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Simulating and Scoring the Traffic Efficiency of Airport Security

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Abstract. In this paper, we solve the problem of airport security passing efficiency. First, we processed the raw data to calculate the service efficiency of each region. Next, based on Markov network queuing theory, we established the basic model which can show the passenger traffic situation of airport security. Using this model, we could analyze the impact of different variables on the airport security situation.

Introduction

September 11, 2001 terrorist attacks in the United States, arousing worldwide attention to the airport security. Especially in the United States, airport security is more stringent, and some airports even require passengers to take off belts, shoes, hand over cameras, mobile phones, carrying toys for inspection. Under such stringent inspection, US airport cases are well controlled, but it also brings with them many problems, such as because of the inability to predict the time of security check-ups, frequent flight delays or missed flights. In 2016, the US Transportation Security Administration (TSA) was sharply criticized for its long-distance travelers. After this incident, TSA Investments made several changes to its checkpoint equipment and procedures, along with the Pre-Check Trusted Traveler Program. Although it is successful in reducing waiting time, there are still some issues such as differences between passengers waiting times.

We need to establish an airport security model to explore the problem area of the existing program and the passenger flow of each area. At the same time we use the model to modify the problem area, to get a model which makes the passenger waiting time be shorter, variance be smaller, passenger throughput be greater. Then, considering the cultural differences of different countries, we revise and perfect the model again, improving the security efficiency while improving the security. In the process of building the model, we apply the method of "queuing theory", which has two kinds of methods: "Markov queuing network" and "Petri network". The model is based on Markov queuing network. We use the data given in the table to calculate the efficiency of all aspects of the service, and then use the Markov network based on Jackson network to establish the airport passenger security situation model. This is our basic model, in the model the conventional check passenger ID check window is the A1area, the pre-check passenger ID check window is the A_2 area, X-ray inspection window is the B area, millimeter wave inspection window is the C area, suspicious items check window is the D area.

Symbols Definition

Table 1 Symbols Definition

Symbol	Explanation
R	Probability transfer matrix between nodes
γ	The average arrival rate of each node
L_{si}	The average queue leader for each node

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Establishment and Solution of Model Overview of Algorithm. Queuing Theory Model Queuing theory is based on statistical analysis of the arrival time and service time of service objects, and obtains statistical rules of these quantitative indicators (waiting time, queue length, busy period, etc.), and then improve the structure of service system or reorganize Service object according to these laws, so that the service system can meet the needs of clients, but also the cost of the most economical or some of the best indicators. There are three aspects in the research of queuing theory: statistical inference, modeling based on data; the nature of the system, which is the probability regularity of the quantitative indicators related to queuing; the optimization of the system. The aim is to design correctly and run the various service systems effectively to make best benefits. For the airport security problem in this paper, we believe that using the queuing theory model, the security process can be evaluated by calculating the average step size and the average waiting time. However, due to the basic queuing theory model, customers are only requested a service, served, and then leave. But the airport security contains multiple processes, if we think each process as a node, then formed a queue network. In view of this situation, we choose the optimization model of queuing theory - Markov queuing network based on Jackson theory.

The opened Jackson queuing network model There are k nodes in the network. Suppose there are m servers on each node called i (i = 1,2…k), and the average service time of each server is $1/\mu_i$, obeying exponential distribution and independent of each other. And the client arrives at node i in a rate γ_i ,When the client completes the service at the node i, it enters the node j with probability r_{ij} and leave the queuing network with probability r_{io}. On the basis of this assumption, the correlation between the queue and the arrival rate of the node is eliminated, then each queuein the network is derived as an M / M / 1 queueMarkov queuing network Markov queuing network refers to that customer flow is Poisson flow in which each node external arrival, each node service time is negative exponential distribution .Combined with opened Jackson queuing model, suppose each link is independent of each other, then constitutes a Markov queuing network model based on Jackson theory, which can analyze the process of the number of indicators, then the process together to form a network by combining the whole process, then we can analysis the whole network.

Establishment and Solution of Basic Model. In the airport security problem, Any one check can be described as follows, the input arrival time interval obeys the negative exponential distribution M, service time also obeys the negative exponential distribution M, and the number of service window is, and in accordance with the first-come-first-served wait system. Therefore, the airport security system can be modeled as a M/M/L_i (i=1,2,3,4,5) five-queue composed of Jackson network model.

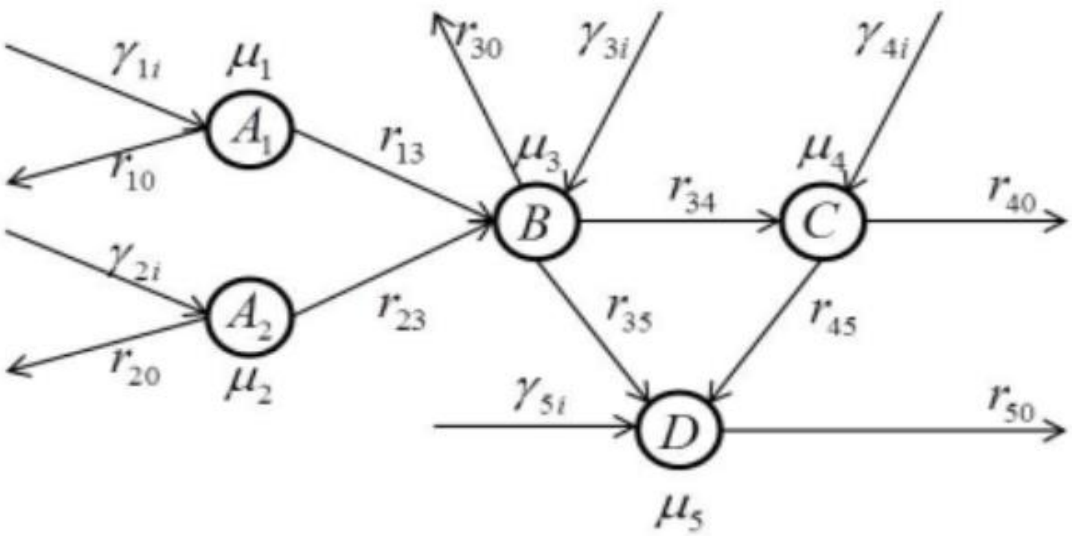

Figure 1: Airport Security Model Based on Markov Queuing Network

According to the data given in the title, while there are three windows, and there will open a pre-check window. To simplify the model, we set one pre-inspection ID window, two regular inspection ID windows, two X-ray inspection windows and one millimeter scan window, so as to solve the efficiency of the various links. Using Markov queuing theory and Jackson network, the airport security system is modeled as a queuing network, each process is represented as a node, with the arrival rate and service rate and other attributes, as shown in Fig 1. Where A_1 is the general ID check window, A_2 is the pre-inspection window, B is the X-ray inspection, C is the millimeter-wave inspection, and D is the suspicious item inspection.

Theorem 1: In the opened Jackson queuing network model, in order to solve the customer arrival rate, we access the information and we get the equation:

$\lambda = \gamma + R^T\lambda$

Where R denotes the transition matrix between nodes, and γ denotes the arrival rate of each client flow. On the basis of the established model, Transition probability matrix R is:

$$\begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{25} \\ r_{31} & r_{32} & r_{33} & r_{34} & r_{35} \\ r_{41} & r_{42} & r_{43} & r_{44} & r_{45} \\ r_{51} & r_{52} & r_{53} & r_{54} & r_{55} \end{bmatrix}$$

Further on the subject given in the airport security process analysis, because each passenger should be in accordance with the order of the security process security, that there is a directional, easy to obtain:

$r_{i1,i2}$= 0(i = 1,2, 3, 4, 5); r_{j3}= 0(j = 3, 4, 5); r_{k4} = 0(k = 1, 2,4, 5); r_{m5}= 0(m = 1, 2, 5)

Therefore, its transition probability matrix R can be rewritten as:

$$\begin{bmatrix} 0 & 0 & r_{13} & 0 & 0 \\ 0 & 0 & r_{23} & 0 & 0 \\ 0 & 0 & 0 & r_{34} & r_{35} \\ 0 & 0 & 0 & 0 & r_{45} \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Therefore, we can obtain the arrival rate matrix ρ of the node network by the formula:$\lambda = (1 - R^T)^{-1}\gamma$ and the queue strength matrix of each node can be obtained from the equation $\rho = \frac{\lambda}{\mu}$ and then average queue length L_{si} at this node can be further obtained according to the queue strength ρ_i of node I :$L_{si} = \frac{\rho_i}{1-\rho_i}$ and system captain of the entire network is L*s*.

The average residence time of W_{si} the passenger at each node can be deduced from the above formula:$W_{si} = \frac{L_i}{\lambda_i}$.

Theorem 2: Little's Law: In a stable system, the average number of customers L observed for a long time is equal to the product of the effective arrival rate λ observed over a long period of time and the time spent by each customer in the system, $L = \lambda_\omega$. According to Little's rule, we can get the total length of time for a visitor to stay in the network:

$$W_s = \frac{\sum_{i=1}^{5} L_i}{\sum_{i=1}^{5} \gamma_i}$$

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