdrawal time required for the optimization programme.

Because the evacuation and time of personnel also satisfied the curve of S type curve, it can be used to draw the time-varying personnel evacuation curve of hurricane from category 1 - 5, which can be seen in figure4.

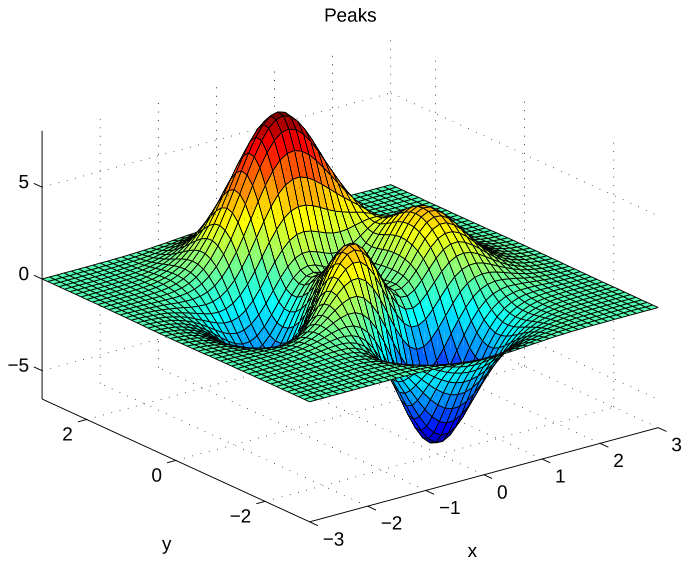

Figure 4: The time-varying personnel evacuation curve of hurricane from category 1 - 5

On the basis of guarantee the safety of life, we put forward the optimization scheme, when hurricane prediction level too high, let let evacuated inland areas, in order to improve the economic benefit of coastal, and reduce economic loss. The maximum population density due to coastal areas, and abide by the S type curve evacuation rules.

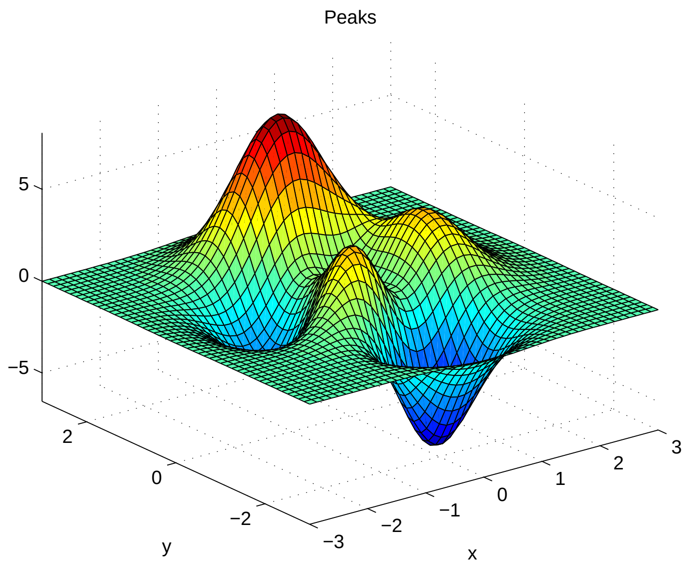

Figure 5: Optimize personnel evacuation curve

Under the same Five - level hurricane conditions, the optimization scheme minimizes the economic loss under the conditions of increasing the cost of the smaller time. It has been proved that evacuating in the right time can get better effect, which has a positive effect on the subsequent development of evacuation plan.

7 Strengths and Weaknesses

7.1 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;
- The constraint conditions such as road carrying capacity and the capacity of escape points are considered in the comprehensive evacuation planning model;
- Determine the coverage scope by Thiessen polygon;
- Considering the demand distribution characteristics in the station nodes;
- In terms of model constraints, the shortest evacuation time is obtained for a 1-5 hurricane;
- Considering the economic benefit gap between inland and coastal areas, the optimal plan for economic loss is proposed;
- Analyze the extreme problems, propose solutions, and obtain the optimal solution through comprehensive consideration of evacuation time, evacuation risks and economic losses.

7.2 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.

References

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Appendices

Appendix A First appendix

In addition, your report must include a letter to the Chief Financial Officer (CFO) of the Goodgrant Foundation, Mr. Alpha Chiang, that describes the optimal investment strategy, your modeling approach and major results, and a brief discussion of your proposed concept of a return-on-investment (ROI). This letter should be no more than two pages in length.

Dear, Mr. Alpha Chiang

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

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Sincerely yours,

Your friends

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

Input matlab source:

```
function [t,seat,aisle]=OI6Sim(n,target,seated)
pab=rand(1,n);
for i=1:n
    if pab(i)<0.4
       aisleTime(i)=0;
    else
        aisleTime(i)=trirnd(3.2,7.1,38.7);
    end
end
```

Appendix B Second appendix

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

```
//===============================================================================
// Name        : Sudoku.cpp
// Author      : wzlf11
// Version     : a.0
// Copyright   : Your copyright notice
// Description : Sudoku in C++.
//===============================================================================

#include <iostream>
#include <cstdlib>
```

```cpp
#include <ctime>

using namespace std;

int table[9][9];

int main() {

    for(int i = 0; i < 9; i++){
        table[0][i] = i + 1;
    }

    srand((unsigned int)time(NULL));

    shuffle((int *)&table[0], 9);

    while(!put_line(1))
    {
        shuffle((int *)&table[0], 9);
    }

    for(int x = 0; x < 9; x++){
        for(int y = 0; y < 9; y++){
            cout << table[x][y] << " ";
        }

        cout << endl;
    }

    return 0;
}
```