Bottlenecks Identification–Airport Security Checkpoint Process Optimization based on the GSPN theory

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Abstract. Customers satisfaction degree is critical to airlines. Therefore, it is significant for airlines to provide a positive flying experience for passengers by minimizing the time they spend waiting in line at an airport security checkpoint. The key of this problem is to identify the bottlenecks of the airport security process. Based on the Generalized Stochastic Petri Net (GSPN) theory, this article build the bottlenecks identification model to achieve this goal.

Introduction

With the development and spread of international terrorism, airport security has been significantly enhanced throughout the world. However, the enhanced air security increased the waiting time of passengers and bring inconvenience to them. To minimize inconvenience to passengers, we should identify the bottlenecks of the airport security process, which is critical [1].

Research Background

In America, there are Pre-check lanes in some airports for those trusted travelers. To use these lanes, passengers should pay some money to receive a background check and enjoy a separate screening process for some years. The Pre-check passengers have some privileges, they don't need to remove shoes, belts, or light jackets for screening. This article aimed at the airports mentioned above.

Problem Description

In order to facilitate the solution of the problem, this article simplified the security process into the following three steps:

1) Passengers randomly arrive at the checkpoint and wait in a queue for inspecting by security offices.
2) Passengers' belongings are moved by conveyor belt through an X-ray machine and get X-rayed. Meanwhile passengers detected by a millimeter wave scanner.
3) Passengers collect their belongings and depart the checkpoint area.

Single Channel GSPN Model Establishment

Before establishing our model, we first simplify the process and assume it as a single channel, which means there are only one ID verification station, one X-ray machine and one millimeter wave scanner. Based on the simplification, we utilize the GSPN theory to build our model, as shown in Fig 1 [2].

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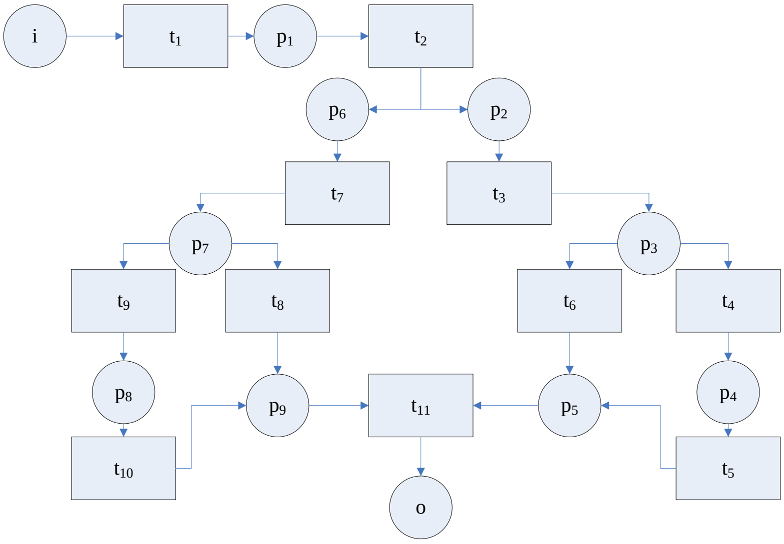

Fig 1: passengers' security process GSPN model

According to the Fig 1, we build MC (Markov Chain) that is isomorphic to it. Since M_3, M_6, M_7, M_8, M_9, M_{11}, M_{15} is transient transition, which don't have concrete time length, need to be delete from MC. Then, we use the average trigger rate λ instead of the delay time t and obtain the isomorphic MC, as shown in Fig 2.

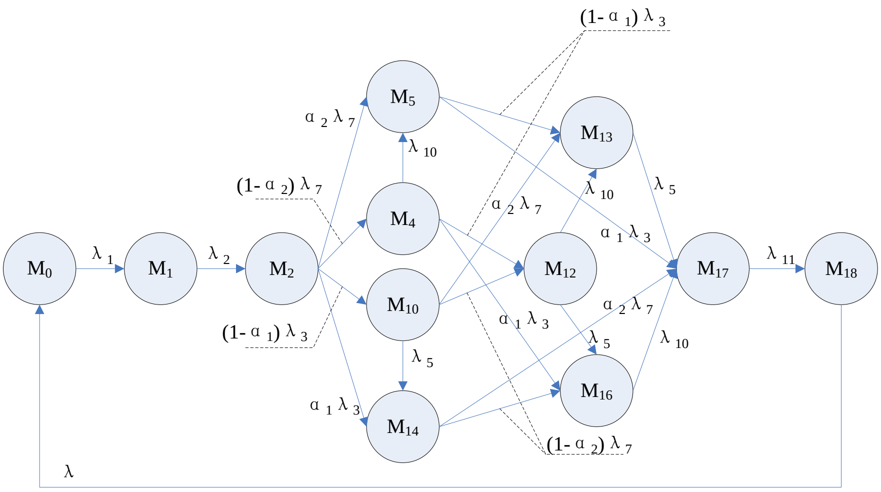

Fig 2: isomorphic MC

Combined with the correlation theory of MC [3], we get the transfer rate matrix Q. Assume the probability set $X=(x_0,x_1,x_2,\cdots,x_{18})$ and put it into:

$$X \cdot Q = 0 \tag{1}$$

We can obtain the probability distribution of the steady state.

Model Solving and optimization

Data about how passengers proceed through each step of the security screening process is shown in Tab 1.

Tab 1: optimized simplified data

IDCP time	MWS time	X-Ray Scan Time	Queuing time
10.19	10.26	5.5	11.45

Note: IDCP time—ID Check Process Time, MWS time—Millimeter Wave Scan times

According to Tab 1, we list the symbols and assign them, as shown in a Tab 2.

Tab 2: data of steps

Step	t_i	Times(s)	Symbol	Symbol value
ID check	t_1	10.19	λ_1	5.40
Queuing	t_2	11.45	λ_2	4.80
X-ray scanning	t_3	5.5	λ_3	10
Dangerous baggage	t_4	-	$1-\alpha_1$	0
Safe baggage	t_6	-	α_1	1
Millimeter wave scanning	t_7	10.26	λ_7	5.36
Dangerous people	t_8	-	α_2	0
Safe people	t_9	-	$1-\alpha_2$	1

Put them into Eq. (2), we obtain Tab 3.

$$\begin{cases} 27x_0 = 5x_{18} \\ 8x_1 = 9x_0 \\ 16x_2 = 5x_1 \\ 125x_4 = 67x_2 \\ x_{10} = 0 \\ \sum x_i = 1 \end{cases} \quad (2)$$

Tab 3: the average number of tokens and the rate of transition utilization

Place	i	p_1	p_2	p_3	P_7	o
Average number of tokens	0.0767	0.2756	0.4134	0.0861	0.1481	0

From the Tab 3, we can see that there are more tokens in p_1, p_2 and p_7, which p_1 is ID check time, p_2 is queuing time and p_7 is Millimeter scan time. So, we identify them as bottlenecks. Moreover, we can give priority to bottlenecks optimization when optimize the process. For example, we can increase the number of security officers and the millimeter machines.

Conclusions

Based on the Generalized Stochastic Petri Net (GSPN) theory, this article identified the bottlenecks of the airport security process. Besides, according to the identified bottlenecks of the process, this article proposed the corresponding optimization strategies.

References

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