

# An Optimization of the Passenger Throughput at an Airport Security Checkpoint

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**Abstract.** With the rapid development of transportation, we are entering the era of large population distribution. Thus, how to optimize the passenger throughput at an airport security checkpoint has become a universal concern. This paper first builds up a Petri Net model which is based on random Generalized Stochastic Petri Net theory and Markov theory to describe security service process. Then this model is transformed into GSPN model for simplification under the premise of determining the structural reliability of the model. Based on the data given in the excel, we analyze the current process of security checkpoint. Finally, we identify bottlenecks existing in airport by analyzing the average tokens.

## 1. Introduction

### 1.1 Background

Airport is the linkage between the land and air traffic. Unfortunately, insufficient capacity of the airport security has handicapped the development of air transportation industry. Meanwhile, congestion that could cause huge economic loss has become increasingly serious at busy airports. It is of great importance that proposing an optimal strategy for Transportation Security Agency to minimize the time that passengers spend waiting in line at a security checkpoint and waiting for their flight while maximizing security for them.

Although various measures have been applied successfully, there is still a tension between desires to maximize security while minimizing inconvenience to passengers.

### 1.2 Our Work

For ensuring the safety of passenger on their travels and optimizing the airport security check process, we select and analyze Generalized Stochastic Petri Net (GSPN) to make model and simulation analysis.

We begin with a feasible Generalized Stochastic Petri Net model. Based on the data given, we analyze the current queuing process for inspection, checking IDs, preparing luggage, millimeter wave scanning and X-Ray scanning. By reviewing literature, we determine to use Loosely Coupled Inter-organizational Workflow theory and Markov theory to get the determination of parameters. Then we identify bottleneck existed in airport by analyzing and solving the problem of performance indicators.

Since our task is to maximize security while minimizing inconvenience to passengers, we develop two potential modifications to optimizing the passenger throughput at an airport security checkpoint. Based on the bottlenecks which are previously proposed, we change single process time consumption and demonstrate how these modifications impact the process by using models.

## 2. The Petri Net Model

In this section, we figure out how the current security checking process for a US airport security checkpoint display (Figure 2). Then we establish a basic Generalized Stochastic Petri Net model which includes queuing process for inspection, checking identification, preparing belongings, millimeter scanning and X-Ray scanning. Next we transfer this model into GSPN model for simplification under the premise of determining the structural reliability of the model. In this part, we

use GSPN model to analyze the data given in the excel. From our model analysis and conclusion, we determine parameters in order to find out bottlenecks existed in current airport security checkpoint.

After deriving the value of parameters and influence of bottlenecks, we develop two potential modifications to the current process to improve passenger throughput and reduce variance in wait time. Then analyze to what extent do these modifications impact the process.

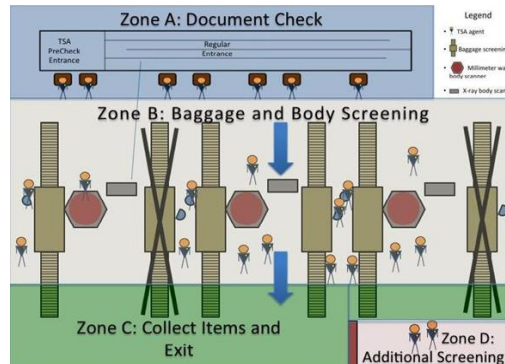


Fig. 1 Process for security check

## 2.1 Assumptions

When applying Petri Net model in the process of single channel security checking, the model's structure is sure to be correctly operated without conflicts and deadlocks.

## 2.2 Basic Model

Based on the data, we could get time consumption of each process including queuing process for inspection, checking IDs, preparing luggage, millimeter wave scanning and X-Ray scanning via regression method by using sample data Hence we conclude the various time of these process.

Table 1 Time consumption of each process

process	consumption of time/s	$T_i$	symbols meaning	symbols value
Checking IDs	11.50	$T_1$	$\lambda_1$	5.22
Preparing luggage	12.95	$T_2$	$\lambda_2$	4.63
X-Ray scanning	6.85	$T_3$	$\lambda_3$	8.76
<b>Having suspicious items</b>	—	$T_4$	$\alpha_1$	0.10
Checking luggage	60.00	$T_5$	$\lambda_5$	1.00
Not having Checking luggage	—	$T_6$	$1 - \alpha_1$	0.90
Millimeter wave scanning	11.64	$T_7$	$\lambda_7$	27.90
Safety inspect door is normal	—	$T_8$	$\alpha_2$	0.01
Safety inspect door alarm	—	$T_9$	$1 - \alpha_2$	0.99
Luggage on the belt	30	$T_{10}$	$\lambda_{10}$	2.00
Personal check	28.61	$T_{11}$	$\lambda_{11}$	2.10

$$\lambda_i = \frac{60}{T_i} \quad (i = 1, 2, \dots, 11) \quad (1)$$

Where:

$T_i$  ( $i = 1, 2, \dots, 11$ ) is the time consumption value of each process;

$\lambda_i$  ( $i = 1, 2, \dots, 11$ ) is the firing speed of each process;

$\alpha_1$  is the probability of having suspicious items;

$\alpha_2$  is the probability that safety inspect door alarm is not warning.

Having obtained time consumption of each process at the security checkpoint from the former calculating, we establish the GSPN model which is based on Generalized Stochastic Petri Net theory for simplification.

To begin with, we determine to get the transfer rate matrix  $Q$  on the basis of homogeneous markov chain. Generally speaking, we can get the elements  $q_{ij}$  which not appear on the diagonal of matrix conceptually. If  $M_i$  is linked with  $M_j$ , the value of  $q_{ij}$  is the rate remarked above the line. When  $M_i$  is not connected with  $M_j$ , we can view  $q_{ij}$  as zero. Theoretically on the diagonal of matrix, the value of is the negative value of the sum of the rates. Matrix  $Q$  is as follows.

$$Q = \begin{pmatrix} -\lambda_0 & \lambda_0 & & & & & & & & & & \\ & -\lambda_1 & \lambda_1 & & & & & & & & & \\ & & -\lambda_2 & \lambda_2 & & & & & & & & \\ & & (1-\alpha)\lambda_4 & (\alpha-1)\lambda_4 - \alpha\lambda_3 & \alpha\lambda_3 & & & & & & & \\ & & & -\lambda_5 & \lambda_5 & & & & & & & \\ & & (1-\beta)\lambda_4 & & (\beta-1)\lambda_4 - \beta\lambda_6 & \beta\lambda_6 & & & & & & \\ & & & & & -\lambda_7 & \lambda_7 & & & & & \\ & & & & & -\lambda_8 & \lambda_8 & & & & & \\ & & & & & & -\lambda_9 & -\lambda_9 & & & & \\ -\lambda^* & & & & & & & & \lambda^* & & & \end{pmatrix} \quad (2)$$

$$\begin{cases} X \cdot Q = 0 \\ \sum x_i = 1 \end{cases} \quad (3)$$

Where:

$g = (x_1 \ x_2 \ x_3 \ x_4 \ x_5 \ x_6 \ x_7 \ x_8 \ x_9 \ x_{10} \ x_{11} \ x_{12})$  is a  $1 \times 12$  matrix which describes the stable probability density;

$x_i (i = 1, 2, \dots, 12)$  is probability density at the  $i$ th array index;

$Q$  is the transfer rate matrix.

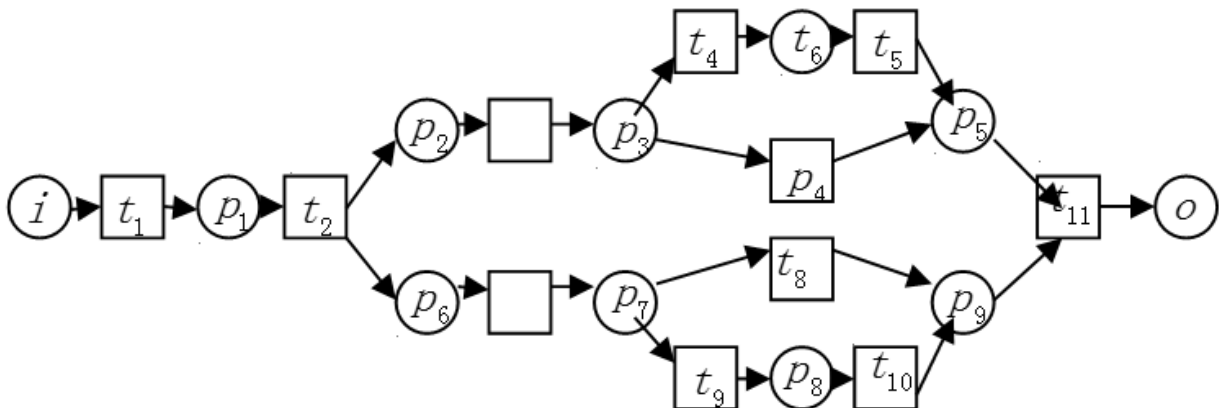


Fig. 2 The Petri model of security checking process

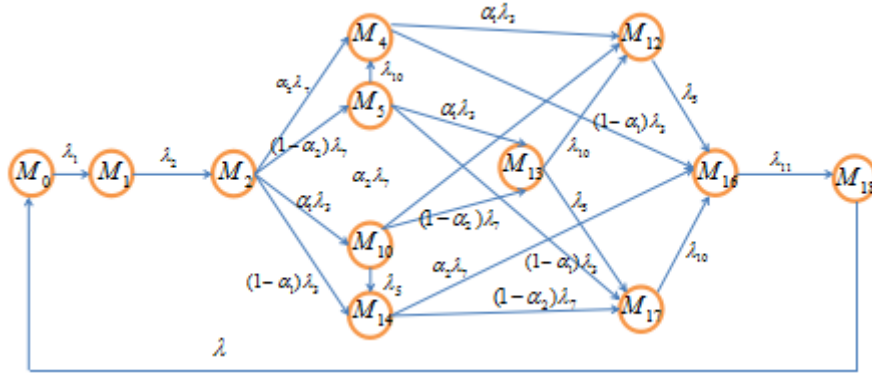


Fig. 3 Isomorphic Markov chain

## 2.3 Bottlenecks

After having put the result of data to the GSPN model, we can get the stable probability density distribution by solving the equation ‘ $X \cdot Q = 0$ ’,  $\sum x_i = 1$ . Then we multiply i tokens by probability belonging to it and plus all of them to get the average tokens of place  $P$ . According to the reaching standard, transition changes’ utilization ratio is the sum of the stable probability that make transition place  $t$  at an enforceable condition. The result is shown in the following table.

Table 2 .Average tokens in each place

place	average token
$i$	0.3560
$p_1$	0.0089
$p_2$	0.0248
$p_3$	—
$p_4$	0.0522
$p_5$	0.2131
$p_6$	0.0133
$p_7$	—
$p_8$	0.1621
$p_9$	0.1813
$o$	0.4596

Table 3 .Transitions usability

transition	transitions usability
$t_1$	0.3560
$t_2$	0.0089
$t_3$	0.0248
$t_4$	0.0522
$t_5$	0.0133
$t_6$	0.1621
$t_7$	0.4593

On the basis of the result, it is known that place  $i$  and place  $o$ 's average tokens are larger than others, indicating the time passengers consume in these proper process is long. Thus these two places tend to form the bottlenecks. Analyzing the reason: place  $i$  is the input place, passengers need to take off shoes and other items, which can take a long time. The output place  $o$  is the bottleneck, meaning that passengers wait here for too long.

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