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Team Control Number

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Problem Chosen

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2019
MCM/ICM
Summary Sheet

The LaTeX Template for MCM Version v6.2.1

Summary

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Keywords: keyword1; keyword2

Contents

1 Introduction

1.1 Problem Background

Natural disasters often bring huge casualties and economic losses on human society. In 2017, the worst hurricane in nearly a century landed in Puerto Rico, and left almost the entire island without power, and many without running water or cell phone service. Many highways and roads were blocked because of widespread flooding, which brought great difficulties to rescue route planning. Demand for medical supplies was also soaring for some time.

HELP, Inc., one of non-governmental organizations, is planning to design a transportable disaster response system called DroneGo to conduct medical supply delivery and video reconnaissance.

1.2 Restatement of Problem

Our task is to design a DroneGo disaster response system to support potential future disaster scenario similar as the Puerto Rico hurricane. Based on the 2017 situation in Puerto Rico, we will:

- Provide the packing configuration for each of no more than three ISO cargo containers to transport the system.
- Find the best locations on Puerto Rico to position these cargo containers to realize both medical supply delivery and video reconnaissance.
- Design the drone payload packing configurations, delivery routes and schedule to conduct medical supply delivery, and a drone flight plan to realize video reconnaissance of road networks.

2 General Assumptions

Assumption I: DroneGo disaster response system consists of up to three ISO cargo containers, a DroneGo fleet and some emergency medical packages.

The three cargo containers are identical with standard size, designated as Container A, Container B and Container C respectively. The DroneGo fleet is a combination of drones selected from eight types of potential candidates, namely Drone A to Drone H. Only three types of emergency medical packages are available, referred to as MED 1, MED 2, and MED 3.

Assumption II: DroneGo disaster response system is designed for possible Puerto Rico hurricane disaster.

When disasters occurs, a DroneGo fleet and some emergency medical packages will be packed in up to three cargo containers first of all.

Next, each cargo container will be transported to one of the 32 populated places, which are represented by yellow square in Attachment 1, to ensure that DroneGo disaster response system can be timely discovered and well operated.

Then both drones and medical packages will be taken out of the containers, and afterwards the latter will be packed into the drone cargo bay that is in fixed connection with the drone.

Finally, all drones will depart from the up to three container locations and fly along the main roads on schedule. As is shown in Attachment 1, these main roads connect 32 populated places and make a road network. It is worth pointing out that there are two possible situations for these drones. If the drone carries a cargo bay with medical packages in it, the drone must fly via five locations in need of medical assistance, referred to as five destinations: Jajardo, San Pablo, San Juan, Bayamon and Arecibo, for the purpose of offloading its cargo. However, if the drone carries no cargo, any route without deviation of the road network is allowed.

3 Symbols and definitions

Symbol	Definition
X	The number of the containers X.
Y	The number of the containers Y.
Z	The number of the containers Z.
X_α	The number of the drones α packed in the container X.
Y_α	The number of the drones α packed in the container Y.
Z_α	The number of the drones α packed in the container Z.
$X_{\alpha ij}$	The number of the MED i transported by drone α from container X's location to the demand location j, where $\alpha = A, \cdots, H$, $i = 1, 2, 3$, $j = 1, 2, \cdots, 5$.
$Y_{\alpha ij}$	The number of the MED i transported by drone α from container Y's location to the demand location j, where $\alpha = A, \cdots, H$, $i = 1, 2, 3$, $j = 1, 2, \cdots, 5$.
$Z_{\alpha ij}$	The number of the MED i transported by drone α from container Z's location to the demand location j, where $\alpha = A, \cdots, H$, $i = 1, 2, 3$, $j = 1, 2, \cdots, 5$.
c_i	The cost of MED i, where $i = 1, 2, 3$.
C_α	The cost of Drone α, where $\alpha = A, B, \cdots, H$.
W	The cost of the container.
V_α	The volume of the drone α, where $\alpha = A, B, \cdots, H$.
v_i	The volume of the medical package i, where $i = 1, 2, 3$.
P_α	The max payload capability of the drone α, where $\alpha = A, B, \cdots, H$.
d	The supporting days for the medical package demand of all 5 locations.
M	A sufficiently large number for big-M method in integer programming.

Symbol	Definition
R	A parameter indicating the significance of the video reconnaissance of road networks compared to medical supply delivery.
l_α	The max flight distance of the drone α.
T	The number of the nodes in the network.
U_{Xm}	$U_{Xm} = 1$ if container X is located at node m, where $m = 1, 2, \cdots, T$. Otherwise $U_{Xm} = 0$.
U_{Ym}	$U_{Ym} = 1$ if container Y is located at node m, where $m = 1, 2, \cdots, T$. Otherwise $U_{Ym} = 0$.
U_{Xm}	$U_{Zm} = 1$ if container Z is located at node m, where $m = 1, 2, \cdots, T$. Otherwise $U_{Zm} = 0$.
$f(m, j)$	The length of the shortest path from node m to node j.

4 Model 1

The DroneGo disaster response system is sent to Puerto Rico for two major missons: medical supply delivery and video reconnaissance of road networks, none of which is dispensable. Nevertheless, to start with, focusing on the former solely helps attain a clear insight into this sophisticated problem. That leads to our integer programming model.

Now assume that the response system are only for medical supply delivery and that the location of each container is so close to its destination that each drone can reach it before the power supply runs out. According to the requirement, the response system must meet the daily medical package demand of the five selected locations in Puerto Rico. Therefore, a natural objective is to maximize the so-called supporting days d. Suppose that the amount of the medical packages provided by the Drone fleet can serve location j $(j = 1, 2, \cdots, 5)$ for d_j days. Then the supporting days is defined as

$$d = \min\{d_1, d_2, d_3, d_4, d_5\}. \tag{1}$$

For the sake of the optimization of d, a lot of independent variables need to be specified appropriately. Firstly, we need to specify the number of the containers transported to the disaster area. We introduce binary variables X, Y, Z to indicate whether the corresponding cargo container is utilized respectively. Secondly, we have to decide the packing configuration for each container in use. Given the definition of X_α and $X_{\alpha ij}$ in section 3, the number of each item to be packed into container X (8 types of drones: Drone A to Drone H; 3 types of medical packages: MED1, MED2, MED3) can be expressed as

$$X_A, \cdots, X_H, \sum_{\alpha=A}^{H}\sum_{j=1}^{5} X_{\alpha 1j}, \sum_{\alpha=A}^{H}\sum_{j=1}^{5} X_{\alpha 2j}, \sum_{\alpha=A}^{H}\sum_{j=1}^{5} X_{\alpha 3j}$$

respectively. Likewise, we can choose values for $Y_\alpha, Y_{\alpha ij}$ and $Z_\alpha, Z_{\alpha ij}$ to give the packing configuration for the container Y and the container Z respectively. Thirdly, we have to decide the drone payload packing configurations, or alternatively how the medical packages are packed into the drone cargo bay. The number of each type of medical package to be packed into the drone α can be expressed as

$$\sum_{j=1}^{5} X_{\alpha 1j}, \sum_{j=1}^{5} X_{\alpha 2j}, \sum_{j=1}^{5} X_{\alpha 3j}$$

Finally, the destination of each drone should be given. That is exactly what the variables $X_{\alpha ij}, Y_{\alpha ij}, Z_{\alpha ij}$ indicate. In a word, we need to adjust the 9 variables

$$X, Y, Z, X_\alpha, Y_\alpha, Z_\alpha, X_{\alpha ij}, Y_{\alpha ij}, Z_{\alpha ij}$$

for the maximization of d.

By imposing proper constraints we obtain the following integer programming problem

$$\max \quad d$$

$$
\text{s.t.}\begin{cases}
\sum_{i=1}^{3}\sum_{j=1}^{5} v_i X_{\alpha ij} \leq 8 \times 10 \times 14 \ \text{ if } \alpha = A, B, D & (1)\\
\sum_{i=1}^{3}\sum_{j=1}^{5} v_i X_{\alpha ij} \leq 24 \times 20 \times 20 \ \text{ if } \alpha = C, E, F, G & (2)\\
\sum_{i=1}^{3}\sum_{j=1}^{5} v_i Y_{\alpha ij} \leq 8 \times 10 \times 14 \ \text{ if } \alpha = A, B, D & (3)\\
\sum_{i=1}^{3}\sum_{j=1}^{5} v_i Y_{\alpha ij} \leq 24 \times 20 \times 20 \ \text{ if } \alpha = C, E, F, G & (4)\\
\sum_{i=1}^{3}\sum_{j=1}^{5} v_i Z_{\alpha ij} \leq 8 \times 10 \times 14 \ \text{ if } \alpha = A, B, D & (5)\\
\sum_{i=1}^{3}\sum_{j=1}^{5} v_i Z_{\alpha ij} \leq 24 \times 20 \times 20 \ \text{ if } \alpha = C, E, F, G & (6)\\
\sum_{\alpha=A}^{H} V_\alpha X_\alpha + \sum_{\alpha=A}^{H}\sum_{i=1}^{3}\sum_{j=1}^{5} v_i X_{\alpha ij} \leq 231 \times 92 \times 94 & (7)\\
\sum_{\alpha=A}^{H} V_\alpha Y_\alpha + \sum_{\alpha=A}^{H}\sum_{i=1}^{3}\sum_{j=1}^{5} v_i Y_{\alpha ij} \leq 231 \times 92 \times 94 & (8)\\
\sum_{\alpha=A}^{H} V_\alpha Z_\alpha + \sum_{\alpha=A}^{H}\sum_{i=1}^{3}\sum_{j=1}^{5} v_i Z_{\alpha ij} \leq 231 \times 92 \times 94 & (9)\\
\sum_{i=1}^{3}\sum_{j=1}^{5} X_{\alpha ij} \leq M X_\alpha \ \text{ for } \alpha = A, B, \cdots, G & (10)\\
\sum_{i=1}^{3}\sum_{j=1}^{5} Y_{\alpha ij} \leq M X_\alpha \ \text{ for } \alpha = A, B, \cdots, G & (11)\\
\sum_{i=1}^{3}\sum_{j=1}^{5} Z_{\alpha ij} \leq M X_\alpha \ \text{ for } \alpha = A, B, \cdots, G & (12)\\
\sum_{\alpha=A}^{H} X_\alpha \leq M X & (13)\\
\sum_{\alpha=A}^{H} Y_\alpha \leq M Y & (14)\\
\sum_{\alpha=A}^{H} Z_\alpha \leq M Z & (15)\\
X \leq 1 & (16)\\
Y \leq 1 & (17)\\
Z \leq 1 & (18)\\
\sum_{j=1}^{5} (2X_{\alpha 1j} + 2X_{\alpha 2j} + 3X_{\alpha 3j}) \leq P_\alpha \text{ for } \alpha = A, B, \cdots, G & (19)\\
\sum_{j=1}^{5} (2Y_{\alpha 1j} + 2Y_{\alpha 2j} + 3Y_{\alpha 3j}) \leq P_\alpha \text{ for } \alpha = A, B, \cdots, G & (20)\\
\sum_{j=1}^{5} (2Z_{\alpha 1j} + 2Z_{\alpha 2j} + 3Z_{\alpha 3j}) \leq P_\alpha \text{ for } \alpha = A, B, \cdots, G & (21)
\end{cases}
$$

$$
\text{s.t.}\begin{cases}
\sum\limits_{\alpha=A}^{H}\left(X_{\alpha 11}+Y_{\alpha 11}+Z_{\alpha 11}\right)\geq d & (22)\\
\sum\limits_{\alpha=A}^{H}\left(X_{\alpha 31}+Y_{\alpha 31}+Z_{\alpha 31}\right)\geq d & (23)\\
\sum\limits_{\alpha=A}^{H}\left(X_{\alpha 12}+Y_{\alpha 12}+Z_{\alpha 12}\right)\geq 2d & (24)\\
\sum\limits_{\alpha=A}^{H}\left(X_{\alpha 32}+Y_{\alpha 32}+Z_{\alpha 32}\right)\geq d & (25)\\
\sum\limits_{\alpha=A}^{H}\left(X_{\alpha 13}+Y_{\alpha 13}+Z_{\alpha 13}\right)\geq d & (26)\\
\sum\limits_{\alpha=A}^{H}\left(X_{\alpha 23}+Y_{\alpha 23}+Z_{\alpha 23}\right)\geq d & (27)\\
\sum\limits_{\alpha=A}^{H}\left(X_{\alpha 14}+Y_{\alpha 14}+Z_{\alpha 14}\right)\geq 2d & (28)\\
\sum\limits_{\alpha=A}^{H}\left(X_{\alpha 24}+Y_{\alpha 24}+Z_{\alpha 24}\right)\geq d & (29)\\
\sum\limits_{\alpha=A}^{H}\left(X_{\alpha 34}+Y_{\alpha 34}+Z_{\alpha 34}\right)\geq 2d & (30)\\
\sum\limits_{\alpha=A}^{H}\left(X_{\alpha 15}+Y_{\alpha 15}+Z_{\alpha 15}\right)\geq d & (31)\\
X,Y,Z,X_\alpha,Y_\alpha,Z_\alpha,X_{\alpha ij},Y_{\alpha ij},Z_{\alpha ij}\text{ are nonnegative integers.} & (32)
\end{cases}
$$

If we take the cost of containers, drones and medical packages into consideration and fix the value of d, minimizing the total cost also makes sense. To address the minimization problem, we only need to transform the objective function into the following form while all original constraints (1)-(32) still hold:

$$
\min \quad \sum_{\alpha=A}^{H}\sum_{i=1}^{3}\sum_{j=1}^{5} c_i\left(X_{\alpha ij}+Y_{\alpha ij}+Z_{\alpha ij}\right)+\sum_{\alpha=A}^{H} C_\alpha\left(X_\alpha+Y_\alpha+Z_\alpha\right)+W(X+Y+Z).
$$

5 Model 2

Now it is time to extend our analysis to the complete case that both medical supply delivery and video reconnaissance of road networks need to be carried out. Since the variable d named supporting days has been shown to be a reasonable measure of the effect of medical supply delivery, developing some appropriate measures of the effect of video reconnaissance is our priority.

Assume that drones cannot be recharged, which implies each drone will fly along the road network until its batter is discharged. When the number of drones is rather large, it is totally reasonable to assume that under no circumstances will any two drones fly abreast along a same road. Thus the sum of flight distances of all the drones can well measure the effect of video reconnaissance.

$$\max \quad d + R\sum_{\substack{\alpha=A\\ \alpha\neq F}}^{G} l_\alpha(X_\alpha + Y_\alpha + Z_\alpha)$$

Additional constraints:

$$\text{s.t.}\begin{cases}\sum\limits_{m=1}^{T} U_{Xm} = 1\\ \sum\limits_{m=1}^{T} U_{Ym} = 1\\ \sum\limits_{m=1}^{T} U_{Zm} = 1\\ \sum\limits_{i=1}^{3} X_{\alpha ij} \leq M(1-U_{Xm}) \text{ if } l_\alpha < f(m,j),\ \text{for } \alpha = A,\cdots,G, m=1,\cdots,T, j=1,\cdots,5\\ \sum\limits_{i=1}^{3} Y_{\alpha ij} \leq M(1-U_{Ym}) \text{ if } l_\alpha < f(m,j),\ \text{for } \alpha = A,\cdots,G, m=1,\cdots,T, j=1,\cdots,5\\ \sum\limits_{i=1}^{3} Z_{\alpha ij} \leq M(1-U_{Zm}) \text{ if } l_\alpha < f(m,j),\ \text{for } \alpha = A,\cdots,G, m=1,\cdots,T, j=1,\cdots,5\\ U_{Xm}, U_{Ym}, U_{Zm} \in \{0,1\}\end{cases}$$

$$\begin{aligned}\min \quad & \sum_{\alpha=A}^{H}\sum_{i=1}^{3}\sum_{j=1}^{5} c_i\left(X_{\alpha ij}+Y_{\alpha ij}+Z_{\alpha ij}\right) + \sum_{\alpha=A}^{H} C_\alpha\left(X_\alpha+Y_\alpha+Z_\alpha\right) + W(X+Y+Z)\\ & - R\sum_{\substack{\alpha=A\\ \alpha\neq F}}^{G} l_\alpha(X_\alpha+Y_\alpha+Z_\alpha)\end{aligned}$$

6 Introduction

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- minimizes the discomfort to the hands, or
- maximizes the outgoing velocity of the ball.

We focus exclusively on the second definition.

- the initial velocity and rotation of the ball,
- the initial velocity and rotation of the bat,
- the relative position and orientation of the bat and ball, and
- the force over time that the hitter hands applies on the handle.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

- the angular velocity of the bat,
- the velocity of the ball, and
- the position of impact along the bat.

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center of percussion [Brody 1986], Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetuer.

Theorem 6.1. *LaTeX*

Lemma 6.2. *TeX.*

Proof. The proof of theorem. □

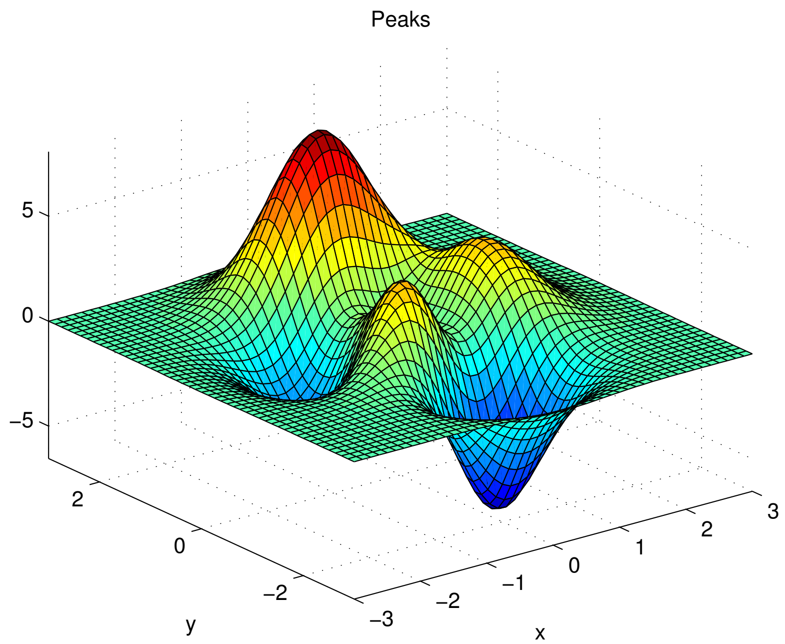

Figure 1: aa

7 Analysis of the Problem

(2)

$$a^2 \tag{2}$$

$$\begin{pmatrix} *20ca_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} = \frac{Opposite}{Hypotenuse} \cos^{-1}\theta \arcsin\theta$$

00

$$p_j = \begin{cases} 0, & \text{if } j \text{ is odd} \\ r!\,(-1)^{j/2}, & \text{if } j \text{ is even} \end{cases}$$

$$\arcsin\theta = \oiiint\limits_{\varphi} \lim_{x\to\infty} \frac{n!}{r!\,(n-r)!} \tag{1}$$

8 Calculating and Simplifying the Model

Sed feugiat. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Ut pellentesque augue sed urna. Vestibulum diam eros, fringilla et, consectetuer eu, nonummy id, sapien. Nullam at lectus. In sagittis ultrices mauris. Curabitur malesuada erat sit amet massa. Fusce blandit. Aliquam erat volutpat. Aliquam euismod. Aenean vel lectus. Nunc imperdiet justo nec dolor.

9 The Model Results

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10 Validating the Model

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11 Conclusions

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

12 A Summary

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

13 Evaluate of the Mode

14 Strengths and weaknesses

Etiam euismod. Fusce facilisis lacinia dui. Suspendisse potenti. In mi erat, cursus id, nonummy sed, ullamcorper eget, sapien. Praesent pretium, magna in eleifend egestas, pede pede pretium lorem, quis consectetuer tortor sapien facilisis magna. Mauris quis magna varius nulla scelerisque imperdiet. Aliquam non quam. Aliquam porttitor quam a lacus. Praesent vel arcu ut tortor cursus volutpat. In vitae pede quis diam bibendum placerat. Fusce elementum convallis neque. Sed dolor orci, scelerisque ac, dapibus nec, ultricies ut, mi. Duis nec dui quis leo sagittis commodo.

14.1 Strengths

- **Applies widely**
  This system can be used for many types of airplanes, and it also solves the interference during the procedure of the boarding airplane,as described above we can get to the optimization boarding time.We also know that all the service is automate.

- **Improve the quality of the airport service**
  Balancing the cost of the cost and the benefit, it will bring in more convenient for airport and passengers.It also saves many human resources for the airline.

-

References

[1] D. E. KNUTH The TEXbook the American Mathematical Society and Addison-Wesley Publishing Company , 1984-1986.

[2] Lamport, Leslie, LaTeX: " A Document Preparation System ", Addison-Wesley Publishing Company, 1986.

[3] http://www.latexstudio.net/

[4] http://www.chinatex.org/

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:

```
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>
```

```
#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;
}
```