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Simulation method for dispatching national border security manpower to mitigate manpower shortage

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A B S T R A C T

Recently, a record number of passengers have entered and exited Taiwan from Taiwan Taoyuan International Airport (TTIA). The number of passengers from Taiwan to mainland China has increased largely because of the improvement of cross-strait cultural interaction and other policies, as well as the opening of direct flights. Not only located in the transport hub of the East Asia Taoyuan International Airport is becoming more important and can provide 24 h Airport service, but also airport immigration officers must take 24 h shift to carry out the passenger document inspection requirement, Immigration officers can be fatigued by long shifts, thus negatively affecting border security clearance efficiency and work performance. Consequently, innovative management practices regarding immigration officers are necessary to strengthen international cooperation against terrorism. This study used system simulation Delphi interviews and a heuristic algorithm to determine the required number of airport immigration officers during a fixed passenger waiting time, for improving the efficiency and stability of airport immigration officers who work to consolidate the border security of the country. The results showed that the utilization of airport immigration officers at Taiwan Taoyuan International Airport is higher than 97.99%, and their work hours have been reduced by more than 54.68%. These results proved that using a system simulation can reduce long work shifts and negligence, which can lead improved border security and airport service quality. Additionally, the simulation results that when the National Immigration Agency and Taiwan Taoyuan International Airport implement the biometrics verification system for noncitizens, significant manpower shortages are expected. These shortages can cause complaints from customers and result in a negative image of the quality of airport service. Assigning priority to setting the E-GATE system to compensate for the lack of immigration officers would result in more efficient and effective border security.

1. Introduction

Under the international trend of globalization, international travel is frequent, and the number of people traveling for business and sightseeing is increasing rapidly (Yu and Huang, 2014). By 2027, the number of tourists in the Asia-Pacific region will increase by 45%, and this region will become the world's largest air transport market (Boeing Company, 2007). This will lead to the development of global trade (Allroggen and Malina, 2014) for which the Taiwan Taoyuan International Airport (TTIA) will be a key hub, connecting northern Japan, South Korea, Beijing, and Southeast Asia's Hong Kong and ASEAN members, all of which are roughly 2.5 h from TTIA in flight time. TTIA is located on one of the major east–west routes between the United States and China. This prime location is a potential advantage for TTIA (Wang et al., 2011).

Taiwan opened regular direct flights to mainland China in 2008, promoting cross-strait economic exchanges and social interaction (Lin and Fu, 2014), which caused a record number of air passengers to travel between Taiwan and mainland China. According to Taiwan's Civil Aeronautics Administration (CAA) flight statistics (CAA, 2015), the number of flights at TTIA in April 2012 was 1.15 times higher than in September 2009. Therefore, the number of flights increased to 4,500 flights per month (Lu and Liu, 2014). Because the flow of international passengers has increased rapidly, immigration officers are essential for border security. The influx of passengers at TTIA has increased the workload for security officers, and the

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government did not timely increase the number of immigration officers to compensate for the shortage of manpower. The lack of immigration officers affects the stability of border operations and the management of immigration services. Therefore, airport immigration officials require proper human configuration to achieve stable border security operations.

Currently, most staffing research has focused on hospital nurses (Wong et al., 2014) and customer service staffing (Valls et al., 2009) as well as airport patrol and aircraft flight staffs (Farhadi et al., 2014; Soukour et al., 2013). No research has been conducted regarding airport immigration-related staffs. TTIA is the primary airport and provides services 24 h a day in Taiwan (Lin and Fu, 2014). Consequently, the airport immigration officers must rotate shifts. However, the long work shifts make immigration officers prone to fatigue. When fatigue increases, reaction times also increases, and attention and judgment decrease (Samaha et al., 2007; Takeyama et al., 2005; Winwood et al., 2006). Fatigue also affects the efficiency and stability of immigration officers (Milne and Kelly, 2014). Therefore, the proper configuration of immigration border security officers is worth exploring.

2. Literature review

2.1. Border security management

Border enforcement is a crucial part of border management. The primary objective is to prevent the illegal flow of goods and people from entering. Furthermore, the management of country borders at the time of the population across the border results in a gate of security (Patrick, 2006). Therefore, the government has the authority to determine who can cross the border, which enables protecting border security (Timothy, 2001). The government can establish a safety system based on risk management to conduct an evaluation. The results of a previous analysis that used risk management to assess travelers suggested that screening by immigration officers is the most crucial task of maintaining border security (Nie et al., 2009).

Most travelers who pass through the borders of Taiwan use international airports into and out of Taiwan. To strengthen the management of border security, Taiwan implemented a preflight passenger information system or the Advance Passenger Information System (APIS) at the end of 2011, to ensure security for cross-border travelers and to strengthen international cooperation against terrorism (Yu and Huang, 2014). Transferring these data facilitates security and customs inspection. Reviewing prior traveler lists and auditing passenger documents help airport immigration officers, security departments, and customs inspectors (Sulmona et al., 2014). Therefore, the primary function of the APIS is to provide immigration officers with immigration-related information before flight departure or landing. This information allows for screening of suspicious information to assist in rapid processing incoming passengers and to warn officials of potentially dangerous passengers. Additionally, this information will facilitate extending the security audit mechanism outside the country and assist airport immigration officials through a computer early-warning function, seizing function, detection, prevention, and control of illegal immigrants function, and query function. The advance passenger information system (APIS) can effectively screen out suspicious personnel or potential terrorists from entering a country to engage in illegal activities. In addition, it saves passengers from the extra time that they have to spend to undergo more stringent security checks following a terrorist attack (Beck et al., 2016).

Passport and customs inspections monitor the cross-border flows of people and goods, and create a “bottleneck” in the international transportation system that can cause significant and costly waiting times for many passengers (Prager et al., 2015). How to ensure that high numbers of visitors clear immigration counters smoothly per measurement hour. (Manataki and Zografos, 2006; Odoni and de Neufville, 1992; TRB, 1987). Therefore, because effective staff scheduling is crucial, researchers have used a heuristic genetic algorithm to improve staff scheduling problems and verify the accuracy of simulation methods (Soukour et al., 2013).

2.2. System simulation

Recently, a generic system dynamics based airport performance tool has been developed (Manataki and Zografos, 2009a, 2009b). System simulation involves using a computer program that employs existing systems and consistent allocations of logic for simulations that entail using different algorithms for system simulation and optimization. To simulate an aerial flight situation, the system uses a clustering method and system architecture. For flight planning, added size as well as peak and off-peak flight data analysis and other modeling might be generated at various times points during flight traffic (Öttl et al., 2013). Under the original condition, only originally estimated data can be used. After construction of the system, the model can be obtained by using simulation correction data more accurately for airport improvement. The system simulation approach can be used to construct the airport model (i Casas et al., 2014).

Existing simulation models are either models of specific airports, or general simulation platforms that require substantial modeling effort and knowledge to represent a given airport terminal (Manataki and Zografos, 2009a). The simulation system can be used to make a prediction, and the algorithms can then be used for problem-solving (Yan et al., 2014). Therefore, the system simulation can be used to test decision-making, and can be verified in practical situations to ensure that the system and method are feasible and effective (Wu et al., 2014a, 2014b). Consequently, the system simulation can be used to obtain data that are otherwise difficult or expensive to obtain. These data can then be used for decision-making.

2.3. Human resources

Integrating the human resources and total quality management of a company is paramount, because it influences the development and competitiveness of the company (Izvercian et al., 2014). Under the current multiple-tasks arrangement, staff can easily be distracted. This can be improved by using automation to increase the efficiency of auxiliary personnel (Cullen et al., 2013). In addressing the multistandard combination of staffing problems, genetic algorithms and the decision-model approach can be used to achieve effective results (Lin and Gen, 2008). For the randomness of overtime work, the optimal redundant remaining-time system can be used for optimization and planning (Chen and Nakagawa, 2013).

When staff work continually in the same environment, the use of staff is diminished, thus increasing job turnover rates. However, an exchange environment can increase the use of staff (Blaga and Jozsef, 2014). An exchange environment can also use bonuses or equipment to improve the use of staff (Dai et al., 2014). Simulation algorithms and heuristic approaches can also be applied to solve the problem of staff usage (Costa Filho et al., 2012).

3. Border immigration service counter simulation

In Taiwan, passenger auditing documents from airports are handled by the Department of Immigration’s border affairs brigade. The number of tourists visiting Taiwan has been increasing every year and contact with each passenger is most frequent at the border immigration officers services counters. Border security and passenger clearance services closely relate to the current border immigration services counter. TTIA has seven types of border immigration service counters. For effectively collecting proper data from these counters, the following sections introduce the method for data collection.

3.1. Data collection

The simulated border immigration service counter data in this study were collected from the main airport in Taiwan, TTIA, on the basis of the data of the Immigration Department and the APIS, simultaneous Delphi method (immigration interviews), and heuristic algorithm. The data in this study were collected from July 01 to July 02, 2014, with a total of 144 flight classes and 27,446 visitors; from August 13 to August 14, 2014, with a total of 154 flight classes and 27,592 visitors; and from September 20 to September 21, 2014, with a total of 140 flight classes and 30,501 visitors. The total 438 flight classes and 85,539 visitors were analyzed to construct the required simulation data.

Currently, when flights arrive at TTIA Terminal 2 (T2), the walking time for passengers varies based on the gate at which the aircraft parks. According to the Taoyuan International Airport Corporation (TIAC) operation research, TIAC announced that analyzing T2 passenger walking time facilitates reducing the gap in quality of service, thus enhancing overall satisfaction and service quality at the airport.

After interviewing immigration officers, the current document audit time is around 25 s for citizen and 45 s for non-citizen. However, implementing the biometrics verification system requires an additional 10–15 s of capture time. Furthermore, the use of E-GATE has an operating time of 15 s. Relevant information was obtained regarding backup manpower. Three squads of 24 fixed immigration officers in addition to backup manpower are alternately assigned on a 24 h shift to execute tasks associated with national border security at T2 of the TTIA. The goal is to improve the effectiveness of immigration officers by preventing them from working excessively long shifts, thus enhancing border security and passenger clearance service quality. (Shown in Table 1).

3.2. Border immigration system configuration

Based on the information collected to construct the required simulation, the number of staff members involved in the immigration and passenger waiting times is closely related to the number of airport immigration officers, Therefore, diminished passenger fixed waiting times resulted in a minimum number of required airport immigration officers. Through different time intervals, which increased the number of immigration officers at the airport service counter, the simulation then constructed the airport immigration system configuration. The objective function and decision variables were divided into two parts.

3.2.1. Objective function and decision variables

In this study, the objective function of the allocation of immigration officers in the simulation system was to maximize the average service rate of an immigration officer at the service counter. Regarding the airport immigration services, the objective function can be expressed as follows:

$$MaxU = \frac{T_c}{T_S} \tag{1}$$

where T_c is the time of inspection for travelers, and T_s is the time on duty for immigration officers. When visitors arrive at the immigration area, they are divided into non-citizen and citizen, and E-GATE categories. Therefore, in each instance, the number of required immigration officials directly affects the required waiting time of passengers. Consequently, airport immigration officers require flexibility in their configurations to increase the average service rate of immigration officers. This implies that the decision-making variables are the number of immigration officers and the length of each period required at the service counter.

3.2.2. System process

The system architecture was divided into two parts. The first part entailed applying the described simulation method and objective function to construct the required number of airport immigration officers. This part involves using the simulation approach, which can obtain the required passenger waiting time and then adjust the number of airport immigration officers. Therefore, the number of airport immigration officer to satisfy a fixed waiting time of passengers was required. Using computing architecture, the numbers of necessary airport immigration officials were calculated by using the pitch shift time to obtain the optimized configuration for airport immigration services. This architecture involved repeatedly applying mathematical models. The calculation was repeated to handle the usage of airport immigration services in various periods. Once the optimal time of service and the number of allocated immigration officers were achieved, the simulation model was used to simulate the immigration service operations for obtaining detailed data for further verification by using the heuristic algorithm, as explained in Section 4.5. The system architecture of immigration officer allocation is shown in Fig. 1.

4. The simulation stage and analysis

In this study, the interface of the allocation of immigration officers system was programmed by language C++ under the environment of 64-bit Windows 7. The Codeblocks 13.12 Version was used for constructing the system simulations and computing the collected information. Finally, the results were compared with those for TTIA T2 for verification and validation processes.

Table 1
Type of business immigration service counters and duty hours.

Service counter business type	Immigration officer On duty period	Immigration officer Off duty time
Office, Diplomatic, Official, Crew. Fraternity, customs clearance, APEC. E-GATE. Citizen. Residence permit or permanent residence card. The mobility and strollers. Non citizen.	From 1st Day noon 12:00 To 2nd Day noon 12:00	1st Day meal time: 50 min. Break: 50 min. 2nd Day Break: 50 min

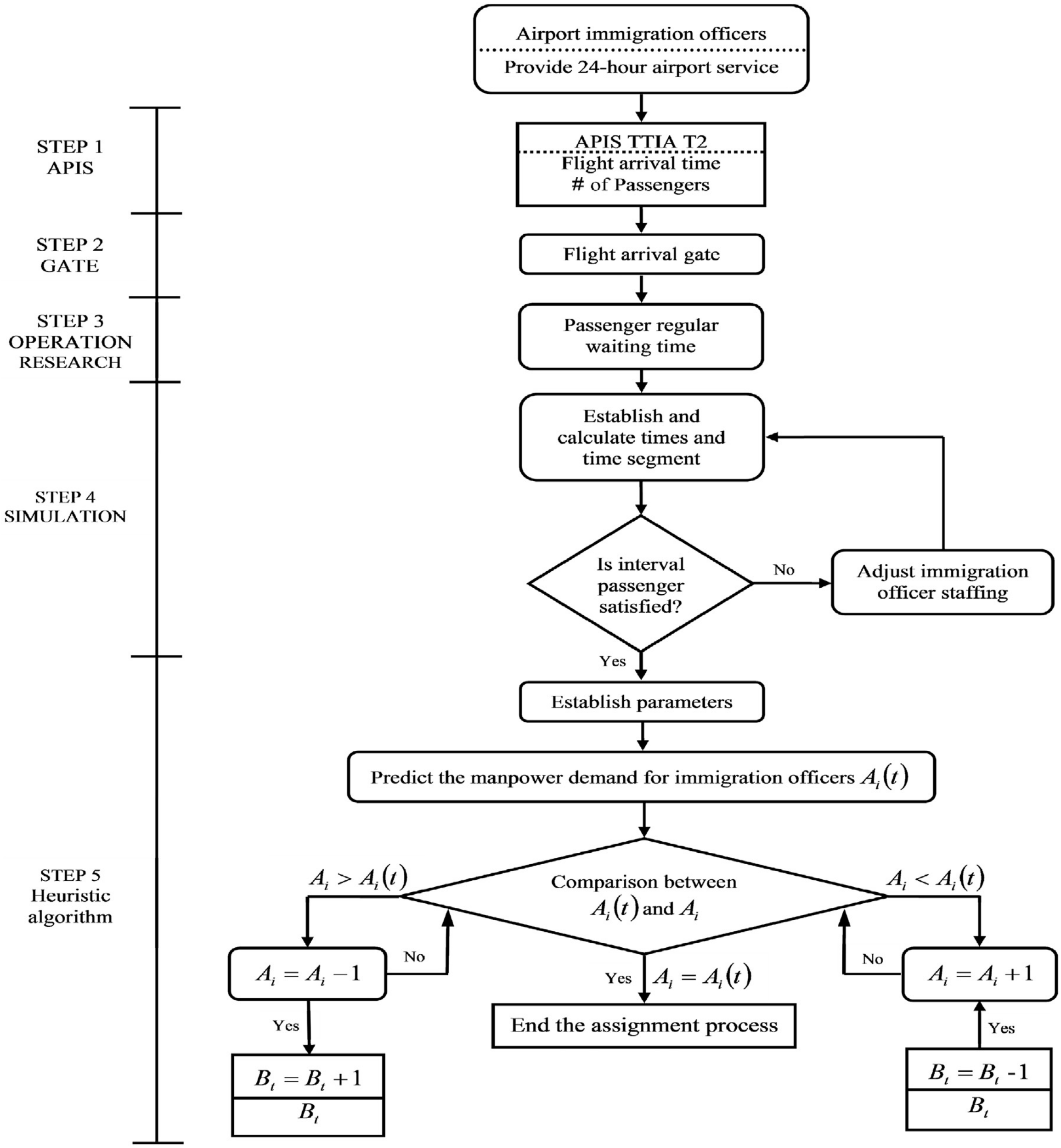

Fig. 1. Flow chart of the overall system architecture.

The settings of the system simulation were divided into four sections, which are described in detail as follows.

4.1. Immigration documents audit service time

The number of immigration officers at the time of auditing passenger documents varies because documents held by different passengers have different review times. The passengers are categorized as citizen or non-citizen. In this study, the APIS data were collected and authenticated using the Arena 14.0 input analyzer program to confirm the distribution and establish the corresponding time allocation. Distribution of the time spent on serving citizens and non-citizens was established and confirmed. As a results, a $p > 0.5$ indicated that the distribution correctly corresponded with the information.

4.2. Time required for passengers to walk from their boarding gates to the immigration inspection area

In this study, regarding the collection of boarding door data, the data obtained by subtracting the average use were necessary for determining the distribution of the different walking durations of passengers. This information was used to connect the mean walking time and then to simulate the time required to walk from the boarding gate to the immigration area. The differences in passenger walking times are shown in Table 2.

4.3. Passenger waiting time

According to the TIAC, in the TTIA T2, an immigration officer provided services for the investigation stage, and the average

Table 2
Immigration officers document review service, visitors walk through each boarding gate simulation model validation to confirm the time required for immigration officer clearance area distribution summary. (Units: second).

Distribution summary		Citizen service distribution	Non citizen service distribution	Passenger walking time difference distribution
Distribution		Normal	Normal	Normal
Expression norm		24.7, 1.92	44.3, 2.75	0.683,1.50
Square error		0.002221	0.006843	0.004273
Chi Square Test	Test statistic	1.63	3.76	1.47
	Corresponding p-value	0.665	0.152	0.467
Kolmogorov-Smirnov Test	Test statistic	0.0376	0.0668	0.0545
	Corresponding p-value	>0.15	>0.15	>0.15

passenger waiting time was verified by the simulation model. The actual passenger waiting time was 23 min, and the simulated passenger waiting time was 25.2 min, with a standard deviation of 0.91 (Shown in Table 3). Therefore, the results obtained from this simulation model represent the current operational status of the TTIA T2 (see Table 4).

4.4. Airport immigration system simulation module configuration results and analysis

This study used the verified simulation models to simulate the collected data. The current situation of the TTIA T2 was set as the parameter value to simulate the operation. The simulation results can be applied to the current passenger average waiting time and maximum waiting time. The data can then be input into the airport immigration system simulation module to compare the two results. Operation results show the average waiting time of all passengers under the parameters on the first day is 1.75 min. This result, with the maximum average waiting time of 10.45 min among visitors, shows that the current utilization rate is only 66.43%. This study controlled the duty intervals to change the variables into the basic unit of 1 h. The longest passenger waiting time was set as 10 min. The immigration system simulation module configuration and passenger demand interval were entered (the average passenger waiting time was 2.32 min, the maximum passenger waiting time was 9.23 min, and the average service rate of the immigration officer was 97.99%). The allocation of airport immigration officers in different periods is shown in Fig. 2. This study used airport immigration officers to configure the system simulation for estimating the impact of the NIA on implementing the biometrics verification system by the TTIA. The optimal allocation of the airport immigration officer in different periods is shown in Fig. 3, and it is expected that the system will be able to assist the immigration officer, which will make border security management more efficient.

4.5. Heuristic algorithm and verification

Rules for the supply and demand of immigration officers at T2 of TTIA:

4.5.1. Reducing immigration officers

If the number of immigration officers (A_i) stationed at the immigration inspection station of T2 for processing visitors per duty hour (t) is estimated to reach a surplus after X_1 consecutive duty hours, A_i is reduced during t such that the surplus is prevented. The number of reduced immigration officers is added to backup manpower$B(t)$.

4.5.2. Increasing immigration officers

If the number of immigration officers (A_i) processing visitors per duty hour (t) is estimated to reach a deficit after X_2 consecutive duty hours, A_i is increased during t such that the deficit and necessity of adding backup manpower $B_{(t)}$ are prevented.

4.5.3. Providing backup manpower

If A_i fails to process the number of visitors received at a specific duty hour, backup officers are dispatched to assist A_i on demand by the National Immigration Agency (NIA).

4.5.4. Heuristic verification

In the proposed method, the variables for each duty hour are adjusted to estimate the overall minimum supply of manpower per duty hour, and the objective function can be expressed as:

$$Min\sum_{i=1}^{n} S_i(t) \tag{2}$$

If the fixed manpower or backup manpower does not decrease, the maximum manpower supply is estimated as follows:

$$S_i(t) = [MaxA_i(t)] \tag{3}$$

Where $MaxA_i(t)$ denotes the maximum number of immigration officers at a specific duty hour i, which is expressed as an integer.

If A_i can work overtime, then the overtime rate, a, is added to the preceding equation, and the manpower demand is expressed as $\frac{1}{(1+a)}$ in$A_i(t)$. Therefore, the manpower supply under this condition is estimated by

$$S_i(t) = \left[Max\frac{A_i(t)}{(1+a)}\right], \tag{4}$$

and the overall manpower supply is estimated by

$$\sum_{i=1}^{n} S_i(t) = \sum_{i=1}^{n}\left[Max\frac{A_i(t)}{(1+a)}\right] \tag{5}$$

Table 3
Airport immigration system simulation module configuration.

Simulation	Actual situation	Simulation with current situation	Simulation with fixed waiting time
# of Passengers	27446	27592	30501
Immigration officers on duty (hour)	24	13.12	15.62
Passenger waiting time (min)	23	25.2	10
Utilization rate	66.43%	97.99%	91.93%
SD	1.871	0.91	0.96

Table 4
Assigning immigration officers.

STAGE 1	Set up parameters according to the rules for the supply and demand of immigration officers.
STAGE 2	Predict the demand for immigration officers per duty hour. On the basis of flight information delivered by the Advance Passenger Information System, the NIA predicts the immigration officers demanded per duty hour (A_i(t)). Once Stage 2 is completed, the following information is obtained $A_i(t)$,*for* $i = 1$ to n.
STAGE 3	Examine manpower per duty hour $i = 1$ to n. If $S_i(t)–A_i(t) \geq 0$ then If $S_i(t)–A_i(t) = 0$, then no change in manpower assignment is necessary. Or else, proceed to Stage 4 and 5.
STAGE 4	Examine whether A_i is still greater than the manpower demand for X_1 consecutive duty hours. If A_i is still greater than the manpower demand for X_1 consecutive duty hours, then A_i is reduced by one officer, and the officer is added to $B_{(t)}$ as backup manpower. $[B_{(t)} = B_{(t)} + 1, S_{(i)}(t) = S_i(t)–1]$ and reinitiate Stage 4.

STAGE 5	Examine whether A_i is still lower than the manpower demand for X_2 consecutive duty hours.
	If A_i is still lower than the manpower demand for X_2 consecutive duty hours, then
	If $B_{(t)} \geq 0$, then
	$B_{(t)}$ is dispatched to assist the immigration officers on duty at that particular hour.$[S_i(t) = S_i(t) + 1, B_{(t)} = B_{(t)}–1]$ and reinitiate Stage 5.
	Or if A_i can work overtime, then A_i continues to process visitors after his or her regular duty hours are over. Proceed to Stage 6.

STAGE 6	Examine whether $B_{(t)}$ should be reduced. If $B_{(t)}$ remains greater than zero for X_1 consecutive duty hours, then one officer is laid off or transferred to administrative duties $B_{(t)} = B_{(t)}–1$ and reinitiate Stage 6. Or if $B_{(t)}$ is constant, end the assignment process.

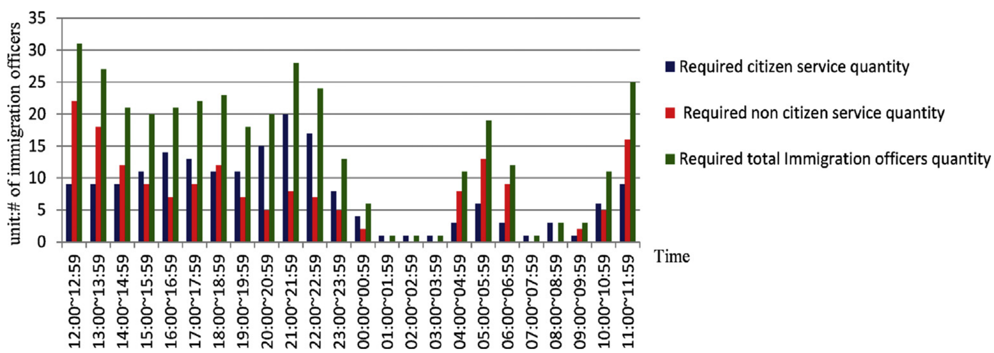

Fig. 2. Allocation of airport immigration officers.

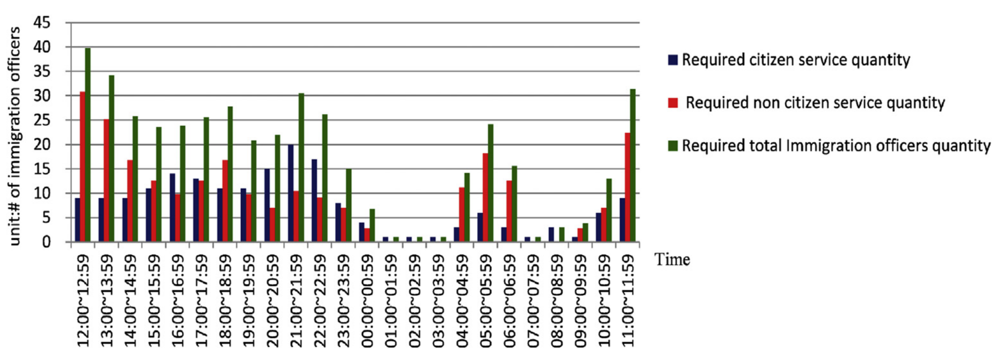

Fig. 3. The allocation of Airport immigration officer by implementing the biometrics verification system.

In this study, A_i is assisted by the members of each squad. Therefore, the manpower supply $A_i(t)$ can be estimated under three conditions: (1) when the manpower supply at a specific duty hour is predicted to be greater than the demand(n_1), (2) when the manpower supply at a specific duty hour is estimated to be equal to the demand(n_2), and (3) when manpower supply at a specific duty hour is projected to be less than the demand(n_3). According to Eq. (4), $A_i(t)$ in n_1 and can be estimated as follows:

$$S_i(t) = \left[Max\frac{A_i(t)}{(1+a)}\right] \quad i \in n_1 n_2 \tag{6}$$

Because $A_i(t)$ in represents manpower shortage and because officers in n_1 should be dispatched as backup, the manpower supply under the third condition is estimated as follows:

$$S_i(t) < \left[Max\frac{A_i(t)}{(1+a)}\right] \quad i \in n_3 \tag{7}$$

Hence, the overall manpower supply can be obtained as follows:

$$\sum_{i=1}^{n} S_i(t) = \sum_{i \in n_1 n_2}^{n} \left[Max\frac{A_i(t)}{(1+a)}\right] + \sum_{i \in 3}^{n} S_i(t) \tag{8}$$

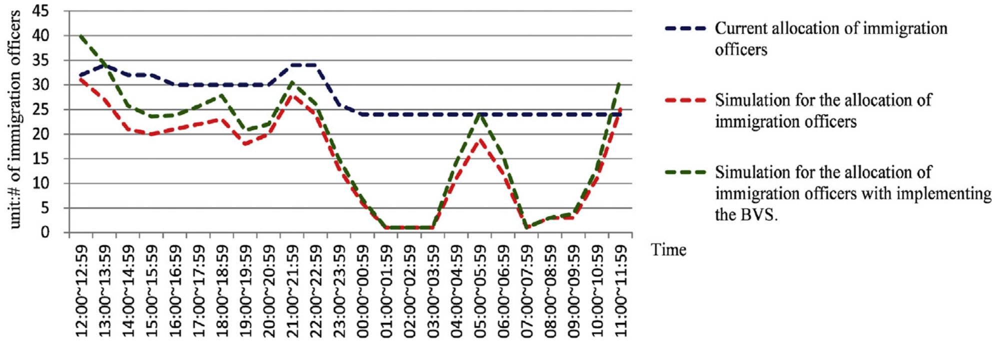

Fig. 4. Simulated allocation system of airport immigration officers.

However, an effective solution to streamlining manpower can be derived by subtracting Eq. (5) from Eq. (8) (Wang, 2011):

$$\sum_{i=1}^{n}\left[Max\frac{A_i(t)}{(1+a)}\right]-\sum_{i\in n_1n_2}^{n}\left[Xax\frac{A_i(t)}{(1+a)}\right]+\sum_{i\in 3}^{n}S_i(t)$$
$$=\sum_{i\in 3}^{n}\left[\left[Max\frac{A_i(t)}{1+a}\right]\right.$$
$$\left.-S_i(t)\right]>0\quad\left(\because i\in n_{3,}S_i(t)<\left[Max\frac{A_i(t)}{(1+a)}\right]\right)\tag{9}$$

Therefore, the proposed simulation method for assigning airport immigration officers is validated to be a superior manpower-streamlining solution to conventional methods.

This study simulated the allocation system of airport immigration officers to estimate the optimal configuration of airport immigration officers in implementing the biometrics verification system for the efficiency of border security at TTIA. We found that the immigration officer requires additional 10–15 s to retrieve passengers' personal biometric data (fingerprint and restrain recorded facial biometric data collection). We also discovered a significant shortage of immigration officers (Shown in Fig. 4). A shortage occurs on the first day between 12:00 p.m. and 12:59 p.m., and on the second day between 11:00 a.m. and 11:59 a.m., with eight and seven immigration officers exceeding the original configuration, respectively. Additionally, the longest passenger waiting time exceeds 10 min. The generated waiting time negatively affects not only the moods of tourists but also passenger satisfaction. In the past 6 years (Tourism Bureau Taiwan, 2014), business travelers and tourists have increasingly visited Taiwan (Yu and Huang, 2014), and visitors often consider waiting time to be lost time (Wu et al., 2014a, 2014b). Therefore, the government should increase the manpower of immigration officers to stabilize the management of border security and promote the satisfaction of travelers.

This study applied the concept of rotating shifts among police officers and systematically constructed the simulation module to simulate the allocation of airport immigration officers. We found that airport immigration officers in Taiwan check significantly more passengers per year than do airport immigration officers in neighboring Asian countries (Shown in Fig. 5). However, an increase of visiting Taiwan also implies a risk of dissatisfaction if travelers are forced to wait for long periods during the immigration security process. The NIA should provide continual broadcast programs reduces the waiting time perception of the passengers, and use assistive technology, such as E-GATE, to improve the efficiency of the staff. The NIA also recommends using the APIS air front passenger information review system, the Advanced Passenger Processing System (APP) and the American Terrorist Screening Center (TSC), terrorist database system, Remote Query International (RQI), to diversify the use of information technology to strengthen the effectiveness and application of services. Additionally, the NIA suggests engaging in activities that allow customers to perceive that they are the top priority of the airline and addressing providing the manpower necessary to rectify airport immigration gaps. This would enable airlines to achieve higher safety standards and enhance the efficiency of customs clearance for travelers entering and exiting Taiwan, which would enhance Taiwan's image.

5. Conclusions

Development of high quality schedule can lead to more

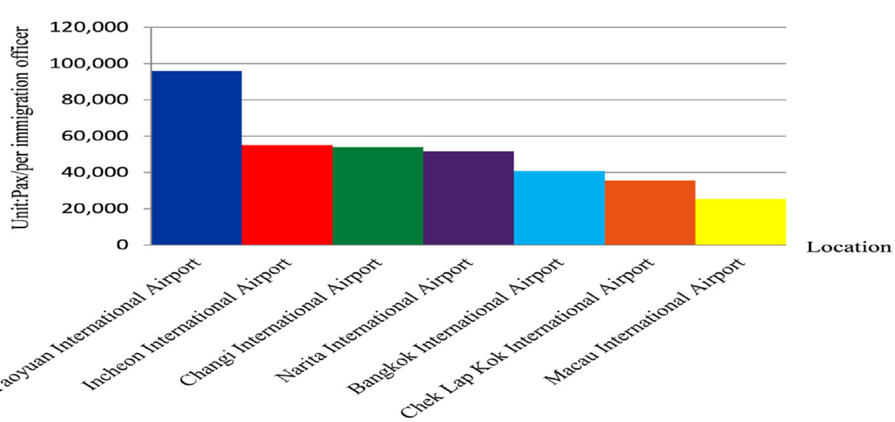

Fig. 5. Numbers of passenger checked per year in Asian countries (Source: National Immigration Agency, 2014).

contented and thus more effective workforce (Lin et al., 2012). Consequently, airport immigration officials require proper manpower configuration to achieve stable border operations. This study used a simulation and heuristic algorithm to construct the allocation system of airport immigration officers, to strengthen the management of border security and improve the utilization of airport immigration officials. This study derived the following two conclusions:

The TTIA is Taiwan's main airport. According to the APIS data collected by the Immigration Department, the simulation of the allocation system of airport immigration officers, which used data from 438 flights and 85,539 passengers, showed that the utilization of airport immigration officers is 97.99% higher than the original. The total work hours were initially 662 before the use of the system. After this simulation system was applied to allocate the manpower of immigration officers, the total work hours were reduced to 362, which is 54.68% of the original total. This indicated that the simulation of the allocation system of airport immigration officers promotes efficiency, which can improve the efficiency and stability of airport immigration officers, and enhances border security management and service quality.

This study simulated the allocation system of airport immigration officers to estimate the optimal configuration of airport immigration officers in implementing the biometrics verification system for the efficiency of border security at TTIA. The immigration officer requires additional 10–15 s to retrieve passengers' personal biometric data. A significant shortage of immigration officers is discovered because of the use of biometrics verification system. Additionally, the longest passenger waiting time exceeds 10 min. The generated waiting time negatively affects not only the moods of tourists but also passenger satisfaction. Therefore, to properly allocate the manpower of immigration officers to reduce the waiting time of passengers is very important, and the simulation system for allocating the immigration officers can practically response the needs.

The airport immigration officers were divided into arrival and departure teams to audit border passenger documents. However, in the future, such teams could be combined to enhance the overall configuration of the immigration officers. Moreover, different algorithms could be used to simulate, compare, and revise these results. This study adjusted variables for each duty hour. Future studies may reduce the time for variable adjustment to yield a more precise simulation of immigration officer manpower designation, thereby enhancing organizational effectiveness and strengthening government performance.

Conflict of interest

The authors declare that there are no conflicts of interest.

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