

Optimization on Checkpoint based on Petri Net

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Abstract: This paper focus on searching the bottleneck in the security checkpoint to meet the trade-off between the security and convenience. we allocate certain time to each step which meet the duration of Poisson distribution. Then, with the airport security model based on Petri net, the whole process is simulated by programming and the relevant indexes, such as the average number of tokens, equipment utilization and passenger throughput, are obtained by the homogeneous Markov Chain to the Petri Net. To prove the reliability of our solution, it is simulated and the results show that passenger throughput has been greatly improved 17.6% .

Introduction

As we know, airport security attract tremendous amount of attention throughout the world, but, meanwhile, inconvenient process and long time it takes to screen a passenger still remains a concern^[1]. To meet the trade-off between the security and convenience and put forward two modifications for current process, this paper focus on searching the bottleneck in the security checkpoint. In addition, to avoid those unnecessary conflicts for the differences between various cultures, we assure whether the model corresponds to these cultures. Based on our model, our team propose ideas and policies to address the problem in current aviation security.

Simulation Modeling Based on Petri Net

A. Intoduction to the TSA Security Screening Process.

In the mainstream airport, the passengers have to go through the process displayed in the figure 1. Here are some extra information to explain the whole process in the picture. Zone A: passengers randomly arrive at the checkpoint and wait in line until a security officer can inspect their identification. Zone B: Then, the passengers move to a subsequent queue, which would be more or less lines due for the different activity level at airport, After reaching the front of the queue, the passengers prepare all of their belongings for X-ray screening. They must remove the items, such as shoes, metal objects, electronics, and containers with liquids, placing them in a into be X-rayed separately. All of their belongings are moved by the belt through an X-ray machine and the marked items need additional process in the Zone D. Meanwhile the passengers accept the test with either a millimeter wave scanner or metal detector. People who fail this step additional inspection in the Zone D. Zone C: The passengers walk to the other side of the belt to collect their items and then leave the checkpoint area[2].

In addition, people could pay extra money and enroll in a program called Pre-check to enjoy a separate screening process with a few modifications designed to reduce the time in test.

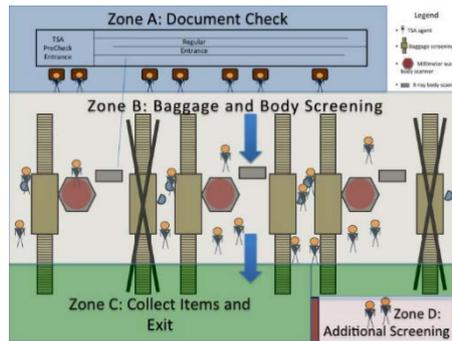


Figure 1: Illustration of the TSA Security Screening Process.

B. Assumptions

- (1)The policy is same in all airport
- (2)The frequency of people arriving at the checkpoint is stable
- (3)The probability distribution of people arriving at the checkpoint is corresponded with the Poisson Distribution
- (4)Do not consider the time that s passengers spend on passports and visas.
- (5)The input of the system can be discrete
- (6)The number of passengers would not have a surge.

C. Model

To mitigate the pressure from the people spending enormous time waiting in queue, it is vital for the whole process to identify where problem areas exist in the current course and come up with the idea address these problems[3].

After searching tremendous literature and paper on this field, we choose the Petri Net to find the disadvantage in the process. As the foregoing circumstances in the checkpoint area, the aviation security could be seen as a synchronized and concurrent system[4].So, according to the variety of circumstances and moment, we introduce the time as the parameter in our model and determined to utilize the GSPN, Generalized Stochastic Petri Net, to establish the mathematical model.

With the definition of the Petri Net, combined with the airport security passengers go through, a basic net based single lane security process is created.

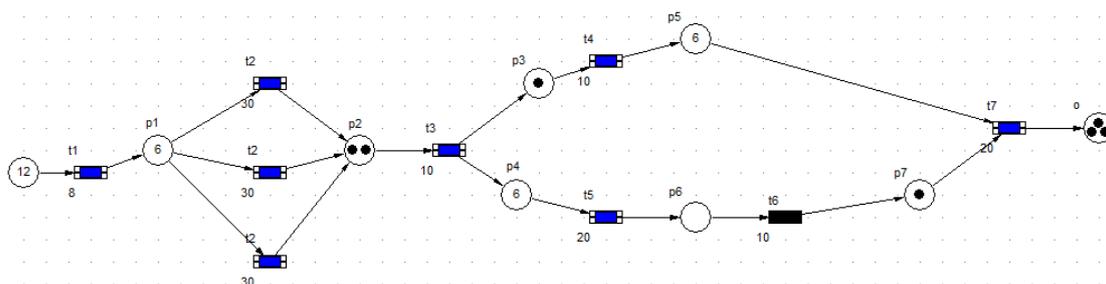


Figure 2: Petri network model for passenger security process

Here are symbol definition in the Figure2.

i:the passengers from last process such as the person who just got the boarding pass and waitin line;
o:the passengers prepared to next step. P_i : place, $P_i \in P = P_1, P_2, \dots, P_9$, t_i : transition, $t_i = T = t_1, t_2, \dots, t_{11}$.

P_1 :person going through the identification; P_2 :item the person just took off and person who take off the his belongings; P_3 :items prepared to the test; P_4 :person prepared to the screening; P_5 :luggage person would take away; P_6 : person who is ready to take his belongings; P_7 : person who waits for the luggage; t_1 :verify the document and boarding pass; t_2 :person takes off their belongings; t_3 :luggage and person wait for accept the X-ray test; t_4 :luggage accept the screening; t_5 :examine passengers with the detection devices; t_6 :people take their belongings; t_7 :people wait for their luggage;

Solving the model

A. Build the MC

Build the MC which is isomorphic to the GSPN model and the density matrix. Existing state: (M₀, M₁, M₂, M₃, M₄, M₅, M₆, M₇, M₈) Disappeared state: () With the for -going precondition, we simplify the GSPN and build the homogenous MC in Figure3.

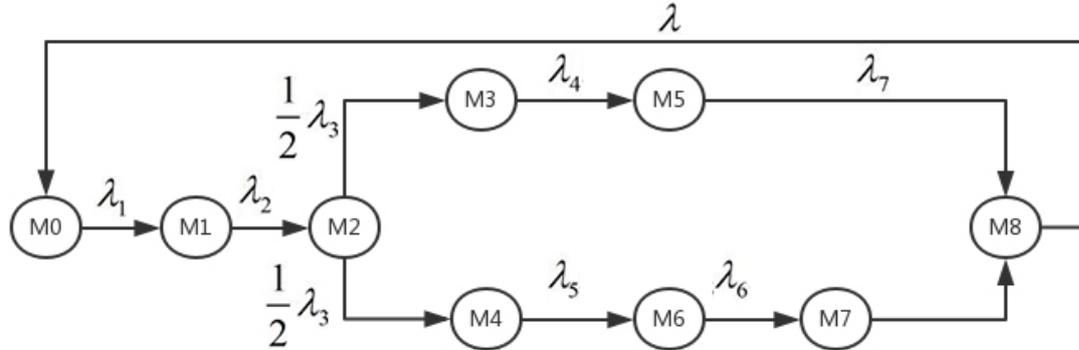


Figure 3: Isomorphic MC

Solve the steady state probability of MC Assuming the probability of every state is $X = (x_0, x_1, \dots, x_{18})$, we use the equation $X \cdot Q = 0$ with density matrix Q to get the probability distributions of steady state. the system based on the SPN and homogenous MC. It is supposed that $x_i (1 \leq i \leq n)$ is the steady probability of reachable markings. To any marking $M_i \in [M_0]$ which $[M_0]$ is the set of reachable markings of SPN. To both $M_i, M_k \in [M_0, M_k[t_k > M_i, M_i[t_i > M_j]$, the meaning is that M_i is the successor marking of M_j , M_k is the successor marking of M_i . There is the equation:

$$\left(\sum_j \lambda_j\right)x_i = \sum_k (\lambda_k x_k) \tag{1}$$

$$\sum_i x_i = 1 \tag{2}$$

Table 1: The average number of tokens

| Transition | Time | Symbol | Value |
|---|------|-------------|--------|
| Verify the document and boarding pass | 8 | λ_1 | 0.125 |
| Person takes off their belongings | 30 | λ_2 | 0.0333 |
| Luggage and person wait for accept the X-ray test | 10 | λ_3 | 0.1 |
| Luggage accept the screening | 20 | λ_4 | 0.05 |
| Examine passengers with the detection devices | 20 | λ_5 | 0.05 |
| People take their belongings | 10 | λ_6 | 0.1 |
| People wait for their luggage | 11.6 | λ_7 | 0.0863 |

B. The Calculation of Model

As Figure 3 shown, we get the matrix Q from the homogeneous MC of the Petri net and the stable probability in Table 2 can be solve by the foregoing equation.

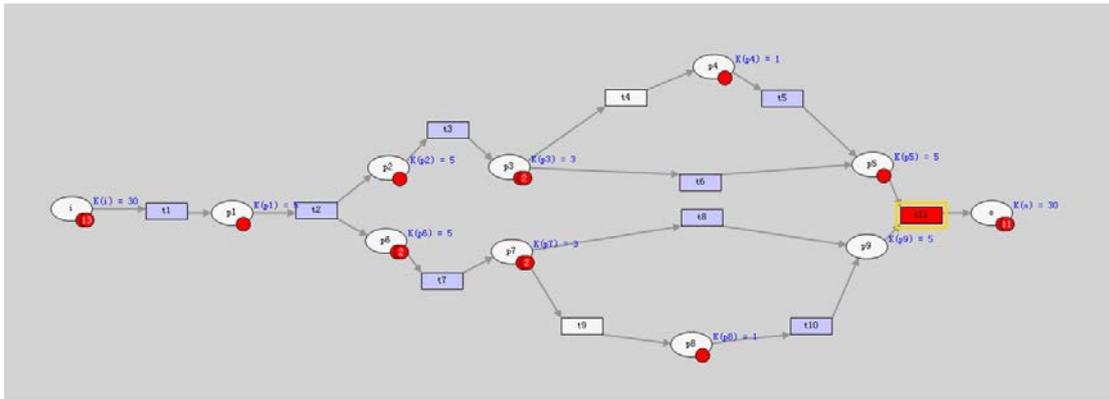


Figure 4: Simulation for Petri Net

After getting the stable probability, we combine it with the tokens in every place in order to bring them into the foregoing formula and calculate the average tokens^[5].

Table 2: Stable probability

| Place | Average token |
|-------|---------------|
| i | 0.133 |
| p1 | 0.241 |
| p2 | 0.331 |
| p3 | 0.101 |
| p4 | 0.795 |
| p5 | 0.812 |
| p6 | 0.111 |
| p7 | 0.131 |
| 0 | 0.971 |

In addition, the program record the tokens for each place in every second and create the curve in Figure 5 in order to see which place is more likely to be crowded.

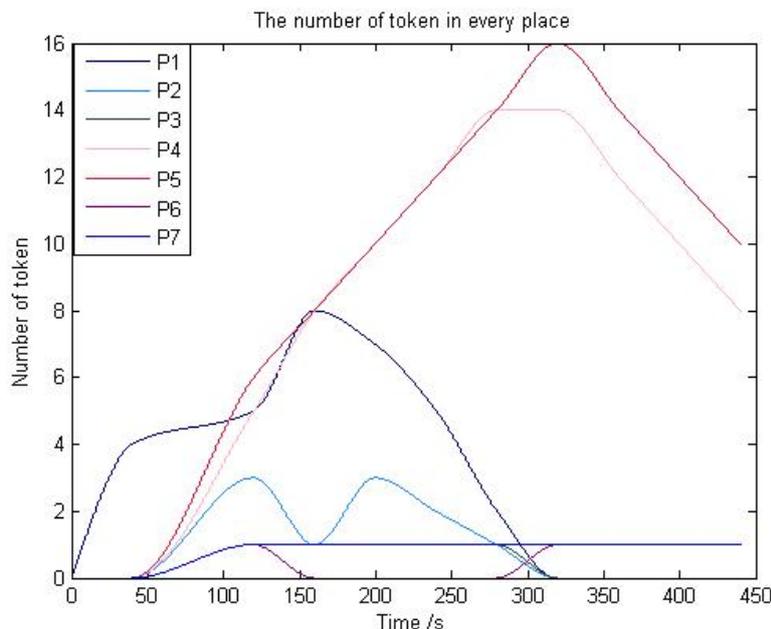


Figure 5: Tokens for each place

According to the average tokens and the curve shown in the Figure 5, the p5 and p6is obviously higher than other places in the process, which illustrate that taking the luggage and taking off costs easily congested^[6]. So, to avoid the congestion and improve the efficiency of aviation security, the airport have to add more staff charged with detection and add corresponding equipment expediting the process.

Conclusion

From the analysis of model, the bottleneck in security process is the procedure that people take away their items and that detection devices screening them. We use Petri Net model to explore the flow of passengers through a security check point and identify bottlenecks. To prove the reliability of our solution, it is simulated and the results show that passenger throughput has been greatly improved.

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