Optimization Model of Airport Security Screening

Ying Wei

Computer Department, Wuhan Polytechnic Wuhan, Hubei, 430074

915745208@qq.com

Abstract. Airport security is a necessary link for passengers to enter the airport. In this paper, we established a multi-server queuing model to optimize the airport security screening. Concretely, the whole queue process of security screening is decomposed into some parts. For each part, we established a multi-server queuing model, and used the number of passengers in the queuing system and the service intensity to evaluate the model. By utilizing the collected data, we identify the bottlenecks that are mainly caused by the number of open lanes and the service rate of a staffing.

Introduction

Airport security is a necessary link for passengers to enter the airport. It is an important safeguard for the safety of all passengers. When entering the airport, passengers may be subject to the capacity constraints of the security facilities [1-3]. If the maximum processing capacity of the facilities cannot meet the peak demand of the passenger flow, the passengers will be gathered at the security facilities, resulting in the formation of congestion and affecting the smooth entry of other passengers [4]. Therefore, on the premise of ensuring the existing standards of safety and security in the airports, how to improve the passenger throughput, reduce their waiting time and variance in wait time are very urgent issues.

Airport security is a typical queuing problem, where random arrival passengers are regarded as the input data, and the security system as the queuing rule [5-6]. According to the presented problems, we plan to develop a dynamic decision model to solve the optimization problems on the passenger throughput and the variance in wait time. The actual airport security is a very complex queuing process. In this paper, by adopting the part-to-whole idea, we first consider decomposing the whole queue process into some parts, and then analyze and process each part by the queuing theory.

The Model

Airport security process is a queuing process. We offer a brief explanation about the types of facilities and security process of the airport during the security check, and give the concept of airport evacuation capability and the definition of bottleneck.

In order to show the airport security bottlenecks in the process, we decompose the whole process by local considerations. The waiting queue length (the total number in the queuing system) in the queuing system performance index is selected, and the service intensity is taken as the bottleneck identification index of the airport evacuation capacity. The corresponding formula for calculating the bottleneck identification index is given, and the related problems in the airport security inspection process are identified.

Subject Annex statistics the time interval in the four process, that is, the passenger ID information inspection (there may be a number of channels), we call it process I; passengers through the metal detector time interval, we call it process II; items through the conveyor belt X - ray scan time interval (there are several channels), we call it the process III; and the time interval from putting down the baggage to take out, we call it the process IV.

On the one hand, part of the time-consuming of process III is included in the process of IV, the process III, IV's data in the annex cannot be peeled; the other hand, because of that, process III cannot directly reflect Airport security bottlenecks. In summary, we do not consider the impact of

process III, only identify whether there is a bottleneck in process I, II, IV.

Step 1:Identify the bottleneck of the process I, II, IV of security system.

Because in the whole analysis of the entire security process, we can not directly and clearly reflect the concrete queuing process at every stage. And because the process III is involved in process , the data cannot be stripped, therefore, we only locally consider three stages.
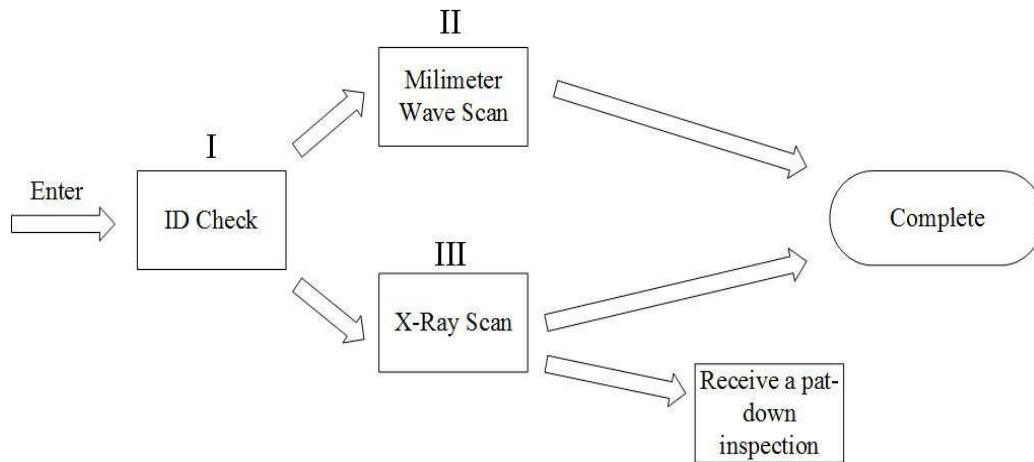

Figure 1.   Finite Airport security process

When locally consider above three stages, we can simplify each stage of airport security process to M/M/1 queuing service system. At the same time in order to facilitate the identification of the bottleneck in this queuing system, make full use of the relevant statistics given in the annex, respectively calculate the security phase of each and service duration , as an indicator of where bottlenecks are identified at each stage, the simplified service process model for stage I, II, and IV.

(1) The input process

The arrival probability of passengers is subject to Poisson distribution, and the probability density function of Poisson distribution is given by the following formula. At the same time, based on hypothesis 1, the capacity of this queuing system is infinite.

$$P(X = k) = \frac{\lambda^k}{k!} e^{-\lambda}, \ k = 0,1,2,\dots$$

where $\lambda > 0$ is the average number of passengers arriving per unit time, that is, the average arrival rate of passengers. Then $frac1\lambda > 0$ is the average arrival time for the passengers.

(2) System queuing rules: first-come-first-served FCFS

(3) Each passenger receives service independently of each other and has the same negative exponential distribution

$$b(t) = \begin{cases} \mu e^{-\mu t} & t \geq 0 \\ 0 & t < 0 \end{cases}$$

where $u > 0$ is the number of passengers that can be serviced by the aircraft security system per unit of time, is a constant. Then $1> 0$ is the service time a passenger in the aircraft security system. Then the security service intensity of I, II,IV three stages.

$$\rho_i = \frac{\lambda_i}{\mu_i}$$

In the above formula,

μ_i refers to average service rate of Stage I;

λ_i refers to passenger arrival rate of Stage I;

And lets use $N(t)$ to indicate the number of passengers in security check system at the time of t; The distribution function of $N(t)$ is P_n(t) and it is easy to get $P_n = (1 - \rho_i)\rho_i^n$. So here we can deduce the queuing number at the 3 security stages, namely Stage, Stage and Stage is

$$L_s = \sum_{n=0}^{\infty} nP_n = \sum_{n=0}^{\infty} n(1-\rho_i)\rho_i^n = \frac{\rho_i(1-\rho_i^n)}{(1-\rho_i)}$$

Where we use the statistics of the question, namely service intensity rho, queuing number Ls as indexes to measure if there are bottlenecks at the 3 security check stages, namely Stage, Stage and Stage .

Step 2: To identify if there are bottlenecks in personnel allocation at the 2 security check stages, namely Stage I and Stage IV.

Then we would utilize the relevant statistics in the appendix of the question. We believe that the process of passenger ID information check and the time used to X-ray the articles on conveying belts (Which is Process I and Process III) falls into the category of multi-way channels. As a matter of fact, the service character value u of each service window would vary because of different service efficiency by security check personnel in Process I and Process III. Here lets make it easy to only consider if there are only to service windows in Process I and Process III.As mentioned above, the time consumed is included in process IV. Therefore, we believe the personnel allocation bottlenecks that exist in Process III are the personnel allocation bottlenecks in Process IV. And only I and IV would be used in the following paragraphs.

Now, we use the statistics in the question and the service intensity in the 2 security check processes, namely Process I and Process IV as indexes to measure if there are bottlenecks in Process I and Process IV.

Now we design an algorithm to solve the model. The description of our algorithm is as follows.

Step 1: To identify the bottlenecks in the 3 stages, namely Stage I, Stage II and Stage III.

We can get the value of the service intensity and the total headcount in the system in the 3 stages, namely Stage I, Stage II and Stage IV of the existing security check system in airport by using the statistics in the appendix and MATLAB. The results are as follows.

Process I: $\rho=0.88$, $L_S=7.16$,

Process II: $\rho=0.94$, $L_S=14.97$,

Process III: $\rho=3.11$, $L_S=\infty$.

According to the collected statistics, it can be deduced from the results of calculation that the queuing number (the total number at this stage) at the 2 service stages namely Stage I and Stage II is within the control, so it can be regarded that there are no bottlenecks at these 2 service stages of security check.

In the service stage of Process IV, there might be a scenario of a sharp increase in total headcount, which is impossible in the factual queuing system. Therefore, we believe there are bottlenecks in the security check stage in Process IV. Moreover, the higher the value of service intensity ρ, the higher the rank of bottlenecks in the security check process of this stage.

Therefore, in the existing security check system of Airport, the bottlenecks mainly exist in the service stage of Process IV, i.e., the process from passenger dropping to taking out the articles. Besides, as there are no bottlenecks in Process I, it is unnecessary to calculate the index to identify if there are bottlenecks in personnel allocation in Process I. It can also be regarded that there are no bottlenecks in personnel allocation in Process I.

Step 2: Identify if there are bottlenecks in security check personnel allocation in Process IV.

At this moment we are considering how to identify if there are bottlenecks in security check personnel allocation in the 2 security check stages, namely Stage I and Stage IV.

It can be deduced from calculating service intensity index. It can be deduced from the above result: in the existing security check in Airport, the bottlenecks mainly exist in Process IV. Moreover, besides the bottlenecks in the processes of security check itself, there are bottlenecks in personnel allocation.

Conclusions

In this paper, we established an optimization model of the airport security screening based on the multi-server queuing model. In this model, in order to identify the bottlenecks of the airport's

current security process, we decompose the whole process into the four parts by local analysis method, and introduce the relevant indicators in the queuing theory to analyze and process each part. It can greatly simplify the problem.

Acknowledgments

References

[1] R.B. Cooper, Introduction to Queueing Theory, Elsevier/North-Holland, Amsterdam, 1981.

[2] G. Bolch, S. Greiner, H.D. Meer, et al, Queueing networks and Markov chains: modeling and performance evaluation with computer science applications, Technometrics 49 (1998) 104-105.

[3] A.A. Kirschenbaum, The cost of airport security: The passenger dilemma. Journal of Air Transport Management 30 (2013) 39-45.

[4] A.J. Lee, S.H. Jacobson, The impact of aviation checkpoint queues on optimizing security screening effectiveness, Reliability Engineering & System Safety 96(8) (2011) 900-911.

[5] N.U. Prabhu, Stochastic Storage Processes: Queues, Insurance Risk and Dams, Springer-Verlag, New York, 1980.

[6] M. Neuts, Matrix-geometric Solutions in Stochastic Models, John Hopkins University Press, Baltimore, 1980.