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Simulation Study on Security Traffic Flow Based on Cellular Automata

Lili Liang[1,a] , Dongmei Xie[2,b] , Guowangchen Liu[3,c] , Hong Fang[4*,d]

[1]College of Engineering and Technology，Tianjin Agricultural University
Tianjin, 300384, China

[2]College of Horticulture，Tianjin Agricultural University
Tianjin, 300384, China

[3]College of Agronomy, Resources and Environment，Tianjin Agricultural University
Tianjin, 300384, China

[4*]College of Basic Science，Tianjin Agricultural University
Tianjin, 300384, China

(* corresponding author)

[a]email 873068328@qq.com, [b]email 970373878@qq.com, [c]email 965020409@qq.com,
[d]email fanghong681019@126.com

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Abstract: Airport security generally have 3 (the paper is divided into A, B, C) security entrance. Since the function of each channel varies from person to person, the time each person spent is not the same. Using traditional data analysis will be a huge project, however, using the cellular automata model is possible to simulate not only the random numbers of the scene, but also to analyze the problem of the design of the security port, and to make appropriate adjustments to the security port.

Introduction

In order to prevent the occurrence of airport terrorist incidents, airport security seems particularly important. However, airlines have a vested interest in maintaining a positive flying experience for passengers by minimizing their waiting time at security checkpoints and waiting for their flights. Therefore, there is a tension between the desires to maximize security while minimizing inconvenience to passengers. To this end, this paper builds an airport security simulation model first, and the simulation results are analyzed to identify the bottleneck areas. Then, according to the bottleneck areas identified above, we improved the model on the basis of the original model to achieve the purpose of improving passenger flow and reducing passengers' waiting time. Considering the cultural differences between various countries, We will further optimize the above model to prevent the cultural collision. Ultimately, we are supposed to propose policy and procedural recommendations for the security managers based on the model established in this paper.

Assumptions

Regardless of the shape of each person, and everyone is assumed to be a cell.

In order to establish a rational model, no emergency is taking into consideration, such as passengers loss of valuables, jump the queue, and sudden onset and so on.

Assume that everyone walking in the same speed.

Assume that each security personnel work in the same efficience.

Symbols And Significance

I	the maximal iterations of simulation
B	number roads
A	the mean total number of passengers that arrives
C	length of the channel
D	time step
V	max speed
T	average waiting time
influx	Passenger flow into the system
outflux	Departure from the system
gap	the distance between adjacent passengers

Model building

Cellular Automata model has a good effect and forward-looking for the security queuing simulation. We refer to the passenger flow NS (single lane) model[1], and use the rules of queuing theory to build the model. And then obtain the security queuing model which is suitable for the question.

On the basis of this model, we consider that some Pre-Check passengers would go into the special channel to reduce the time of Baggage and Body Screening in Zone B. The bottleneck is determined by calculating the saturation of Zone A, Zone B, and Zone C in different passenger flows.

Situation in queuing areas rules. In this case, we simulate a $100*B$ security area (B is the number of channels, suppose B = 5), in which the simulated security area is composed of cells. Line 26, 51, and 68 are the checkpoints for zones A, B, and C, respectively. It should be noted that the passengers' entry to the checkpoints is consistent with Poisson distribution[2-5]. Columns2,5,8,11,14are listed as pedestrian areas, and the rest for the isolation zones.

Pedestrian from the top reach the security area, through Zone A,B,C three checkpoints then from the bottom leave the security area.

Acceleration rules. When the following conditions are met:

*The distance between the current passenger and the next passenger is farther than the distance traveled by the passenger within 1 unit time.

*The current passenger's speed plus 1 is less than or equal to the maximum speed.

*The acceleration generated in the random sequence is less than or equal to the acceleration threshold.

The passenger‘s speed has a certain probability plus 1 (the probability is 0.7 in this question), but can not exceed the maximum speed of 5, namely:

$$v_n^{(1)}(t+1)=\min\{v_{max,}v_n(t)+1\}. \tag{1}$$

Collision prevention rules. When the following conditions are met：

*The distance between the current passenger and the next passenger is less than the distance traveled by the passenger within 1 unit time

*The acceleration generated in the random sequence is more than or equal to the deceleration threshold.

The speed of the passenger is the same as the gap of the previous passenger, that is:

$$v_n^{(2)}(t+1)=\min\{v_n^{(1)}(t+1), gap(t)+v_{(n-1)}^{(2)}(t+1)\}. \tag{2}$$

Random deceleration rules. For any passenger, there exist a possibility to random deceleration, and the probability is 0.3.

Checkpoint rules. If the current checkpoint has no passengers, then the passenger's speed turns to 1; if the current checkpoint exists passengers, then the passengers' speed turns to 0.

Bottleneck analysis. When doing the bottleneck analysis, we need to carry out the saturation analysis of the flow of people in various zones, namely:

$$saturation = \frac{\Sigma Speople}{C \times B}. \tag{3}$$

Among them, $\Sigma Speople$ is the total number of people in each zone, and C is the length of each zone. Because this topic only needs to analyze the biggest passenger flow in which area is prone to the bottleneck, and we only need to simulate the upper limit of the maximum iteration, that is, the number of iterations is 1000. In the traditional model, we will set up two types of passengers: the first is the general visitors; and the second is the one who carry heavy objects, this type of passengers' time will be 20% more than the average passengers in the Zone B.

We use MATLAB to simulate the mean total number of passengers that arrives(A), in order to have a better analysis of the impact of the different number to arrive the checkpoint. A=1 means low passenger flow rate; A=2 means middle passenger flow rate and A=3 means high passenger flow rate. We do a saturation analysis in order to make sure where the bottleneck are. Figure 1.

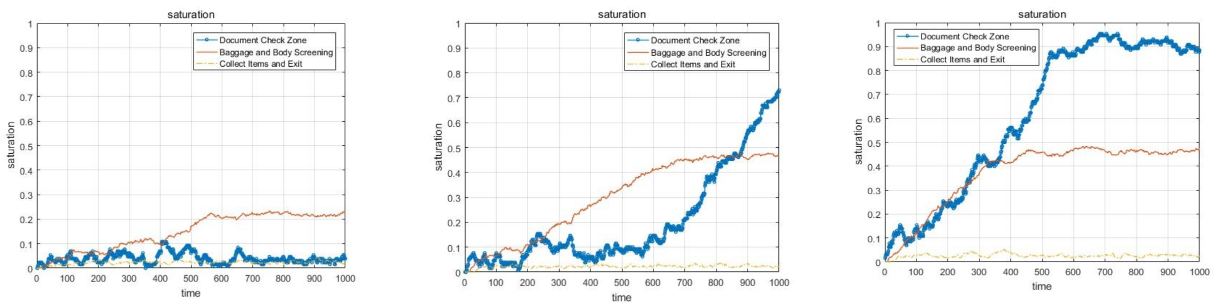

Figure 1: Saturation analysis

As can be seen from the figure 1 above, the larger the value of A, the greater the saturation of Zone A and Zone B. When A = 1, the saturation of Zone A, B, and C has reached a steady state when the saturation is very low, indicating that there is almost no clogging in this case. But the saturation of Zone B is much higher than the other two zones, which is shown that Zone B takes a longer time; when A = 2, the saturation of Zone A and Zone B is much larger than the saturation of Zone C. Zone A is unstable, thus affected by Zone A, and at time = 100 to time = 200, time = 700, there are two stages in a stable state in Zone B. When A = 3, the saturation of Zone A, B and C is obviously different, and the saturation of Zone A is much larger than that of Zone B and C. The saturation of region B is much higher than that of C, and the Zone A and B tend to be stable when time = 500 and time = 400. Hence, B is the bottleneck area.

Model Optimization. From the previous model we can see that when the increase with the flow of people, the saturation of the security area is also increasing. How to reduce the waiting time in the peak of passenger flow has become a serious problem. In order to reduce the waiting time and optimize the passenger security experience, we can further optimize the model. Firstly, the average security time is defined as T as a measure of the standard:

$$T = \frac{\Sigma_{i=1}^{n} time_i}{n}. \quad (4)$$

Among them, $time_i$ is the time spent by the i person, and n is the total number of people who have security checked.

According to the traditional security system model, we can see from Table 1 that with the increase of passenger flow, however, T is still at a high value. Therefore, it's necessary to optimize the model.

Table 1: T_0 values for traditional models

	1	2	3	4	5	T_0
A=1	145	223	202	204	155	185.8
A=2	365	293	340	354	288	328
A=3	369	382	347	369	427	378.8

Analysis of the shunt security system. In the real airport, the use of shunt to reduce traffic saturation method have been applied in the large airports of United States and China .Compared with the traditional system, the shunt system can maximize the use of the airport area. Thus, For this question, Zone B is been shunted, as shown in Figure 2.

Matlab can be used to simulate the traditional model and shunt model simulation diagram, as shown in Figure 3.

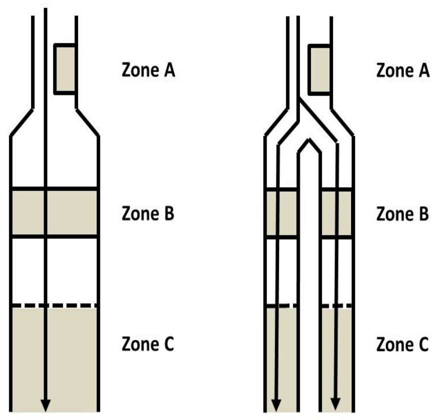

Figure 2: the comparison structure between traditional channel and shunt channel

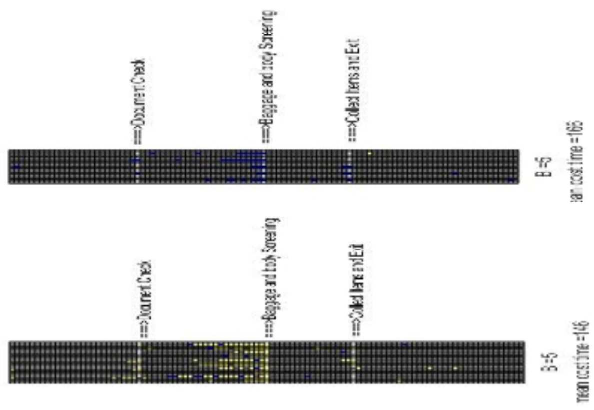

Figure 3: Comparison of traditional

As with the traditional model, the number of iterations is still 1000, Zone A has 5 channels, while Zone B's channel is been shunted. Simulated by MATLAB， A = 1, 2, 3 on behalf of three types of low, medium and high traffic average time-consuming respectively. Because of the random of cellular automata, each of our traffic patterns were simulated five times, in order to obtain more accurate T value as well as to reduce the occurrence of random events, as shown in Table 2.

Table 2: T_1 values for traditional models

	1	2	3	4	5	T_1
A=1	96	100	107	126	105	106.8
A=2	174	157	169	158	191	169.8
A=3	276	248	273	239	279	263

As can be seen from the Table 1 and Table 2, the effect of the shunt model is significantly better than the traditional model. When A = 1, the effect presented from the traditional model and the shunt model is not particularly clear ,that is, we can choose the traditional model when in the low passenger flow ;When A = 2, the advantages of the shunt model are outstanding , for it's average time in passing the shunt model is only half compared with which in passing the traditional model. Indicating that it is better to choose the shunt model when in the medium passenger flow.When A = 3, the average time of the traditional model spent has reached 378.8, the trend of congestion is obvious. While in the case of the same traffic, the average flow time of the shunt model is 263, and there is no congesting situation. Indicating that we are supposed to choose shunt model when in the peak passenger flow.

In general, the shunt model is better than the traditional model. However, considering some small airport with less passenger flow, we recommend to use the traditional model in order to save resources.

Pre-Check channel. Considering the Pre-Check passengers, we will open the Pre-Check channel, which will be added to the shunt model. In this article, every five channels set up a Pre-Check channel, and the probability of passengers entering the Pre-Check channel is 25%. The data in Table 3 are obtained by MATLAB.

Table 3: T_2 values for traditional models

	1	2	3	4	5	T_2
A=1	97	103	113	119	103	107
A=2	168	189	174	170	187	177.6
A=3	241	217	231	245	252	237.2

By comparing Table 2 and Table 3, it can be known that the opening of Pre-Check channel which on the basis of the shunt model has little effect on the T value. When in the middle of passenger flow , whether to open the Pre-Check channel is not influenced significantly on the various channels of the blockage. However, in the peak passenger flow, Pre-Check model's T = 237.2, and the shunt model's T = 263, the Pre-Check model will be better than the shunt model in terms of the numerical value, but the effect is not obvious. Since Pre-Check passengers will be charged additional cost, for the airports' own benefits, we recommend to add Pre-Check channel.

Conclusions

Through the continuous optimization of the above model, comparative analysis can be found: the optimized model does not apply to all airports.

We recommend that the airports with limited passengers is supposed to build traditional models, it will save the cost of machinery and equipment while in the absence of congestion. At medium and high passengers flow, it is advisable to establish a shunt model or a Pre-Check model. Since the establishment of the Pre-Check model can have an additional income, we recommended establishing the Pre-Check model.

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