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# Departure Security Inspection for Special Passengers based on Deep Learning Optimization Method for Setting up Dedicated Channels

Guihong Zhao[1], Shanshan Wang[2, *]

[1] College of Economics and Management, Civil Aviation University of China, Tianjin, China

[2] College of Transportation Science and Engineering, Civil Aviation University of China, Tianjin, China

*Corresponding Author

## Abstract

**In response to the current situation where the allocation of security inspection service resources for special passengers at airports is to be further optimised, this study constructs an optimisation model for special passenger security inspection lanes that integrates service perception.By analysing the dynamic features of special passengers' facial expressions through a convolutional neural network and combining queue behaviour data, a service perception threshold was established, with 7 minutes determined as the maximum waiting time threshold for positive service perception.Based on the characteristics of the log-normal distribution, we established models for passenger arrival volumes across multiple flights, security check queue lengths, and estimated waiting times. We innovatively constructed an optimisation framework for two modes: the addition of dedicated lanes for special passengers and the mixed use of dedicated and general lanes. We proposed a time-series dynamic adjustment strategy, which has a certain degree of practical value.**

## Keywords

**Convolutional Neural Network; Special Passengers; Queue; Airport Security.**

## 1. Introduction

Special passengers are an important group in civil aviation transportation service support work. As a vulnerable group among air travellers, most special passengers cannot have their needs met by being placed in the same service environment as ordinary passengers, i.e. security check lanes.Due to the standardisation of security checkpoints, the effectiveness of security checks cannot be fully realised [1]. The ‘Regulations on the Management of Air Transport Services for Passengers with Special Needs’ and the ‘Measures for the Air Transport of Persons with Disabilities’ also clearly stipulate that airport management authorities shall set up dedicated security checkpoints for passengers with special needs (including persons with disabilities).

In studies on the allocation of aviation security resources, modelling optimisation is often performed using flight schedules for different time periods [2, 3] and the peak hour method is considered in the context of flight delays ,Simulation methods for security check processes and queuing theory methods [4, 5, 6, 7] were used to conduct specific research on the reasonable configuration of passenger security check lanes.Among them, Zhao Yuandi and Jiang Xiaolei[8] conducted an in-depth analysis of the queuing mechanism of airport terminal security check systems and constructed two different security check queuing models based on queuing theory,It was also found that as passenger arrival

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rates increased, the minimum number of security checkpoints required also increased accordingly;YiruW[9] established a network flow structure based on the idea of abstracting passenger flow as network flow and arrival flow at the airport to analyse bottlenecks in security check throughput at international airports;SeoS [10] built upon previous research and, from the perspective of passenger satisfaction, used a Markov model to determine the number of security checkpoints required for each time period.These conclusions provide scientific theoretical support and decision-making references for the rational allocation of security checkpoint numbers in the terminal building and the improvement of security check efficiency.

In summary, the optimised configuration of security checkpoints is of great significance for improving the security check experience for all passengers, including special passengers, and for enhancing the efficiency of airport security checks. By employing convolutional neural network deep learning algorithms and mathematical modelling methods for queuing problems, a new approach is proposed to optimise the configuration of security check lanes.

# 2. Perception Analysis of Departure Security Inspection Services for Special Passengers and Determination of Queuing Waiting Time Thresholds

## 2.1 Perception Analysis of Special Passenger Services

The special passengers defined in this article include elderly passengers (aged 60 and above) with cognitive abilities and self-care abilities, passengers with hearing or visual impairments who have cognitive abilities, passengers with limited mobility, passengers with illnesses or disabilities, pregnant women, unaccompanied children aged 6 and above, first-time passengers, and passengers travelling with infants.Based on existing research, service perception in the security screening queue for special passengers is mainly composed of four factors: service quality, waiting time, risk, and environmental perception [11].Research has found that, apart from service quality, perceived waiting time contributes the most to the explanatory variance.Since special passengers only interact with service staff during the verification process, their perception of service quality is transformed into a perception of waiting time through the cumulative effect of time spent waiting. This makes waiting time a key indicator that affects the service experience.Therefore, this study focuses on the factor of security check queue waiting time as an effective entry point for measuring the service perception of special passengers.

Secondly, special passengers are more susceptible to distractions than ordinary passengers and are more likely to show changes in facial expressions while queuing.Research shows that customers often bring their own emotions with them when they first engage with a service. Customers are influenced by the service context, which causes emotional changes that affect their perception of the service .Some scholars have also emphasised the relationship between emotional responses and waiting time in their research [12],His research found that tourists may experience mood swings while waiting.Short waits may be acceptable, but long waits can lead to low moods and even negative emotions such as frustration, anger, or sadness.Furthermore, prolonged periods of time can lead to the expression of negative facial expressions, highlighting their anxiety and stress levels. More importantly, facial expressions are essentially an intuitive feedback of emotions and perceptions[13], and can effectively reveal the state of passengers at a given stage.Convolutional neural networks (CNN) are a type of deep learning algorithm that is already well established in the field of facial expression recognition in many areas. Therefore, this study applies convolutional neural networks to the recognition of facial expressions of special passengers while they are waiting in line.

## 2.2 Determining the Threshold for Special Passenger Security Check Queue Waiting Times under the CNN Service Perception Mechanism

Facial expression recognition has advantages such as non-contact, ease of implementation, and low cost, and has been applied in various scenarios [14].The training of convolutional neural networks (CNNs) requires a large amount of data. This study selected the RAF-DB dataset, which covers a variety of emotional states and involves different groups of individuals, effectively simulating the

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emotional reactions that special passengers may exhibit during security checks.At the same time, since the ResNet series performed exceptionally well in the ImageNet image classification challenge, the ResNet-18 deep convolutional neural network model [15] was selected,the execution process is shown in Figure 1 below.

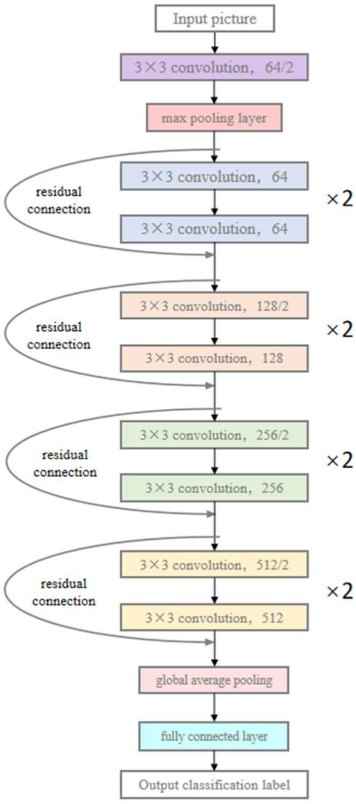


**Figure 1.** ResNet-18 convolutional neural network model execution flow

Based on the imported pre-trained model, the ResNet-18 model was trained using the RAF-DB dataset. The epoch was set to 60 during training. After multiple rounds of training, the model with the best performance on the validation set was selected. The training time was approximately 90 minutes. The training set loss (loss function) curve and accuracy are shown in Figure 2 below.The loss curve shows a rapid decrease in loss during the first 10 epochs of training, indicating that the trained model performs well on the test set. After 40 epochs, the loss curve stabilises and no longer changes. When the epoch reaches 50, the accuracy value reaches 0.95, which means that the model has strong generalisation capabilities and excellent prediction performance in standard tasks.

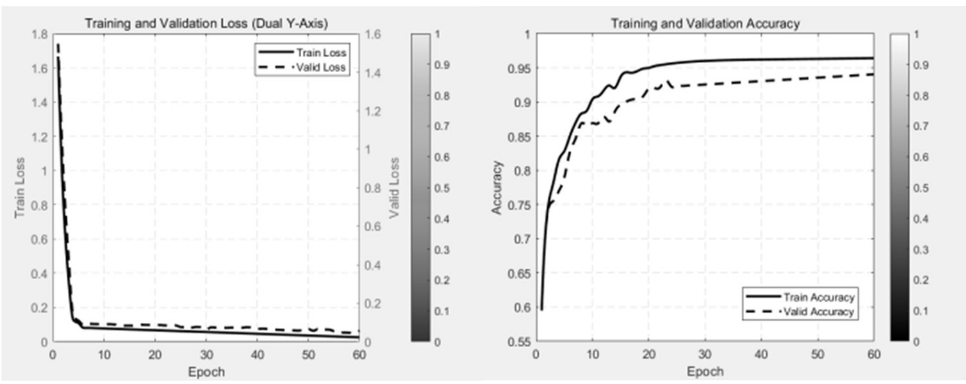


**Figure 2.** Training Loss Curve and Accuracy Chart

The study was conducted from August to September 2024 at a security checkpoint isolation area in a certain airport in X City, where facial images of special passengers were collected on-site during the queuing and waiting process,The data collection period is from 08:00 to 12:00 and 13:00 to 18:00, which basically covers the peak arrival times of passengers in the security check area of the terminal building and fully records passenger flow characteristics.The collection area is the special security check channels for special passengers inside the terminal building: S347 and S348 security check channels (for passengers travelling with children), and S339 security check channels (for first-time passengers ).Figure 3 shows the process of facial expression recognition using the ResNet-18 neural network model for self-captured images, with the final output being the emotional label for each image.

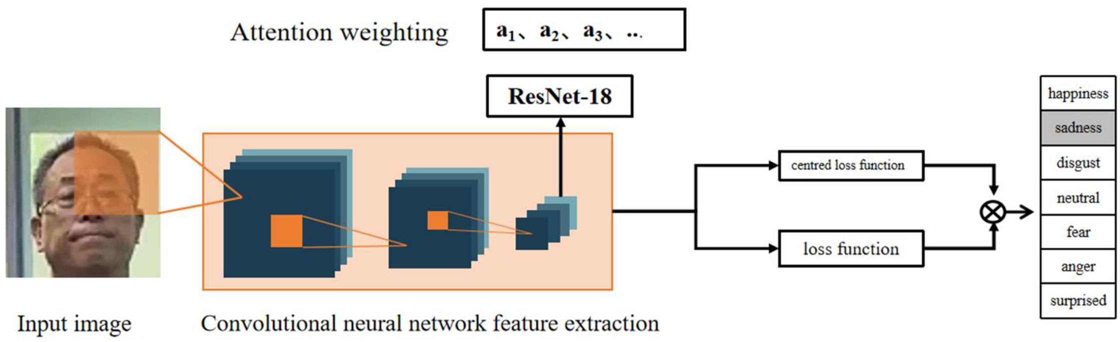


**Figure 3.** Facial expression recognition process for special travelers

This study divides the security check queueing process for special passengers into three stages: early stage (entering the queue), middle stage (waiting), and late stage (leaving the queue).By recording significant facial expression data at each stage, we quantitatively analysed the relationship between emotional changes and perceived waiting time. The results showed that facial expression trends during queuing could be divided into three categories: positive facial expressions increased over time (category b), positive facial expressions decreased (category c), See Figure 4 below.,and positive facial expressions remained unchanged (category a).The study aims to determine the threshold waiting time for positive service perception among special passengers through three-stage emotional fluctuation characteristics, i.e., the maximum tolerable duration before the group's emotional trend declines.This threshold is a key indicator for optimising the efficiency of security check services. It can analyse emotional dynamics at different stages and provide a theoretical basis for scientifically regulating queueing times, ultimately achieving positive service perception.

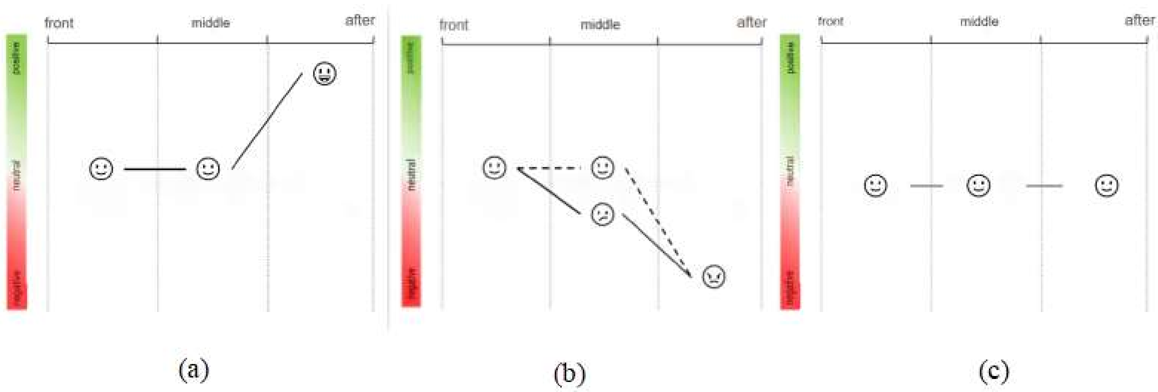


**Figure 4.** Trends in facial expression positivity (a) Increase (b) Decrease (c) Remain unchanged Example

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See Table 1 below,among the 246 passengers whose facial expressions showed a downward trend, after excluding the extreme maximum and minimum values where the number of passengers was 1 within certain waiting time ranges,the waiting time ranged from 7 minutes to 15.5 minutes.It can be inferred that when the waiting time for special passengers exceeds 7 minutes (excluding), most passengers tend to show negative facial expressions, such as anger, disgust, sadness, etc., during the middle and latter stages of waiting in line.This indicates that a waiting time of more than 7 minutes does not meet the perceived needs of special passengers. Taking into account the 65 passengers whose facial expressions showed an upward trend, when the waiting time exceeded 7 minutes, although a small number of special passengers maintained positive facial expressions, this phenomenon may have been influenced by factors such as the environment and peers.Therefore, based on the comprehensive analysis results of this study, the security check queue waiting time that meets the perceptions of special passengers is determined to be 7 minutes.According to the ‘Civil Airport Service Quality Standards MH/T 5104-2013’ 6.4.5.1, the waiting time for domestic passengers is as follows: 95% of domestic economy class passengers should have a waiting time of no more than 10 minutes for check-in and boarding procedures in order to achieve a higher level of service. This study sets the standard waiting time for ordinary passengers at 10 minutes.

**Table 1.** Waiting times and number of people in categories a and b

| Waiting time range for category B /min | Number of people within this range | Waiting time range for category A/min | Number of people within this range |
|---|---|---|---|
| (6-6.5] | 1 | (1-1.5] | 4 |
| (6.5-7] | 0 | (1.5-2] | 0 |
| (7-7.5] | 28 | (2-2.5] | 2 |
| (7.5-8] | 26 | (2.5-3] | 5 |
| (8-8.5] | 31 | (3-3.5] | 11 |
| (8.5-9] | 27 | (3.5-4] | 9 |
| (9-9.5] | 16 | (4-4.5] | 6 |
| (9.5-10] | 14 | (4.5-5] | 3 |
| (10-10.5] | 11 | (5-5.5] | 4 |
| (10.5-11] | 13 | (5.5-6] | 6 |
| (11-11.5] | 11 | (6-6.5] | 7 |
| (11.5-12] | 7 | (6.5-7] | 3 |
| (12-12.5] | 5 | (7-7.5] | 2 |
| | | (7.5-8] | 0 |
| ... | | (8-8.5] | 2 |
| | | ... | |
| (15-15.5] | 1 | (10-10.5] | 1 |

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# 3. Analysis and Model Construction of Departure Security Check Queuing System for Passengers

## 3.1 Anlysis of Passenger Departure Patterns

This study focuses on a multi-service window, multi-queue system and assumes that special passengers only queue and receive services at the special passenger security checkpoint, while ordinary passengers only queue and receive services at the ordinary passenger checkpoint. This approach not only adheres to the first-come, first-served queuing rule to ensure the service satisfaction of both types of passengers, but also improves the service rate of the security check system.The following data, representing all passengers arriving early at the airport during peak hours on a random day during the summer season, was used as a sample. A total of 17,260 data points from 150 flights were used to describe the overall distribution pattern of passenger arrivals. In Figure 5, the horizontal axis represents the time of early arrival, and the vertical axis represents the arrival rate.As can be seen from the figure, the arrival behaviour of all passengers in the security check area of the terminal building is highly non-uniform, and activity levels fluctuate dramatically over time. The average arrival rate curve has a long tail and exhibits obvious heavy-tailed characteristics.

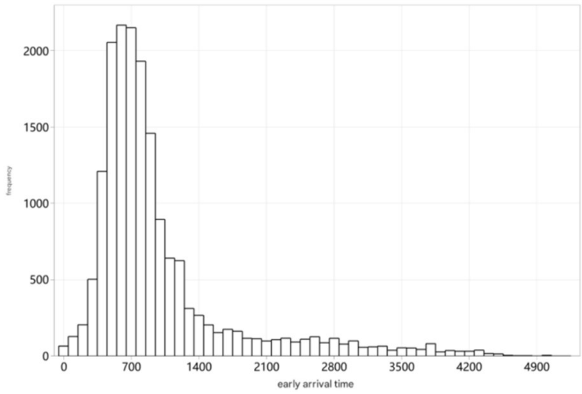


**Figure 5.** Distribution of early arrival times for all passengers

After performing frequency statistics and normalisation on the data, a goodness-of-fit test was applied. Using MATLAB, the time at which passengers arrive at the security check area in advance for a single flight was calculated, i.e.tw,Linear curve fitting revealed that the data on the time passengers arrived at the security check area in advance followed a lognormal distribution. The cumulative probability distribution function of the lognormal distribution is shown in Figure 6:

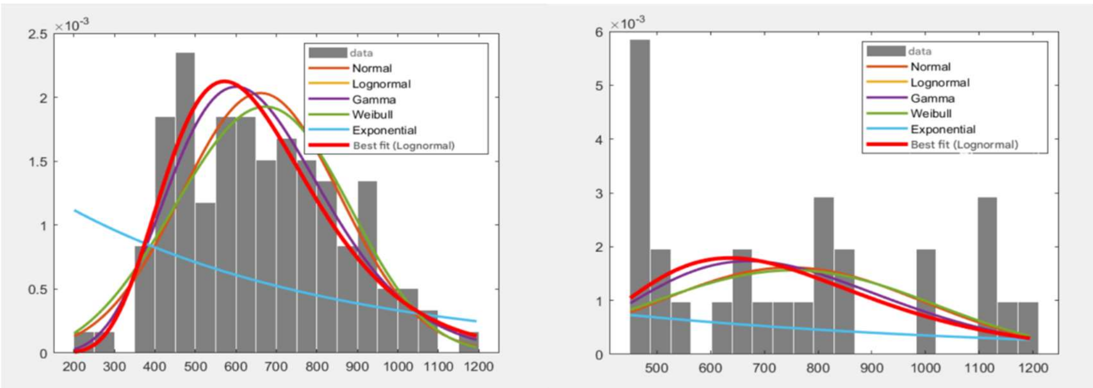


**Figure 6.** Fitted Distribution of Early Arrival Process for Regular Passengers (Left) and Special Passengers (Right)

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The definition of the log-normal distribution is: if the logarithm lnX of a random variable X follows a normal distribution,, then X is said to follow a log-normal distribution with parameters μ and σ. Its probability density function is:

$$f(x;\mu,\sigma)=\frac{1}{x\sigma\sqrt{2\pi}}e^{-(\ln x-\mu)^2/2\sigma^2},\quad x>0 \tag{1}$$

Based on the above analysis, a single-flight departure passenger aggregation model was established, assuming that the arrival time of passengers obeys a log-normal distribution and that the flight departure time is represented by t0,the time when passengers arrive at the terminal is t.Then waiting time $t_w=t_0-t$ , $F(t_0-t)$ ,that is $F(t_w)$ ,satisfy the following relations:

$$F(t_w)=\int_{t_w}^{\infty}f(s;\mu,\sigma)ds=1-F(t_w,\mu,\sigma) \tag{2}$$

That is:

$$F(t_0-t)=\frac{1}{2}-\frac{1}{2}erf\left[\frac{\ln(t_w)-\mu}{\sigma\sqrt{2}}\right] \tag{3}$$

### 3.2 Model Construction of Passenger Departure Queuing System

Although most security check areas are fully open, data shows that passengers typically arrive at the security check area at least three hours before the flight departure time, while the flight cut-off time is generally 40 minutes before departure. Therefore, when constructing the model, these actual time constraints must be taken into consideration. Assuming that the number of passengers arriving at the security check area during multiple time periods follows a log-normal distribution, the following model is established:

$$A_{\text{i-normal}}=\sum_{r=s}^{k}\sum_{j\in J}S_j\cdot\left[F_{h(j)}\left(t_{0,j}-t_r\right)-F_{h(j)}\left(t_{0,j}-t_{r+t_p}\right)\right] \tag{4}$$

$$A_{\text{i-special}}=\sum_{r=s}^{k}\sum_{j\in J}S_{j-\text{special}}\cdot\left(F_{h(j)-\text{special}}\left(t_{0,j-\text{special}}-t_{r-\text{special}}\right)-F_{h(j)-\text{special}}\left(t_{0,j-\text{special}}-t_{(r+t_p)-\text{special}}\right)\right) \tag{5}$$

Among them:

$$F_{h(j)}\left(t_{0,j}-t_i\right)=1/2-1/2erf\left[\frac{In\left(t_0-t\right)-\mu_i}{\sigma_i\sqrt{2}}\right] \tag{6}$$

$A_i$ --passenger arrivals in the i-th time sequence

$t_{0,j}$ --departure time of flight j

$t_r / t_{r+t_p}$ --unit discrete interval under i-time sequence

$F_{h(j)}\left(t_{0,j} - t_i\right)$ --cumulative distribution function of hourly segment h(j)

$s_j$ --number of seats available on flight j

$J$ --the set of all flights taken by all passengers arriving at i time

$\mu_i$ $\sigma_i$ --parameters of the cumulative distribution function of the log-normal distribution of passenger arrivals in each time period

After discretisation, the length of the passenger security check queue changes at intervals within a unit of time. Based on the known initial queue length, the length of the next interval can be determined by the increase in the number of people queuing in the next interval, and the lengths of all intervals can be added together to obtain the queue length at a given time. The following model can be used to calculate the length of the passenger security check queue at a given time:

$$\begin{aligned} L_{i-normal} &= L_{(i-1)-normal} + \sum_{r=k}^{s} (\mathrm{A}_{t_r-normal} - N_{normal}\mu_{i-normal}t_p) \\ L_{i-special} &= L_{(i-1)-special} + \sum_{r=k}^{s_s} (\mathrm{A}_{t_r-special} - N_{special}\mu_{i-special}t_p) \end{aligned} \tag{7}$$

Among them:

$\mu_{i-normal}$ --average service rate for each ordinary passenger security check channel within the time sequence

$\mu_{i-special}$ --average service rate for each special passenger security check channel within the time sequence

$r$ --the rth discrete interval within the ith time sequence

$N_{normal}$ --number of open security checkpoints for general passengers

$N_{special}$ --number of open security check lanes for special passengers

$L_{(i-1)-normal}$ --initial queue length for regular passengers

$L_{(i-1)-special}$ --initial queue length for special passenger queues

$L_{i-normal}$ --the length of the security check queue for ordinary passengers at the end of the time sequence

$L_{i-special}$ --the length of the security check queue for special passengers at the end of the time sequence

$\mathrm{A}_{t_r-normal}$ --the number of ordinary passengers arriving at the rth discrete interval within the ith time sequence

$\mathrm{A}_{t_r-special}$ --the number of special passengers arriving in the rth discrete interval within the ith time sequence

This study builds on previous research to construct a model for estimating passenger security check queue waiting times, assuming that only one passenger is allowed to leave the queue at a time to proceed to the security checkpoint for baggage and personal checks.Assume that passengers arrive at the start of time unit tp. The passenger security check queue waiting time estimation model is iterated once per time unit until the end of the current time sequence. The passenger security check queue waiting time estimation model is as follows:

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$$T_{rg} = \sum_{i=1}^{g-1} \Delta t_s^{(i)} + \max\left(0, \left\lceil \frac{g-h-1}{h} \right\rceil \Delta t_m\right) \tag{8}$$

Among them:

$g$ --passenger position in a single queue

$h$ --start counting from the replacement point,To satisfy the maximum positive integer of $\Delta t_s \geq h * \Delta t_m$

$\Delta t_s$ --the service operation time required for a single passenger in the queue to complete security checks and verification.

$\Delta t_m$ --the time it takes for subsequent passengers to fill the seats vacated by the previous passengers.

$r$ --number of iterations within the sequence

Previous studies have analysed and implemented simulation runs from the establishment of process simulation models to simulation outputs, and have determined passenger security check times based on on-site survey data from the terminal building .Therefore, this study combines data from previous studies with data from practical investigations conducted within the terminal building to determine the security check verification time, i.e., the security check service operation time, for ordinary passengers, $\Delta t_{s-normal}$ is 21s, $\Delta t_{s-special}$ is 28s, $\Delta t_m$ is 3s.

# 4. Model Construction Method for Optimising and Iterating the Setup of Dedicated Security Check Lanes for Special Passengers Departing from the Airport

Develop different configuration plans for dedicated security check lanes for special passengers, including adding dedicated security check lanes for special passengers, temporarily sharing dedicated security check lanes for special passengers with regular security check lanes, and when sharing, including guiding special passengers to regular security check lanes to receive services and guiding regular passengers to dedicated security check lanes for special passengers to receive services.Therefore, this study proposes multiple differentiated decision-making scenarios and constructs models primarily focused on the setup and optimisation of dedicated security check lanes for special passengers.

## 4.1 Threshold Setting Model Construction for Special Passenger Security Check Lanes

Situation 1: When calculating the estimated waiting time model for the special passenger security check lane queue at iteration $t_r$, the maximum waiting time for special passengers exceeds 7 minutes.The estimated waiting time for ordinary passengers in the security check queue did not exceed 10 minutes in the $t_k$ iteration of the waiting time estimation model.When the estimated waiting time model for iteration exceeds the threshold for special passengers, synchronously detect the operational status of the next sequence channel. Combine the security check channel status of the next sequence to comprehensively determine the optimisation model for special passenger security check channel settings under a specific sequence.Calculate the number of additional security check lanes required for each time sequence based on the actual situation when additional security check lanes for special passengers are added as needed. $y(t)$ indicate The total number of passengers waiting in the queue at the special security checkpoint for passengers with special needs whose waiting time exceeds the threshold can be expressed by the following objective function:

$$\triangle N_{special}(i) = \left\lceil \frac{y(t)}{\{g | T_{rg} = 7\}} \right\rceil \tag{9}$$

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Constraint 1: At time i, when the estimated waiting time model for the special passenger security check lane queue is iterated $t_r$ times, the calculated waiting time for special passengers exceeds 7 minutes.

$$T_{rg} > 7; g = L_{it_r - special} \tag{10}$$

Constraint 2: At time i, when the estimated waiting time model for the ordinary passenger security check queue is iterated $t_k$ times, the calculated waiting time for ordinary passengers does not exceed 10 minutes.

$$T_{rg} \leq 10; g = L_{it_k - normal} \tag{11}$$

Constraint 3: Under the premise that the queue waiting time threshold for special passengers is not exceeded, at time i, the total number of passengers in the queue for the special passenger security check channel whose queue waiting time exceeds the threshold $y(t)$, is greater than the total number of special passengers that can be accommodated in the queue for the ordinary passenger security check channel $x(t)$.

$$\begin{cases} x(t) \middle| T_{rg} = 10; g = L_{it_k - normal} + x(t) \\ y(t) = L_{i-special} - L_{it_r - special} \\ y(t) > x(t) \end{cases} \tag{12}$$

Constraint 4: At time i+1, the waiting time for passengers in the special passenger security check queue still exceeds the threshold, and the regular passenger security check lanes have no additional service capacity to serve special passengers.

$$T_{rg} > 7; g = L_{(i+1)t_r - special} \wedge T_{rg} > 10; g = L_{((i+1)t_r - normal} \tag{13}$$

Situation 2: At a certain time, the estimated waiting time model for the special passenger security check lane calculates that the waiting time for special passengers exceeds 7 minutes after $t_r$ iterations, and the estimated waiting time model for the regular passenger security check lane calculates that the waiting time exceeds 10 minutes after $t_k$ iterations. Simultaneously, the operating status of the lane is checked for the next time sequence.

Calculate the number of additional security check lanes required for each time sequence when additional lanes are needed for special passengers based on actual conditions. The objective function can be expressed as:

$$\triangle N_{special}(i) = \left\lceil \frac{y(t)}{\{g|T_{rg} = 7\}} \right\rceil \tag{14}$$

Constraint 1: At time i, when the estimated waiting time model for the special passenger security check lane queue is iterated $t_r$ times, the calculated waiting time for special passengers exceeds 7 minutes.

$$T_{rg} > 7; g = L_{it_r - special} \tag{15}$$

Constraint 2: At time i, when the estimated waiting time model for the ordinary passenger security check queue is iterated $t_r$ times, the calculated waiting time for ordinary passengers exceeds 10 minutes.

$$T_{rg} > 10; g = L_{it_r - normal} \tag{16}$$

Constraint 3: At time i, the proportion $p(t)$ of passengers waiting in the general passenger security check queue for more than 10 minutes is greater than 5% of the total number of passengers.

$$\begin{cases} p(t) = \dfrac{L_{i-normal} - L_{it_r - normal}}{L_{i-normal}} \\ p(t) > 5\% \end{cases} \tag{17}$$

Constraint 4: At time i+1, the estimated waiting time model for the special passenger security check queue at iteration $t_r$ calculates that the waiting time for special passengers exceeds 7 minutes.

$$T_{rg} > 7; g = L_{(i+1)t_r - special} \tag{18}$$

### 4.2 Model Construction for Temporary Shared Use of Special Passenger Security Check Lanes and Regular Lanes under Threshold Settings

Scenario 1: The constraints for guiding some special passengers to the regular passenger security check channel for service under the i sequence in Section 3.1 are shown below. This scenario maximises the avoidance of the security resource allocation cost pressure caused by adding channels while ensuring that the waiting time for special passengers in the queue is less than their waiting time in the original queue, thereby achieving the goal of optimisation.

When directing certain special passengers to the general passenger security checkpoint, under the condition that the threshold is met, the objective is to minimise the immediate queue length and waiting time for special passengers directed to the general passenger security checkpoint, thereby maximising the number of general passenger security checkpoints utilised. The objective function can be expressed as:

$$\min\left[\left(\frac{y(t)}{N_{\text{normal}}}\right)\right] \tag{19}$$

The constraints are:

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$$\begin{cases} T_{rg} > 7; g = L_{it_r - special} \\ T_{rg} \le 10; g = L_{it_k - normal} \\ x(t) \big| T_{rg} = 10; g = L_{it_k - normal} + x(t) \\ y(t) = L_{i-special} - L_{it_r - special} \\ y(t) \le x(t) \end{cases} \tag{20}$$

Situation 2: Situation 2: At a certain point in time, the estimated waiting time model for the special passenger security check lane in iteration tk calculated that the waiting time for special passengers did not exceed 7 minutes, while the estimated waiting time model for the ordinary passenger security check lane in iteration tk calculated that the waiting time exceeded 10 minutes.If the number of passengers exceeds the capacity of the security checkpoint for ordinary passengers at a given time, additional security checkpoints for ordinary passengers should theoretically be added.However, airport security resources are limited, and adding security checkpoints to cope with the pressure of single-sequence traffic flows lacks practical significance.Therefore, considering the principle of effective allocation of airport security inspection resources and the increase in security inspection costs and decrease in security inspection resource conversion rates caused by the idle rate of dedicated channels , it is possible to guide ordinary passengers to special passenger dedicated security inspection channels to receive services under appropriate circumstances. The model for this situation is constructed as follows.

When directing some regular passengers to the special security checkpoint for special passengers, under the condition that the threshold is met, the goal is to minimise the immediate queue length and waiting time for regular passengers directed to the special security checkpoint for special passengers, i.e., to maximise the number of special security checkpoints for special passengers occupied. The objective function can be expressed as:

$$\min \left[ \left( \frac{\mathrm{m}(t)}{N_{\mathrm{special}}} \right) \right] \tag{21}$$

Constraint 1: When calculating the estimated waiting time model for the special passenger security check lane queue at iteration tk, the estimated waiting time for special passengers does not exceed 7 minutes.

$$T_{rg} < 7; g = L_{it_k - special} \tag{22}$$

Constraint 2: At time i, the estimated waiting time for the queue at the security checkpoint for ordinary passengers exceeds 10 minutes in the tr iteration waiting time estimation model.

$$T_{rg} > 10; g = L_{it_r - normal} \tag{23}$$

Constraint 3: Under the condition that the queue waiting time of ordinary passengers does not exceed the threshold, the total number of passengers in the queue for the dedicated security check channel for ordinary passengers at time i whose queue waiting time exceeds the threshold $\mathrm{m}(t)$ is less than

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or equal to the total number of ordinary passengers that can be accommodated in the queue for the special passenger security check channel at time i $n(t)$.

$$\begin{cases} n(t)\left| T_{rg} = 10; g = L_{it_k - special} + n(t) \right. \\ m(t) = L_{i-normal} - L_{it_r - normal} \\ m(t) \le n(t) \end{cases} \tag{24}$$

## 5. Summary

This paper analyses the changes in facial expressions of special passengers during the pre-, mid-, and post-security check queuing process. By combining the actual queuing time from the moment special passengers enter the security check queue until they receive security check information verification services and leave the queue, a comprehensive analysis was conducted. The results indicate that the threshold for special passengers' security check queuing waiting time, considering service perception, is 7 minutes.Based on this, a model for passenger arrivals at a given time was established by combining multiple single flights, assuming that passenger arrival times for each flight follow a log-normal distribution. This was followed by the construction of a security check queue length model and a waiting time estimation model.Based on the set threshold for special passenger queueing wait times, four iterative scenarios for optimising the configuration of dedicated security check lanes for special passengers under multiple time sequences were proposed and modelled, including a dedicated security check lane configuration model for special passengers and a temporary shared lane model for special passengers and regular passengers,This study provides an important method for optimising the configuration of security check lanes under a single-sequence scenario. Subsequent research will utilise a greedy algorithm to conduct model validation and empirical analysis using actual operational data from real airports, with the aim of determining a dynamic configuration scheme for dedicated security check lanes for special passengers during peak hours at airports under multi-sequence scenarios.

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