An Optimal Model of the Passenger Throughput

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Abstract. How to both maximize security and minimize the security time has long been a key concern. Based on the requirement and the existing airport security system, we construct a stochastic model to research how to raising security efficiency. A concept of increasing security efficiency is also defined as increasing the passenger throughput per hour in our model for further study. The security process is simplified as a linear process.Firstly, by separately calculating the difference between two adjacent data of millimeter Wave Scan moment and X-Ray Scan moment, the duration of passing these two scan checks can be determined. Considering data variation, we use regression analysis to draw regression curves and work out the time to pass disparate checks.Secondly, we construct a queue flowing model. The major flaw of the existing airport security process is that the average time spending on the preparation and packing area is excessively long. However, that only increase the amount of checkpoints has no obvious effect on increasing passenger throughput. After carefully calculating, the passenger throughput is 802 per hour, which is consistent with the reality. Model gets verified.

Lastly, the strength and weakness are given and further discussion is expected.

Introduction

How to make airport security safe and rapid is always the concern of people. When in the study of this problem, the security check is simplified as the following four steps: ID check process, prepare all of their belonging for X-ray screening, mm wave scan and X-ray scan, get scanned property. We use average value on behalf of the time that every passenger pass each check process. The amount of time that the last passenger required to pass through security is equivalent to the length that the queue end up check process.

In our model, we take into consideration both the longest checking time and the airport security checkpoint utilization rate. So, the optimization model is defined as the arrangement which can balance these two parts to the optimum degree.

The existing security process model is given as follows.

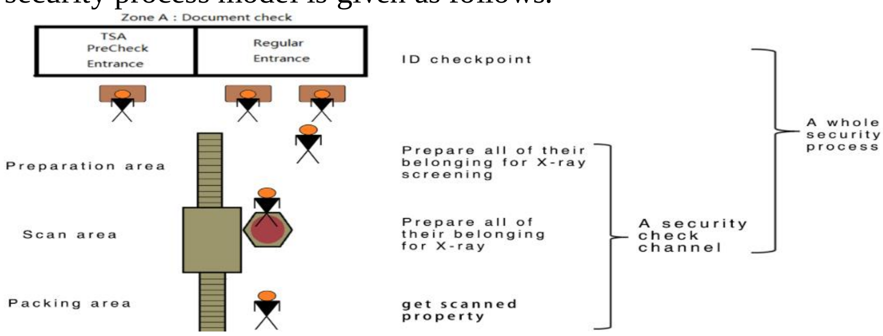

Figure 1. Basic model of the existing security process

Model: Queue Flowing Model

Basic Assumptions

1. The screening process runs normally. 2. There isn't anyone cutting in line.
3. Time to prepare all of their belonging for X-ray screening is roughly the same as the time to get scanned property.4.A security check channel mentioned following include three steps: prepare all of their belonging for X-ray screening, mm wave scan and X-ray scan, get scanned property. Hence a whole security process has two parts: passing ID checkpoint and a security check channel.
5. Basic notations in the article are list as follows.

Table 1 Notation

Symbol	Meaning
T_{ID}	The average value of time to pass ID check process
T_{pre}	The average value of time to prepare all of their belongings for X-ray screening
T_{scan}	The average value of time to pass scanning process
T_{get}	The average value of time to get scanned property.

Computing Data. By separately calculating the difference between two adjacent data of millimeter Wave Scan moment and X-Ray Scan moment, the duration of passing these two scan checks can be determined.

Considering data variation, in order to explain how long needed to go through different security process precisely and accurately, we use regression analysis to draw the following regression curves and work out the time to pass disparate checks.

After computing data founded, we can draw the following conclusions.

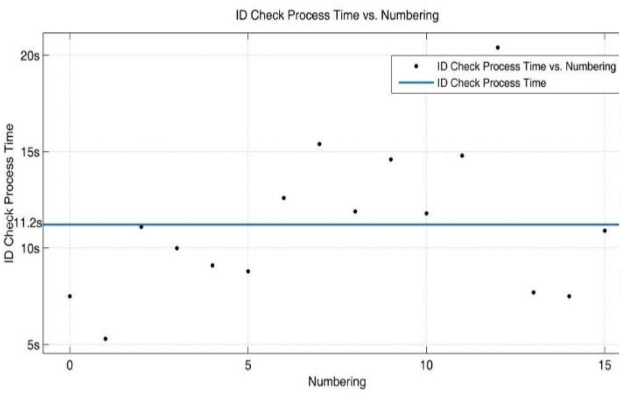

Figure 2. Time to pass ID check process

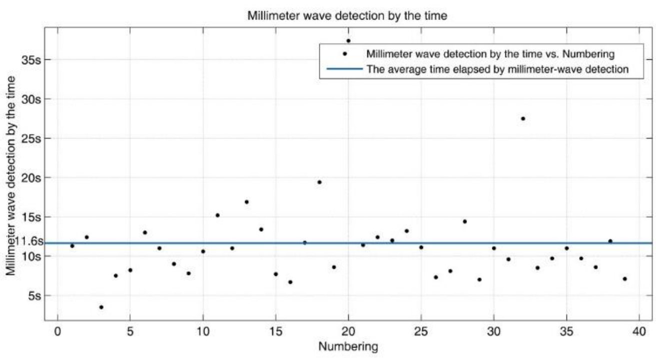

Figure 3. Time to pass X-ray scan

According to Fig1&Fig2&Fig3, we can see that passing ID check, millimeter wave scan and X-ray scan needs 11.2s, 11.6s and 6.6s.

Model with Single Checkpoint and Single Security Check Channel. Based on the existing security process, passengers who fail in passing through the scanner test should receive a pat-down inspection by a security officer (Zone D). This step has no influence to through security time. Therefore we construct a model describing the time that required to finish check process in the situation of single checkpoint and single X-ray scanner channel on the basis of the above general assumption.

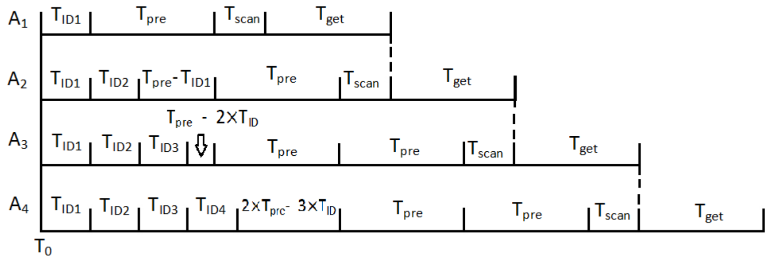

Figure 4. Time Axis of model2.3

After analyzing above time axis, we can see that:

$$\begin{cases} T_1 = T_{ID} + T_{pre} + T_{pre} + T_{scan} + T_{get} \\ T_2 = 2\times T_{ID} + T_{pre} - T_{ID} + T_{pre} + T_{scan} + T_{get} \\ T_3 = 3\times T_{ID} + 2T_{pre} - 2T_{ID} + T_{pre} + T_{scan} + T_{get} \end{cases} \quad (1)$$

According to the basic assumption, $T_{pre} = T_{get}$

After analysis, we recursive the model:

$Tn(2.3) = TID + Tpre + Tscan + n \times Tget$

Where T_n is on behalf of the time that N individual need to go through all the security process.

When n=1, 2, 3, $T_{n(2.3)}$ is the same as T_1,T_2,T_3. Recursive model get verified.

Model with Two Checkpoints and Single Security Check Channel. In this section, based on model 2.3, we make a further analysis about model with two checkpoints and single security check channel.

Assuming that there are separate n people in check point A，A' waiting for security. Since $T_{pre} > T_{ID}$, queue B will form as the following Fig6.

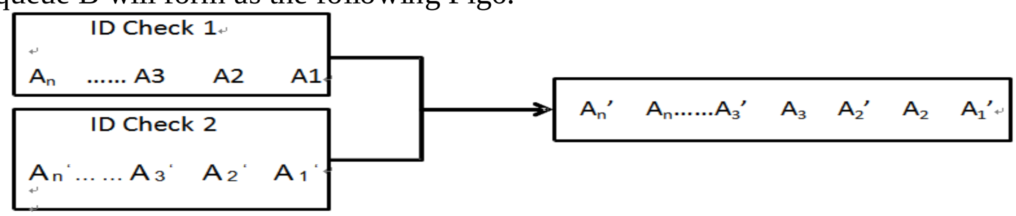

Figure 5. Schematic Diagram of Model 2.4.1

We assume that there are two columns, A_1，A_2...A_n and A_1'、A_2'…An', digital subscript representative the nth passenger at checkpoint. Two checkpoints are independent to each other，so the passengers in the same sequence number are independent to each other, such as A_1 and A_1', A_2 and A_2'. These two passengers pass ID check at the same time.

However, one can prepare all of his belongings, the other one should line up to wait. Since $T_{scan} < T_{pre}$, the difference of time for passengers in the same sequence number to through a whole security process is T_{pre}. As for the A_m and A_{m-1}'， they are equivalent to A_2 and A_1 in model 2.3,which means $A_m - A_{m-1}' = T_{get}$.

Since $T_{get} = T_{pre}$, after analysis， we recursive the model：

$$T_{n(2.4.1)} = T_{ID} + T_{get} + T_{scan} + 2n \times T_{get}$$

Model with m（m>2）Checkpoints and Single Security Check Channel.

M checkpoints are independent to each other，so the passengers with the same sequence number are independent to each other, such as A_1, A_1',A_1'',$A_1^{(3)}$…$A_1^{(n)}$.These m passengers form one queue B waiting for pass security check channel. Based on the analysis in section 2.4.1, the difference of time for passengers in the same sequence number to through a whole security process is T_{pre}.After analysis， we recursive the model：

$$T_{n(2.4.2)} = T_{ID} + T_{get} + T_{scan} + m \times n \times T_{get}$$

Model with Single Checkpoint and Two Security Check Channels. Now, there are single checkpoint A and 2 security check channels (Q1 and Q2) in the model 2.5.1.Assumption that there are 2n passengers, then A_{2k-1} enter Q1channel while A_{2k} enter Q2. (k is integer, k belong to[1,n]). Since $2T_{ID}>T_{pre}$, the queue Q1 and Q2 will form as the following Fig6.

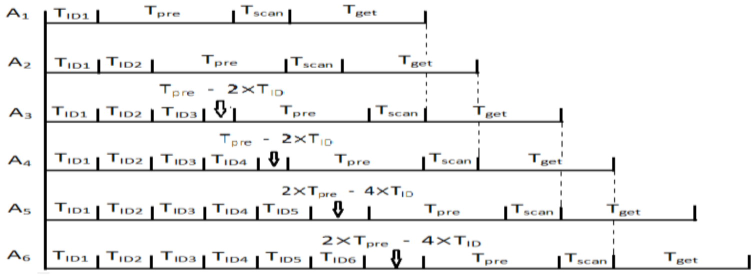

Figure 6. Time Axis of model 2.5.1

After analyzing time axis of model 2.5.1, we can see that:

$$T_{n(2.5.1)} = T_{ID} + T_{pre} + T_{scan} + (2n/2) \times T_{get}$$

Model with Single Checkpoint and m (m>2) Security Check Channels

In this section, on the basis of model 2.4.2,we make a discussion about different situations due to different m.Since $MT_{ID}>T_{pre}$, after passing checkpoint security, passengers don't need to wait in preparation and packing area any more. We can derive that $T_{n(2.5.2)}= n \times T_{ID}+T_{pre}+ T_{scan}+ T_{get}(n > 2)$.

Analysis.1.After passing checkpoint security, if there only exists one security check channel, a mass of passengers form queue B waiting for the next security check. It fits the empirical life experience. In the meantime, after analyzing formula $T_{n(2.3)}$、$T_{n(2.4.1)}$ and $T_{n(2.4.2)}$,

We can see that T_{pre} and T_{get} determine the time to through a whole securityprocess.Because of the Effect of superposition principl,the more passengers are, the bigger influence T_{pre} and T_{get} result in. This is where the major flaw lies on. In the existing airport security system, according to formula $T_{n(2.4.1)}$

$$T_{n(2.6.2)} = 3600 = T_{ID}+T_{pre}+T_{scan}+n_p \times T_{get}$$

$$n_p = 133, n = 802$$

We can see that the passenger throughput is 802 per hour in this existing system.On January 20th, Baiyun Airport departure 166700. people. According to our model, assuming airport work 12 hours a day, when there are 65 security check channel, ,the passengers throughput is 65× 802 × 12 = 156390.This is consistent with the reality. Model get verified.

3.We manage data and print curve so that we can clearly find the relationship between T_{ID} or T_{pre} and throughput.

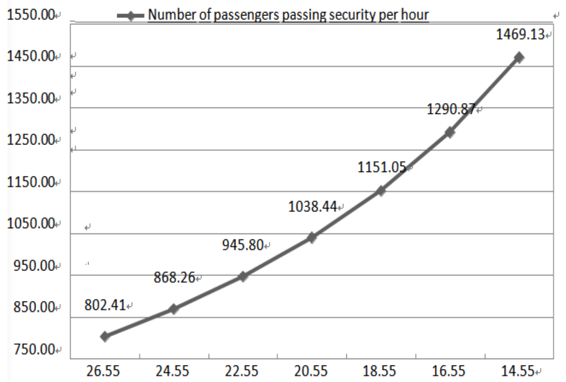

Figure 7. The connection between throughput throughput and T_{ID}

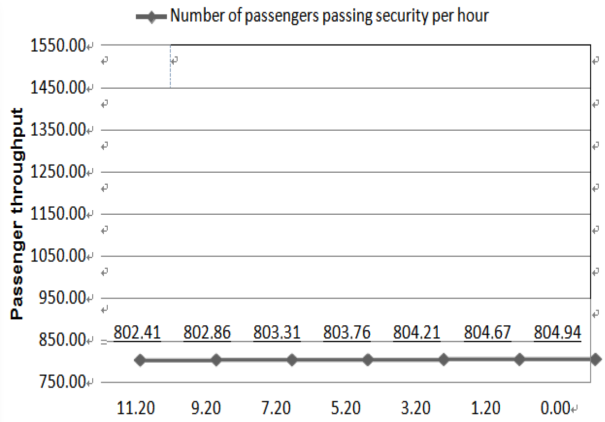

Figure 8. The connection between and T_{ID}

We can see that the T_{get} have a much greater impact to passenger throughput per hour than T_{ID}.

Conclusions

According to the analysis of model 2.4.1, we can draw the following conclusions:

1. The major flaw of the existing airport security process is that the average time spending on the preparation and packing area is excessively long.
2. That only increase the amount of checkpoints have no obvious effect on increasing passenger throughput.
3. The smaller T_{pre} and T_{get} can results in a bigger passenger throughput[10].

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