The Establishment and Optimization of Airport Security Check Process Model

Haodi Wang[1], Kaicen Liu[2], Zhenqi Qi[1], Junqi Guo[1*]

1. College of Information Science and Technology, Beijing Normal University, Beijing 100875
E-mail: 201411202028@mail.bnu.edu.cn

2. School of Statistics, Beijing Normal University, Beijing 100875
E-mail: 201411202038@mail.bnu.edu.cn

1*. College of Information Science and Technology, Beijing Normal University, Beijing 100875
E-mail: guojunqi@bnu.edu.cn

Abstract: This article aims at the increasing waiting time for security check of passengers in the airports, which due to the increasing amount and stricter measures of security check. We model the airports' security checkpoints with a view to the typical procedure of security check, basing on the real data collected. By analyzing and modifying the model, we successfully stimulate the whole security checkpoint and is capable of pointing out the bottleneck of the passengers' put through. Stimulation and testing has demonstrated that this model is valid and reliable. What's more, the optimize model is instructional and practical.

Key Words: airport; security check; waiting time.

1   INTRODUCTION

After the terrorist attack in the US on September 11th, 2001, great importance has been attached to airport security. Although the raising amount of procedure of security check do increase the security of the passengers, it extends the time passengers waiting in queue. Now more and more passengers complain about the low efficiency of the airports' security checkpoints. During 2016, the U.S. Transportation Security Agency (TSA) came under sharp criticism for extremely long lines. Following this public attention, the TSA invested in several modifications to their checkpoint equipment and procedures and increased staffing in the more highly congested airports. Though these modifications did reduce the waiting time in a way, they not only cost quantities of money but also couldn't solve the problem fundamentally. Nowadays, the phenomenon of the long waiting line has drawn a great attention among scholars in all works of life and made some achievements[1-3].

This article models the security checkpoints based on the typical American airports. The model includes parameters such as the flow rate of the passengers, the counters opened in every procedure. It can stimulate the variance of the passengers' through put and the time they waiting in line validly as well as find out the bottleneck of the security checkpoint. Finally, we modify the model and come up with an optimized model. The result shows that our basic and optimized model are practical and conductive.

2   MODEL ESTABLISHMENT

2.1 Model Description

The procedure of a representative airports' security checkpoint in the U.S. is like figure1 below. It is often divided into four Zones.
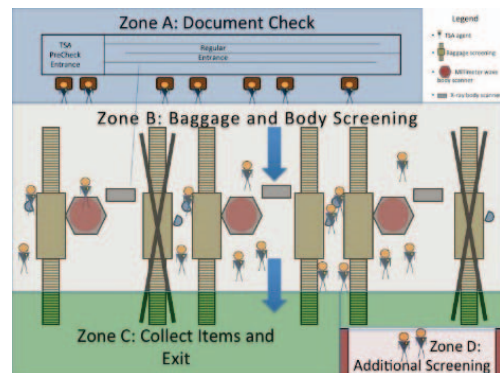

Fig 1. the typical airport checkpoint in the U.S.

Zone A: Passengers arrive at the airport randomly and wait in a queue in Zone A until a security officer can inspect their identification and boarding documents. Analyzing the data we've gotten, the ID-check time obeys normal distribution. Figure 2 is the density of the ID-check time while Figure 3 is the probability of the ID-check time.
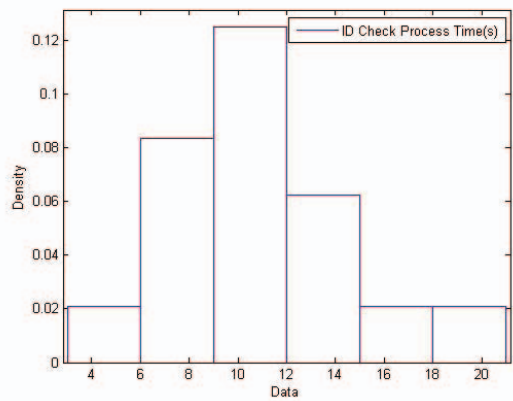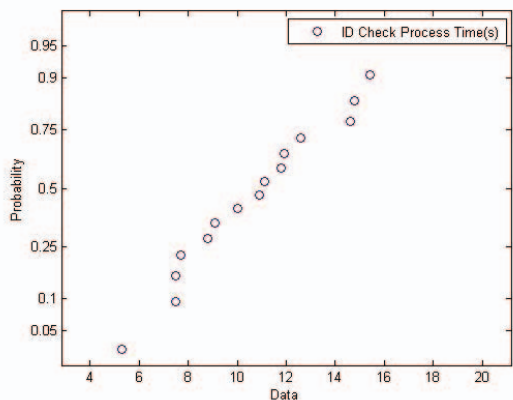
Fig 2. Density of ID Check Time

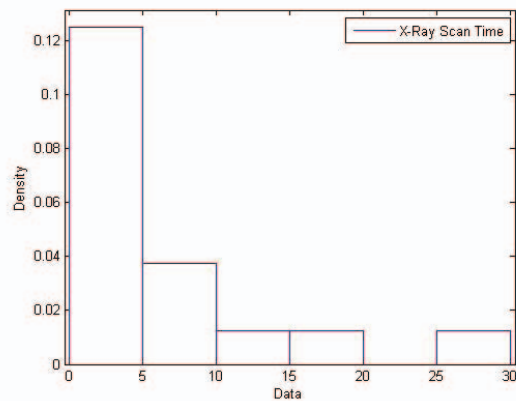Fig 3. Probability of ID Check Time

Zone B: In this link, passengers have to prepare all of their belongings for X-Ray screening. They must remove shoes, belts, jackets, metal objects, electronics, and containers with liquids, placing them in a bin to be X-rayed separately; laptops and some medical equipment also need to be removed from their bags and placed in a separate bin. In the meantime, the passengers process through either a millimeter-wave scanner or metal detector. The data analyzing tells us that the time of millimeter wave scanning obeys normal distribution (Density and Probability of millimeter wave scan time as showed in the figure 4 and 5) while the X-Ray Scanning obeys the Poisson distribution (Density and probability of X-Ray scan time as showed in the figure 6 and 7).
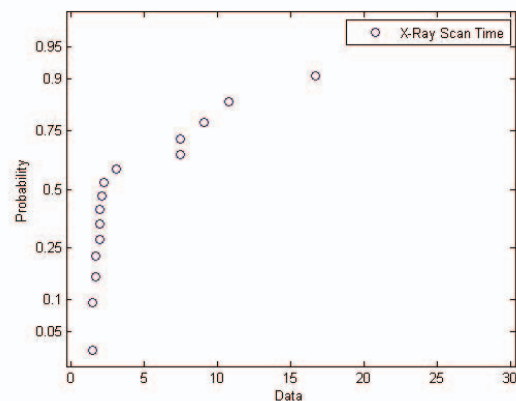

Fig 4. Density of Millimeter Wave Scan Time

Fig 5. Probability of Millimeter Wave Scan Time

Fig 6. Density of X-Ray Scan Time

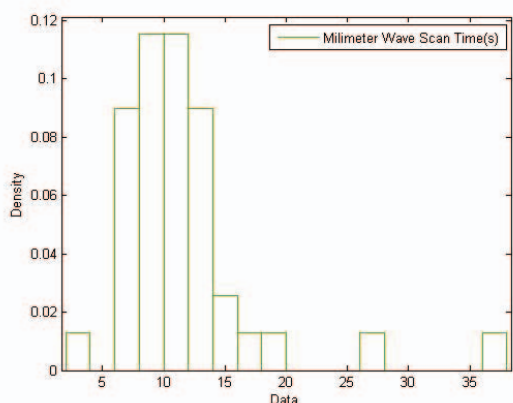Fig 7. Probability of X-Ray Scan Time

Zone C: Zone C is on the other side of the convey belt. Passengers take all of their belongings and leave the security checkpoint.

Zone D: All of the illegal things as well as some items which are flagged for additional search or screening will be sent to zone D. Passengers who didn't pass the millimeter wave scanner must be rechecked in zone D as well.

Approximately 45% of passengers enroll in a program called Pre-Check for trusted travelers. These passengers paid money to receive a background check and enjoy a separate screening process for five years. Pre-check passengers must still remove metal and electronic items for scanning as well as any liquids, but are not required to

remove shoes, belts, or light jackets; they also do not need to remove their computers from their bags. Usually there's one Pre-check lane open for every three regular lanes.

2.2 Algorithm

2.2.1 Assumption:

1) Distance between Zone A and Zone B has been ignored, so the leaving time of Zone A is the arriving time of Zone B.
2) There's no possibility that any two or more people will arrive at the same time[4].
3) Passengers will not change the line during waiting in queue.
4) Passengers would choose the shortest line to get in.
5) Pre-checked counter allows pre-check passengers only. So does regular counters.

2.2.2 Definition of Symbol

Definition of Symbol as in table 1:

Table1. Notations

Symbol	Definition
Passenger[i] or p[i]	The type of this variable is bool, means passenger[i] is not a pre_check passenger
P[i].precheck	The type of this variable is bool，means passenger[i] is not a pre_check passenger
P[i].between	The time gap between Passenger[i] and Passenger[i-1]
P[i].arrivetime1-2	Time when passenger[i] arriving in Zone A, B, C, D
P[i].leavetime1-2	Time when passenger[i] leaving Zone A, B, C, D
P[i].servetime1-4	Time during passenger[i] accept service in Zone A, B, C, D
P[i].starttime1-2	Time when passenger[i] starting to get service in Zone A, B
CounterA	Number of counters in Zone A
CounterB	Number of counters in Zone B

2.2.3 Simulation Algorithm

Simulation Algorithm (For each passenger) as in table 2:

Table2. Simulation Algorithm

Input	The number of the passengers.
Output	Total time in each one.ssenger
Step1	Initialize the variables and passengers. Evaluate each p[i].between, p[i].servetime1-4, p[i].precheck according to a specific distribution.
Step2	Confirm the time that the ith passenger's arrive at the airport. Each person's arriving time equals his/her former passenger's arriving time plus the time gap between them.
Step3	Update the length of each queue in Zone A.
Step4	Choose a shortest queue. Whether p[i] is a pre-check passenger is considered in the meantime.
Step5	Confirm p[i].starttime1. It depends on the people who stand before him/her.
Step6	Evaluate the ith passenger's leave time.
Step7	Calculate the serve time of p[i] in Zone A.
Step8	Confirm the time when the ith passenger enter Zone B. It equals the p[i].leavetime1.
Step9	Update the length of the queue in Zone B.
Step10	Find the shortest line in both pre-check zone and regular zone. If the least number is greater than 20, then open a new counter for pre-check/regular passengers.
Step11	Find a shortest queue for p[i]. Whether p[i] is a pre-check passenger is considered in the meantime.
Step12	Confirm p[i].starttime2. It depends on the people who stand before him/her.
Step13	Evaluate the ith passenger's leave time.
Step14	Calculate the serve time of p[i] in Zone B.
Step15	The ith passenger enters Zone C and take their bags. The time p[i] spends in Zone C equals p[i].servetime3.
Step16	Passenger[i] enters Zone D if it is necessary. The time p[i] spends in Zone D equals p[i].servetime4.

2.3 Further Explanation of the Basic Model

a) This simulation algorithm is of one specific passenger. In our basic model, this procedure will be repeated 10 times. In each cycle there are one thousand passengers. In order to tell the average waiting time (also a steady result) of each passenger during the security check, we change the flow rate of the people as well as the number of counters in Zone A (CounterA). The flow rate of passengers is showed by the time gap between two people. For example, if the time gap equals 0.1 second per person, then the flow rate equals 10 person per second. Therefore, we have the expression below:

$$flow\_rate = \frac{1}{time\_gap} \tag{1}$$

In which, the domain of the time_gap is $[0.1, 10]$. The domain of CounterA is $[4, 100]$.

In the basic model, we test 1000 passengers for 10 times for every combination of time-gap and CounterA, expecting to find out the average waiting time with small variance of each person in a specific situation.

b) In Step1, we initialize the passengers according to the specific distribution. These distributions are concluded by the data given. Analyzing and fitting the data, we found some distillation function. And the parameters in the basic model are chosen from a set of random numbers which is distribute by a particular distribution.

c) The arrive time of p[i] is calculated by equation (2):

$$p[i].arrivetime1 = p[i-1].arrivetime1 + p[i].between \quad (2)$$

d) In Step3, we update the length of each counter in Zone A. To figure out how many people are waiting in each queue, we set two arrays to record the number of people waiting and the last passenger's number in each line. When there's a new passenger coming, we compare the new arrival's arrive time and the former passengers' leave time. If former passengers' leave time is less than the new arrival's arrive time, then reduce the length of the corresponding counter.

e) When choosing the queue, we assume that there are both pre-check counters and regular counters. The proportion is 1:3 (according to the reality) in the basic model.

f) The start time is calculated by:

$$
\begin{aligned}
&if\ (a[i].arrivetime1 \geq a[i-1].leavetime1) \\
&\{ \\
&a[i].starttime1 = a[i].arrivetime1; \\
&a[i].waittime1 = 0; \\
&\}else \\
&\{ \\
&a[i].starttime1 = a[i-1].leavetime1; \\
&a[i].waittime1 = a[i].starttime1 - a[i].arrivetime1; \\
&\}
\end{aligned}
\quad (3)
$$

g) The procedure in Zone B is almost the same with Zone A. The difference is in our model, the number of counters in zone B (CounterB) could change automatically by the flow rate. If the shortest line's length is longer than 20, then there will be a new counter open. These moves can make the model more intelligence and real.

h) Considering the actual life, the possibility of people who bring dangerous arms or equipment abroad a plane is slight. So we set this possibility as 0.1%

2.4 Simulation

Using the model we have developed, we create a simulation of security check process. Variables included the passengers' flow rate and the quantities of counters in Zone A. By performing multiple simulations, we could get large amount of data and draw an image as figure 8.
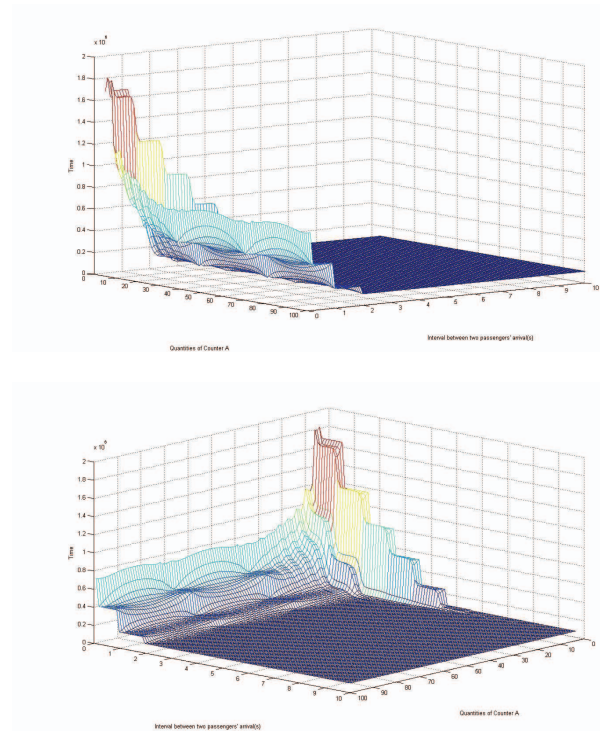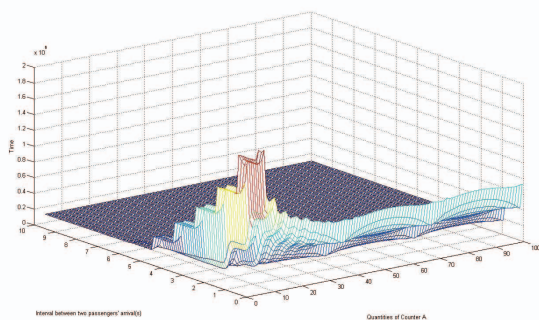

Fig 8. Basic Model From Different Angle. It's about the relationship of the waiting time and the time gap of the passengers' arrival, the number of counters in zone A.

The image reflects the relation among the passengers' flow rate, the quantities of counters in Zone A and the time passengers spend on security check process. X-axis represents time gap between two men's arrival, the flow rate of passengers is showed by the time gap between two people. Y-axis represents the quantities of counters in Zone A while Z-axis represents the time needed.

From the image, we can get a lot of useful information. It is obvious that the waiting time decreases when more counters are opened in Zone A or flow rate is low. However, what surprises us is the rapid change where X gets 5 or Y gets 25. When X is greater than 5, which means the time gap between two passengers' arrival is more than 5 seconds. The quantities of counters in Zone A would not be a major influence factor. When Y gets 25, the airport has the ability to solve the trouble completely no matter how fast passengers come. When considering the real situation, the result is convincing. It means that when the flow rate is low or the numbers of counters in the airport is big enough, the time we have to wait for security check is just a few minutes. According to this image, an arbitrary set of variables corresponds to a specific time. So, we could provide advisory opinions, including an estimated time needed to pass the security checkpoint and the optimizing quantities of checkpoint in Zone B, to the administrator of the airport in accordance with the passenger flow and the quantities of counters in Zone A.

3 MODEL OPTIMIZATION

On the basis of the basic model, we came up with an optimized model in order to be capable of raising suggestions to the administer of the airport[5,6].

The stimulation and testing demonstrate that cancelling the difference between pre-check and regular passengers in

Zone A is a valid method. The difference between the basic model and the modified model is that counters in zone A are no longer divided into two types. All counters are the same and passengers would choose the shortest line to get in regardless they are pre-check or regular passengers. The result of the model is showed as figure 9.
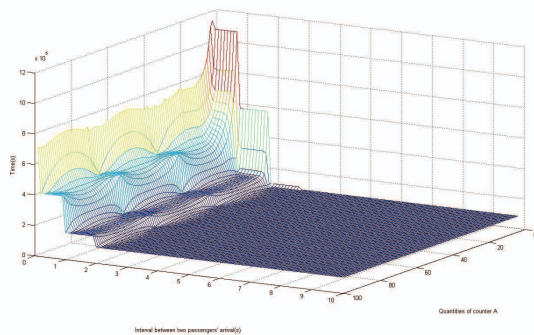

Fig 9. The relationship between waiting time and the time gap of the passengers' arrival, the number of Counters in Zone A after cancelled pre-check in zone A.

For the amount of the data is the same as the basic model, it is possible to compare the result with the basic model. We compared every condition which have the same CounterA and the arrival time gap and tagged the combination which decreased the waiting time. As consequence, we got the result like figure 10.

Among the 9,700 data, 22.0206% group of CounterA and arrival time gap decrease the waiting time validly. From the distribution of the dots, we can conclude that when the number of Counters in Zone A is low, this modification is valid. By analyzing this result, we could tell the manager of the airports when should the airport cancel the pre-check to reduce the waiting time.
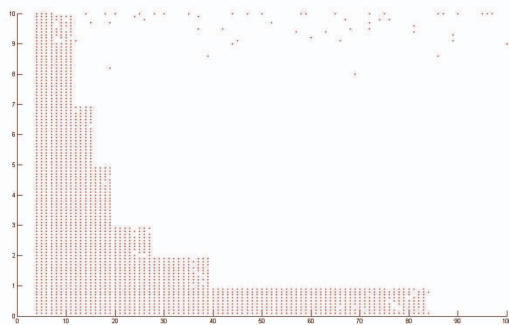

Fig 10. The dots represent the waiting time reduces.

4   CONCLUSIONS

1) We analyze the problem by emulating the situation based on queue model, so that the model we established is of great validity.

2) Our model is fairly robust due to our careful corrections in consideration of real-life situations and detailed sensitivity analysis.

3) Via Fluent software, we simulate the time field of different situations when variables vary. The outcome is vivid for us to understand the changing process.

4) The study method of our establishing model can be applied in other airports as the variables can be changed to fix every situation.

5) Besides what is requested, we still consider about other factors that matter, such as the percentage of windows in Zone A and Zone B, to increase checkpoint throughput and reduce variance in wait time[7,8]. From these model, we can tell the manager of the airport how long should the passengers wait under a specific circumstance, so that they could adjust the equipment and the staff flexibly and timely.

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