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# Space allocation for commercial activities at international passenger terminals

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## Abstract

This study examines the relationships among commercial revenue, passenger service level and space allocation in international passenger terminals. Using mathematical programming, this study constructs a model for maximizing concession revenues while maintaining service level, to optimize the space allocation for various types of stores. This study then uses CKS International Airport as an example to demonstrate the applicability of the models. The results show that total commercial revenues can be maximized by locating the stores with more concession revenue in the more accessible positions. Moreover, the optimal space allocation for commercial activities and public facilities changes with passenger volumes and/or service levels.

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*Keywords:* International airport; Passenger terminal; Airport concession; Space allocation; Service level

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## 1. Introduction

International airports operate in an increasingly competitive, market-driven environment, and moreover are increasingly financially self-reliant. The construction costs of International Airports generally are very high. Recently, due to the financial woes faced by airlines, it has been difficult for airport authorities to increase airport revenue by raising airport charges unless the airport possesses an especially advantageous geographic location. Therefore, how to effectively allocate airport terminal space to maximize revenues from leasing commercial concessions has become

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important. Concession revenues are those generated from non-aircraft related commercial activities in the terminals and on airport land. Space allocation in passenger terminals is an extremely complex task, and influences not only passenger processing efficiency but also airport concession revenue. According to Doganis (1992), in medium to large US airports, commercial concessions contribute 75–80% of total airport revenue. In 1990, more than 90% of total revenue at Los Angeles airport came from commercial revenues. In comparison, in 1998, just 30% of total revenue at Chiang Kai-Shek International Airport was from commercial operations (Civil Aeronautics Administration, MOTC, ROC, 1999). Concession revenue clearly is extremely important to airports, and moreover optimizing the allocation of terminal space to increase commercial concession revenues is crucial.

Previous studies on space allocation of terminal buildings mainly focused on public facilities. Most of these studies dealt with the problem using manual approach, the queuing theory approach, and the user perception approach, and moreover adopted the perspective of architecture design and/or operations research (e.g. Ashford et al., 1976; Piper, 1990; Mckelvey, 1988; Yen, 1995). In another series of studies, the main issues in airport financing management studies focused mostly on airport pricing (e.g. Hamzaee and Vasigh, 2000; Pels et al., 1997; Zhang and Zhang, 1997; Doganis, 1992; Oum and Zhang, 1990). Doganis (1992) presented an excellent discussion on concession revenue maximization strategies. Moreover, Zhang and Zhang (1997) examined the optimal pricing in a model where concession and aeronautical operations of an airport are considered together with an overall break-even constraint. Recently, commercial airports in the US have made financial agreements with airlines operating in their airport terminals. These airports have gradually changed from the Residual Cost Approach, in which airlines collectively assume significant financial risk by agreeing to pay airport running costs, to the Compensatory Approach, in which the airport operator assumes most of the financial risk involved in running the airport and charges the airlines fees and rental (Vasigh and Hamzaee, 1998). Additionally, previous studies on airport operating management generally focused on airport productivity or performance (Gillen and Lall, 1997; Hensher and Hooper, 1997; Seneviratne and Martel, 1991).

However, the relationship between space allocation and concession revenue of passenger terminals at an International Airport has seldom been investigated. Additionally, though the concession revenues of the shops are the main source of airport income, but the extent of their advantage depends on the scheme that determines how much commercial space a large International Airport with high passenger volumes requires, and furthermore how to allocate that commercial space among different types of stores. However, no theoretical space allocation model exists for allocating space for various commercial activities at passenger terminals. This study examines the relationships among concession revenue, passenger service level and space allocation for public facilities and commercial activities. Specifically, this study considers issues including: space allocation for passenger processing and commercial activities, terminal concession rate-setting, and passenger accessibility in terms of their space–time constraints in undertaking consumption activities in terminal buildings.

This study attempts to develop a space allocation model for optimizing the space allocation for various stores at different locations and for public facilities. The model applies mathematical programming methods and attempts to maximize concession revenues while ensuring passenger processing service level. Moreover, this study uses CKS International Airport in Taiwan as an

example to demonstrate the application of the model. The analytical results obtain the optimal sizes and locations for various types of stores in every region of a passenger terminal, and provide a reference for terminal space planning and lease management.

The remainder of this study is organized as follows: Section 2 describes the method for public facility allocation. Section 3 then formulates a mathematical programming model for allocating commercial space in passenger terminals. Subsequently, section 4 presents a case study demonstrating the application and results of the models. Finally, section 5 gives conclusions.

## 2. Public facility space allocation

The public facility space allocation in a terminal seeks to establish gross size requirements without establishing specific locations for individual components. International Air Transport Association (IATA) established various space requirements for various terminal facilities with different levels-of-service. Many studies have examined level-of-service criteria for terminals, and some have attempted to define level-of-service standards (e.g. Mumayiz, 1991; Martel and Seneviratne, 1990; Mckelvey, 1989; FAA, 1980). Level of service measures commonly used in passenger terminals include measures of congestion within terminal buildings, passenger delays and waiting line lengths at various facilities, passenger walking distance, and total passenger processing time. Approximate locations for the processing components are generally indicated based on the sequential nature of the processing system to minimize walking distance and processing time for departure or arrival passengers. IATA (1989) proposed a nearby function matrix,  $\bar{M}$ , part of which indicated that any two public facilities should be located together, and moreover should be classified as essential, desirable or non-essential, as shown in Table 1.

Let  $X_p^U$  represent required square meters of facility  $p$  at level-of-service  $U$ ,<sup>1</sup> then according to IATA (1995),  $X_p^U$  can be formulated as:

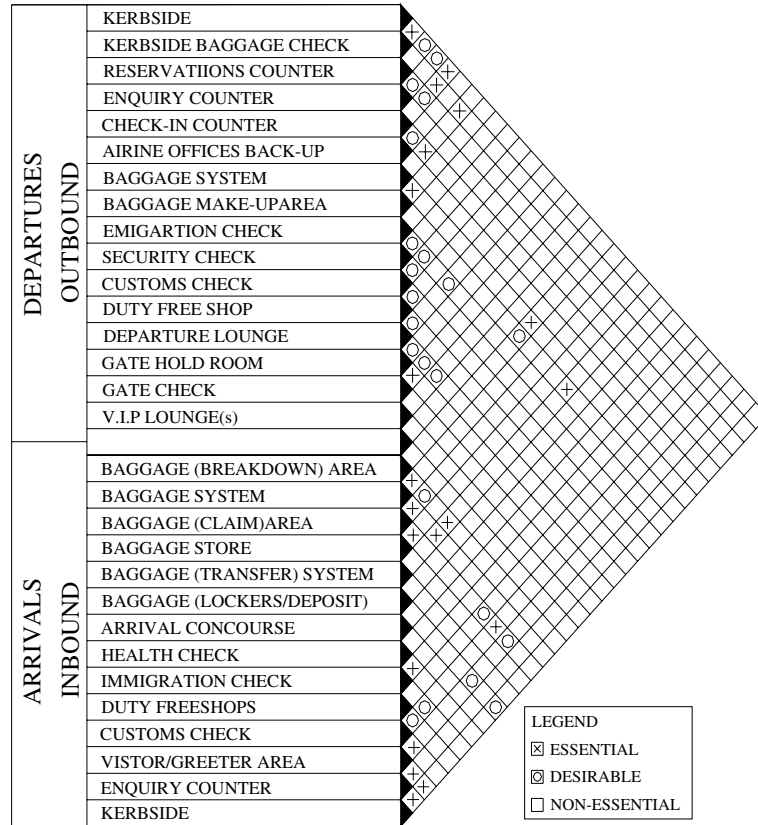
$$X_p^U = H_p \times A_p^U, \quad p = 1, \dots, n; \quad U = A, B, C, D, E, F \quad (1)$$

where  $H_p$  denotes the total number of passengers using facility type  $p$  at peak hour,  $A_p^U$  represents the required square meters per passenger using facility type  $p$  at level-of-service  $U$ ,  $U = A, B, C, D, E, F$ , and  $n$  is the total number of facility types. Facility level of service reduces in alphabetical order, that is, level-of-service  $A$  denotes the highest level while level-of-service  $F$  denotes the lowest level.

Walking distances for departure or arrival passengers also vary according to parking or loading/unloading locations of various ground access modes. Types of ground access modes include public buses, shuttle, taxis, automobile (self-drive), automobile (driven by another person), rail, rapid transit, and so on. Let TD represent the total annual walking distance for all types of passengers, then the space and location for each type of public facility is determined to minimize

<sup>1</sup> To enable comparison among the various airport systems and subsystems, and to reflect the dynamic nature of facility demand, a range of level of service measures from “A” through “F” are defined based on IATA (1995), shown in Appendix A.

Table 1  
Functional adjacency matrix for a typical terminal layout



Source: IATA (1989).

TD subject to the location relationship matrix of any two facilities,  $M$ , satisfying the IATA nearby function matrix dealing with public facilities,  $\bar{M}$ . That is

$$\text{Min TD} = \sum_{g=1}^v (D_g^d \cdot E_g^d \cdot N^d) + \sum_{g=1}^v (D_g^a \cdot E_g^a \cdot N^a) + [D^r \cdot E^r + D^r \cdot (1 - E^r)] \cdot N^r \quad (2)$$

$$\text{s.t. } M \approx \bar{M} \quad (3)$$

where  $D_g^d$  denotes the average walking distance of type  $g$  departure passengers who walk directly from the departures hall, through the check-in counters, immigration, security, and finally the boarding gates without engaging in any consumption activities such as shopping, eating, and so on. Similarly,  $D_g^a$  represents the average walking distance of type  $g$  arrival passengers who walk from the arrival gates, through immigration, baggage claim, customs, and finally to the arrivals hall without undertaking any consumption activities. Furthermore, variables  $D^r$  and  $D^r$  stand

for the average distance walked by direct and indirect transfer passengers, respectively, and difference in that indirect transfer passengers must check-in at the transfer counters before approaching the gates. Additionally,  $N^d$ ,  $N^a$  and  $N^r$  denote the total numbers of departure, arrival, and transfer passengers, respectively;  $E_g^d$  and  $E_g^a$  represent the ratios of type  $g$  departure and arrival passengers to total departure and arrival passengers, respectively;  $E^r$  is the ratio of direct transfer passengers to total transfer passengers, and  $v$  denotes the total number of passenger types.

### 3. Commercial activity space allocation

When passenger volume in an International Airport reaches the designed capacity, airport authorities may re-allocate space between public facilities and commercial activities to accommodate more passengers. Expanding the space available for public facilities can improve passenger processing service level, which allow passengers to finish all procedures more efficiently and have more time available for consumption thus increasing airport concession revenue. However, reducing the space available for commercial activities in a terminal building can degrade the attractiveness of those commercial activities and thus reduce airport concession revenue. This study set up maximum space constraints for stores in different areas. These constraints prevent too much terminal space being allocated to commercial activities, and ensure sufficient space allocation for public facilities to maintain good service quality. The need to maintain good service quality in public facilities implies that it would not affect aviation income. Consequently, commercial revenue maximization also implies total revenue maximization if aviation revenue remains unchanged.

Airport operators generally allocate commercial space in passenger terminal buildings for use by various shops providing all kinds of passenger amenities. Influences on the sizes of different shops include not only the basic service function requirements of an international airport but also the interests and abilities of potential concessionaries and rental rates. Nowadays, most concessions are charged based on a certain proportion of store revenue. Therefore, total airport concession revenue can be calculated by estimating the charging ratio and individual store revenue that can be estimated by figuring out total customer volumes and average consumption per customer. The required square meter of a store can be obtained by figuring out its number of customers at peak hour and average space required per customer. Although allocating larger space for commercial activities can attract more consumers at peak hours, airport operators must also consider the major uses of space in passenger terminals, such as for public facilities and airlines, and also the related operating and maintenance costs. Therefore, to maintain passenger processing service levels and maximize store concession revenues, airport operators must understand how to determine total commercial space and then allocate that space among different types of stores and different areas of the terminal building.

This study formulates the above problem using mathematical programming and attempts to maximize the total concession revenue subject to space constraints. Let  $R_{ij}^k(X_{ij}^k)$  denote the concession revenue for  $X_{ij}^k$ , that is, type  $k$  store at position  $(i, j)$  with an area of  $X$  square meters, and TR represents the total concession revenue, then the problem can be formulated as:

$$\text{Max TR} = \sum_{k=1}^z \sum_{l=1}^h \sum_{j=1}^5 R_{lj}^k(X_{lj}^k) \quad (4)$$

$$\text{s.t.} \quad \sum_{l=1}^h \sum_{j=1}^5 X_{lj}^k \geq S_k, \quad k = 1, \dots, z \quad (5)$$

$$\sum_{k=1}^z \sum_{j=1}^5 X_{lj}^k \leq L^l, \quad l = 1, \dots, h \quad (6)$$

where  $S_k$  is the minimum square meters of type  $k$  stores required to satisfy basic passenger demand;  $L^l$  is the maximum total square meters of commercial space available for all stores in area  $l$ ; superscript  $l$  denotes the region located in different parts of the passenger terminal building, that is, departure, arrival, and transfer terminal areas or controlled and non-controlled terminal areas; subscript  $j$  is the percentage of total passengers passing position  $(l, j)$  in region  $l$ ,<sup>2</sup> and is calculated as the ratio of passengers passing that location after completing all necessary departure or arrival related procedures to total passengers. That is, high passenger flow at a location implies that stores at that location will have high accessibility. Superscript  $k$  indicates the type of store; and  $h$  and  $z$  are the number of regions and types of stores, respectively.

Eq. (5) represents the summation of allocated space for type  $k$  stores at all positions of all regions, and must be larger than the minimum space required for the basic service functions of that type of store in an International Airport. Moreover, Eq. (6) sets the total allocated commercial space for all types of stores at all positions of region  $l$  that must be less than the largest commercial space available in that region. This constraint prevents the allocation of too much space for commercial activities inside the terminal, and allows space to be kept for public facilities as necessary to maintain good service quality.

Let  $\text{TM}_{lj}^k(X_{lj}^k)$  denote the total revenue of  $X_{lj}^k$ , then the concession revenue of  $X_{lj}^k$ ,  $R_{lj}^k(X_{lj}^k)$ , can be formulated as:

$$R_{lj}^k(X_{lj}^k) = \text{TM}_{lj}^k(X_{lj}^k) \cdot F_k \quad (7)$$

where  $F_k$  denotes the concession charging ratio of type  $k$  store. The bidding capability of a store for a particular location depends on store revenues, that is, store with more revenues generally have higher bidding ability than stores with less revenues. For example, the revenues of duty-free stores are generally higher than those of other stores or restaurants, and thus duty-free stores generally have higher ability to bid for and rent the most accessible locations. When airport authorities manage stores directly, then  $F_k$  can be considered to represent store net profit.

Meanwhile, let  $\text{TC}_{lj}^k(X_{lj}^k)$  denote the total number of consumers at  $X_{lj}^k$ , then  $\text{TM}_{lj}^k(X_{lj}^k)$  can be formulated as:

$$\text{TM}_{lj}^k(X_{lj}^k) = \text{TC}_{lj}^k(X_{lj}^k) \cdot \text{AM}_k(X_{lj}^k) \quad (8)$$

<sup>2</sup> To simplify the analysis, this study classifies those into five ranges,  $j = 1-5$ , where,  $j = 1$  indicates that the percentage of passengers passing the location is below 20%,  $j = 2$  indicates a percentage of 20–40%,  $j = 3$  indicates a percentage of 40–60%,  $j = 4$  indicates a percentage of 60–80%, and  $j = 5$  indicates the percentage range between 80% and 100%.

where  $AM_k(X_{ij}^k)$  represents average consumption per customer of  $X_{ij}^k$ . The consumption activities of passengers are constrained by their available time budget, with customers having different amounts of time available for shopping. Customers with minimal time can only shop at the closest stores, while customers with more time can shop at more stores, starting from the closest. Therefore, location is the key determinant of the total number of customers at  $X_{ij}^k$ ,  $TC_{ij}^k(X_{ij}^k)$ . Furthermore, the  $TC_{ij}^k(X_{ij}^k)$  further influences the total revenues of store at  $X_{ij}^k$  directly, as illustrated by Eq. (8). Since the concessions are normally charged by a certain ratio of store revenue, as shown by Eq. (7), then  $TC_{ij}^k(X_{ij}^k)$  also influences the concessions.

This study assumes that the space allocated to various stores should be larger than the size necessary for their operation, as shown in Eq. (5). Moreover, investigations of previous data indicated that variations in average consumption per customer are insignificant due to the changes of store size and location because airport terminal consumption activities are induced secondary demand of passengers. Compared with the total number of consumers at  $X_{ij}^k$ ,  $TC_{ij}^k(X_{ij}^k)$ , average consumption per customer of store  $X_{ij}^k$ ,  $AM_k(X_{ij}^k)$ , does not significantly affect total store revenue. Therefore, this study assumes that  $AM_k(X_{ij}^k)$  is fixed and does not fluctuate according to store location or size. The total number of consumers at  $X_{ij}^k$ ,  $TC_{ij}^k(X_{ij}^k)$ , is thus the most important determinant of store concession revenues. Regarding the estimation of the total number of consumers at  $X_{ij}^k$ , this study further classifies international airport consumers into six groups, that is, departures, arrivals, transfers, well-wishers, greeters, and airport employees, and then calculates the number of consumers in each group that consume at store  $X_{ij}^k$ , respectively.

### 3.1. Departure passengers

This study assumes that guiding instructions are sufficient for passengers to easily find check-in counters, immigration counters, security checks, boarding gates, and all commercial and service facilities. Therefore, passengers are assumed to use the shortest walking distance in undertaking each activity. Generally, departure passengers arrive at the airport some time (ranging from two and half hours to 30 min) ahead of their departure time so as to complete all necessary procedures. Passenger arrival time is influenced not only by individual estimates of travel time to reach the airport and terminal processing time but also on trip type (such as business or leisure) and trip length. After arriving at the passenger terminal passengers can freely undertake all kinds of consumption activities until boarding, provided they complete all necessary departure procedures. The number of consumption activities that passengers can undertake thus is determined by available time and activity spatial distributions. This study introduces the concept of accessibility, which determines the maximum time that an individual passenger can spend at  $X_{ij}^k$ , subject to his or her space–time constraints during departure process. This study can estimate the total number of passengers who can reach store  $X_{ij}^k$  and remain there longer than the shortest duration required for consumption activities. Furthermore, the proportion of total passengers who actually consume can be determined to figure out the total number of departure passengers actually consuming at  $X_{ij}^k$ .

This study defines the total time budget of a departure passenger between arrival at the terminal building and boarding. Let  $\theta_i^m$  denote the time budget of passenger  $i$  taking departure flight  $m$ , then  $\theta_i^m$  can be expressed as:

$$\theta_i^m = t_b^m - t_{zi}^m \quad (9)$$

where  $t_b^m$  represents the boarding time of the departure flight  $m$ , and  $t_{zi}^m$  is the time when passenger  $i$  taking departure flight  $m$  arrives at the departure lobby.

Let  $T_{lji}^m$  denote time duration, which can be used to undertake commercial activities at position  $(l, j)$  by passenger  $i$  of departure flight  $m$ , then  $T_{lji}^m$  can be expressed as:

$$T_{lji}^m = \theta_i^m - T_i^m - (D_{lji}^m/V) \quad (10)$$

where  $V$  denotes the average walking speed of passengers and  $D_{lji}^m$ <sup>3</sup> is the extra-walking distance required to undertake commercial activities at position  $(l, j)$  for passenger of departure flight  $m$ . Furthermore,  $T_i^m$ <sup>4</sup> is the minimal time required to complete all necessary procedures for passenger  $i$  taking departure flight  $m$ , and can be formulated as:

$$T_i^m = t_c + t_l + t_s + (D_i^m/V) \quad (11)$$

where  $t_c$ ,  $t_l$ , and  $t_s$  denote the times required for passengers to complete check-in, immigration, and security procedures, respectively;  $D_i^m$  represents the total walking distance of departure passenger  $i$  taking departure flight  $m$  who completes all necessary procedures without undertaking any commercial activities.

From the above discussion, the necessary condition that passenger  $i$  taking departure flight  $m$  undertaking commercial activities at  $X_{lj}^k$  is

$$T_{lji}^m \geq T_{k0} \quad (12)$$

where  $T_{k0}$  is the shortest duration required for undertaking commercial activities at  $X_{lj}^k$ . Furthermore, as shown in Fig. 1, let  $F(\theta)$  represent the cumulative probability function of departure passengers with time budget  $\theta$ , and let  $\text{TP}_d^k(X_{lj}^k)$  denote the total number of departure passengers who possibly undertake commercial activities at  $X_{lj}^k$ , then  $\text{TP}_d^k(X_{lj}^k)$  can be formulated as:

$$\text{TP}_d^k(X_{lj}^k) = \sum_{m=1}^y \left( \left( \int_{\theta_{lji}^{km}}^{\infty} F(\theta) d\theta \right) \cdot Q_m - G_m^{k'} \right) \quad (13)$$

where the lower bound of  $\theta_{lji}^{km}$  is  $T_i^m + (D_{lji}^m/V) + T_{k0}$ ,  $Q_m$  denotes the number of passengers taking flight  $m$ , and  $y$  represents the total number of departing flights.

Undertaking any particular commercial activity obviously reduces passenger time budget available for undertaking other commercial activities. Therefore, unless passengers have plenty of time they must choose what commercial activities they undertake carefully. Individual passenger choices differ from one another because of socioeconomic characteristics and perceptions.<sup>5</sup>

<sup>3</sup>  $D_{lji}^m$  is not always the same due to different departing flights having different checking-in counters and boarding gates, which obviously have different locations.

<sup>4</sup> Notably, group passengers require more time to complete check-in procedures, because they must wait until all members of the group have completed boarding procedures before they can obtain their boarding cards and are free to wander by themselves.

<sup>5</sup> Nevertheless, most passengers make necessary commercial activities such as exchanging foreign currency and buying insurance their first priorities, while meals and shopping rank second.



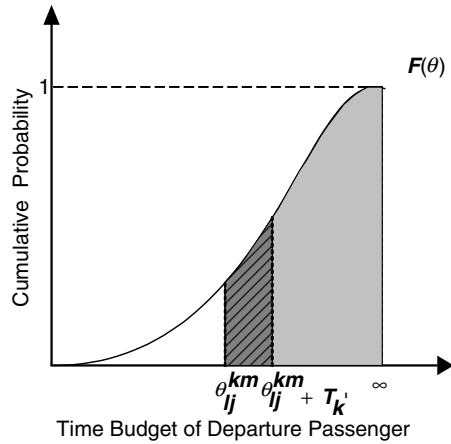


Fig. 1. Condition in which departure passengers can undertake commercial activity at  $X_{lj}^k$ .

Therefore, the total number of passengers possibly undertaking commercial activities at  $X_{lj}^k$  can be determined by subtracting the number of passengers who do not have extra-time for undertaking commercial activities  $k$  at  $X_{lj}^k$ , as they already undertake other commercial activities,  $G_m^{k'}$ , as shown in the shaded area of Fig. 1 and Eq. (14). Moreover,  $G_m^{k'}$  can be formulated as:

$$G_m^{k'} = \sum_{k'=1}^{z-1} \int_{\theta_{lj}^{km}}^{\theta_{lj}^{km} + T_{k'}} F(\theta) d\theta \cdot Q_m \cdot e_d^{k'} \tag{14}$$

where  $k'$  denotes commercial activities other than activity  $k$  at  $X_{lj}^k$ ,  $T_{k'}$  represents total time, including activity and walking time, required for passengers to undertake activities  $k'$ , and  $e_d^{k'}$  is the proportion of departure passengers undertaking activities  $k'$  before undertaking activity  $k$ .

Moreover, let  $C_d^k(X_{lj}^k)$  denote the number of departure passengers actually undertaking commercial activities  $X_{lj}^k$ , then  $C_d^k(X_{lj}^k)$  can be formulated as:

$$C_d^k(X_{lj}^k) = TP_d^k(X_{lj}^k) \cdot e_d^k \tag{15}$$

where  $e_d^k$  represents the ratio of departure passengers who actually do undertake activity  $k$  to total departure passengers who possibly undertake activity  $k$  at  $X_{lj}^k$ . The values of  $e_d^k$  for banks and insurance companies are generally constant and independent of time, while the values of  $e_d^k$  for certain types of shops vary with different time periods.<sup>6</sup> The values of  $e_d^k$  decrease with passenger time budget for some types of shops, such as bookstores and coffee shops. Moreover, store attributes, size, price and service levels also influence  $e_d^k$ .

<sup>6</sup> For example, time spent by consumers in restaurants is usually longer for dinners than for other meals. Moreover, late at night when there is no public transportation or scheduled shuttles demand for rental cars is generally much higher than at other time periods.

### 3.2. Transfer passengers

The time budget of transfer passengers is the boarding time of their departure flights minus the flight arrival times of their arriving flight. Let  $\theta_i^f$  denote the time budget of transfer passenger  $i$  with arrival flight  $f$ , and  $\theta_i^f$  can be formulated as:

$$\theta_i^f = t_{bi}^f - t_{\beta}^f \quad (16)$$

where  $t_{bi}^f$  represents the boarding time of transfer passenger  $i$  with arrival flight  $f$ , and  $t_{\beta}^f$  is the arrival time of arrival flight  $f$ .

Let  $T_i^{kf}$  represent the time available for transfer passenger  $i$  with arrival flight  $f$  to undertake commercial activities at  $X_{lj}^k$ , then  $T_i^{kf}$  can be formulated as:

$$T_i^{kf} = \theta_i^f - T_i^f - (D_{lj}^{kf}/V) \quad (17)$$

where  $T_i^f$  denotes total walking and processing time required for transfer passenger  $i$  with arrival flight  $f$  to complete all necessary transfer procedures, moreover,  $D_{lj}^{kf}/V$  represents the extra-walking time required for transfer passenger  $i$  on arrival flight  $f$  to undertake commercial activities at  $X_{lj}^k$ . Transfer passengers taking the same arrival flight do not always have the same amount of time available for consumption activities, since they may be departing on different flights.

Let  $TP_r^k(X_{lj}^k)$  denote the total number of transfer passengers whose duration time at  $X_{lj}^k$  is longer than the required shortest time to undertake commercial activities at  $X_{lj}^k$ . Then  $TP_r^k(X_{lj}^k)$  can be formulated as:

$$TP_r^k(X_{lj}^k) = \sum_{f=1}^q \sum_{i=1}^u I_i^f, \quad I_i^f = \begin{cases} 1, & \text{if } T_i^{kf} \geq T_{k0} \\ 0, & \text{otherwise} \end{cases} \quad (18)$$

where  $u$  denotes the number of transfer passengers taking flight  $f$  and  $q$  represents the total number of arriving flights. Therefore, the number of transfer passengers who actually undertake commercial activity at  $X_{lj}^k$ ,  $C_r^k(X_{lj}^k)$ , can be formulated as  $C_r^k(X_{lj}^k) = TP_r^k(X_{lj}^k) \cdot e_r^k$ , where  $e_r^k$  denotes the ratio of transfer passengers who actually undertake commercial activity  $k$  to total transfer passengers.

### 3.3. Arrival passengers, well-wishers, greeters and airport employees

Arrival passengers, well-wishers, greeters and airport employees generally have more freedom to undertake commercial activities. The number of consumers in each of these categories increases with total number of individuals in each category. For example, demand for hotel counter service generally comes from foreign passengers. Table 2 summarizes the number of persons in each group actually undertaking commercial activity  $k$  at  $X_{lj}^k$ .

The above formulations can be used to estimate total number of consumers for different types of stores at different regions of the passenger terminal. Furthermore, Eqs. (8) and (7) can be used to estimate the concession revenue of every store. Consequently, mathematical models, that are Eqs. (4)–(6), can be used to allocate commercial space and locations among different types of stores to maximize total concession revenue.

Table 2

Number of persons in each group actually undertaking commercial activity  $k$  at  $X_{lj}^k$ 

Group types	Formulas
Arrival passengers	$TP_a \cdot \omega_k \cdot e_a^k$
Well-wishers	$TP_a \cdot r_{af} \cdot e_{af}^k$
Greeters	$TP_d \cdot r_{df} \cdot e_{df}^k$
Airport employees	$W_l \cdot e_w^k$

*Notation:*

$TP_a, TP_d, W_l$ : the total numbers of arrival, departure passengers and employees at region  $l$ , respectively.

$\omega_k, e_a^k$ : the ratio of arrival passengers possibly and actually undertaking commercial activity  $k$  to total arrival passengers and to those possibly undertaking, respectively.

$e_{af}^k, e_{df}^k, e_w^k$ : the ratios of well-wishers, greeters and  $W_l$  actually undertaking commercial activity, respectively.

$r_{af}, r_{df}$ : the ratio of well-wishers and greeters to departure and arrival passengers, respectively.

#### 4. Case study

Chiang Kai-shek International Airport (CKS) is located in Taoyuan, Taiwan, ROC, about 40 km from Taipei. With an area of 1223 ha, CKS has two terminals and two runways. Appendix B lists the main public facilities of CKS. Currently, 36 airlines operate at this airport.<sup>7</sup>

This study uses CKS as an example to demonstrate the feasibility and usefulness of the constructed models for terminal commercial space allocation.<sup>8</sup> Due to data availability, this study merely discusses the major commercial setting required by most passengers and the concessions that provide the main non-aviation revenue at CKS. The major five types of commercial shops include banks, insurance services, restaurants (including coffee shops), general stores and duty-free shops. Table 3 lists parameter data for these shops.

The simplifications regarding the case study and data are presented below:

- Extra walking distance for undertaking commercial activity  $k$  at  $X_{lj}^k$  ( $D_{lj}^k$ ): The values of  $D_{lj}^k$  are simplified into three ranges, that is under 10, 10–50, and over 50 m. This study also assumes that good guidance exists and thus passengers walk the shortest possible distance in completing their business.
- Shortest time required for undertaking commercial activity  $k$  ( $T_{k0}$ ): The value of  $T_{k0}$  is assumed to be constant for all passengers undertaking commercial activity  $k$ , and only those customers with duration of staying at  $X_{lj}^k$  longer than  $T_{k0}$  will undertake this consumption activity. The value of  $T_{k0}$  is estimated based on actual observations of the time required by customers for that particular commercial activity.

<sup>7</sup> In 2000, passenger volume was 18,681,418, ranking tenth among Asian-Pacific area Airport Council International (ACI) members, and 54th around the world. Moreover, cargo volume was 1,298,838 tons, ranking 15th at Asian-Pacific area and 16th globally.

<sup>8</sup> Types of commercial settings in CKS airport currently include banks, insurance service, post offices, telecommunication services, internet services, food and beverages, bookshop, general stores, duty-free stores, hotel reservation services, business centers, hairdressing salons and car rental, and so on.

Table 3  
Parameter data of major shops

Commercial activities ( $k$ )	$T_{k0}$	$T_{k1}$	$T_{k2}$	$T_{k3}$	$e_d^{k1}$	$e_d^{k2}$	$e_d^{k3}$	$e_r^k$	$e_a^k$	$e_{df}^k$	$e_{af}^k$	$e_w^k$	$AS_k$	$AM_k$	$F_k$
Banks	1.5	1.5	1.5	1.5	0.15	0.15	0.15	0	0.05	0	0	0	0.0825	250	0.1
Insurance	3.5	3.5	3.5	3.5	0.1	0.1	0.1	0	0	0	0	0	0.1075	830	0.15
Restaurant (mealtime)	25	45	30	25	0.65	0.5	0.4	0.1	0.01	0.05	0.15	0.2	1.6	200	0.12
Restaurant (other times)	25	45	30	25	0.16	0.12	0.1	0.02	0.002	0.01	0.06	0	1.6	150	0.12
Shops	5	15	10	8	0.13	0.1	0.08	0.05	0.002	0.005	0.01	0	1.8	400	0.1
Duty-free shops	10	25	15	12	0.3	0.27	0.25	0.1	0.1	0	0	0	3.3	2500	0.19

*Notation:*

$T_{k0}$ ,  $T_k$ : shortest time required and actual time required for undertaking commercial activity  $k$ , respectively.

$e^k$ : the ratio of passengers who actually undertake activity  $k$  to total passengers who possibly undertake activity  $k$ .

$AS_k$ : average space squired per consumer about commercial activity  $k$ .

$AM_k$ : average consumption per customer undertaking commercial activity  $k$ .

$F_k$ : concession charging ratio of type  $k$  store revenue.

Subscripts d, r, a, df, af, w: departure, transfer, and arrival passengers, well-wishers, greeters and employees, respectively.

Subscripts 1, 2, 3: passenger's available time budgets are above 90, between 90 and 60, and under 60 min, respectively.

- (c) Time required for undertaking commercial activity  $k$  ( $T_k$ ): The time passengers spend on commercial activity at banks and insurance services is usually fixed and can be estimated by observing practical consumption activity. However, time on restaurants, shops, and duty-free shops decreases with the time budget available to passengers.<sup>9</sup> The time data is estimated by interviewing store clerks and passengers.
- (d) The ratio of passengers who actually undertake activity  $k$  to total passengers who possibly undertake activity  $k$  ( $e_k$ ): The values of  $e_k$  for restaurants, shops, and duty-free shops change with available passenger time budget.<sup>10</sup> This study estimates the value of  $e_k$  by investigating actual passenger and store manager behavior.
- (e) Average space required per consumer about commercial activity  $k$  ( $AS_k$ ): According to an investigation by Civil Aeronautics Administration, MOTC, ROC (2000), this study estimates the number of departing passengers during the peak hour as being about 19% of the total departure passengers. The values of  $AS_k$  for all types of shops are estimated based on the present data and expressed in units of square meters.<sup>11</sup>
- (f) Average consumption per customer undertaking commercial activity  $k$  at  $X_{ij}^k$  ( $AM_k(X_{ij}^k)$ ): The values of  $AM_k(X_{ij}^k)$  used in the case study were estimated based on the average sales data from various stores at CKS in previous years, and these values do not vary due to changes in store size or location.
- (g) Concession charging ratio of type  $k$  store revenue ( $F_k$ ): The values of  $F_k$  for restaurants, shops, duty-free shops are actual data investigated for CKS International Airport. Moreover, the values of  $F_k$  for banks and insurance service are estimated values from nearby airports. Those values result from bidding involving stores competing to rent the same store location.

Terminal 2 of CKS International Airport was opened on July 29, 2000. Facility fees and rents for the new facility are the same as those in the old terminal, a policy designed to encourage airlines to move to the new terminal. The number of passengers in the new terminal represents 22% of total passengers. This study uses passenger volume in January, 2002 to provide data for running the model.<sup>12</sup> Currently, neither terminal is being utilized at a level approaching its design capacity. The average time per passenger required for completing all procedures including waiting and walking, is estimated as 11.8 min. The cumulative distribution function of the time budget that departure passengers stay at the airport is estimated by Hsu (1993), as described in Appendix

<sup>9</sup> To simplify the calculation,  $T_{k1}$ ,  $T_{k2}$  and  $T_{k3}$  denote three consumption durations, respectively, for three ranges of available passenger time budget, that is above 90, 90–60, and under 60 min, respectively.

<sup>10</sup> Three kinds of probabilities, that is  $e_{k1}$ ,  $e_{k2}$ , and  $e_{k3}$ , are used for three ranges of available passenger time budgets as those for  $T_{k1}$ ,  $T_{k2}$  and  $T_{k3}$ .

<sup>11</sup> The average space required per customer for banks, insurance services, and restaurants is based on the optimum configuration of seats of the present shops. No formal standards exist for general stores and duty-free shops, but larger shops display more goods, thus attracting more customers.

<sup>12</sup> Average daily passenger volume of departures, arrivals, and transfers in Terminal 1 was 16611, 15092, 4367, respectively, while volumes in Terminal 2 were 4655, 4144, 1593, respectively.

C. Well-wishers represent 47% of departure passengers, while greeters represent 57% of arrival passengers, based on previous studies by Jung (1995) and Civil Aeronautics Administration, MOTC, ROC (2000) for CKS International Airport.

#### 4.1. Results

This study applies the models formulated in Section 3 to allocate spaces and positions for all kinds of commercial activities in Terminals 1 and 2. Appendix D shows the model results for square meters, positions, and concessions for all kinds of commercial activities. The results indicate that Terminal 1 has 440 m<sup>2</sup> of unused commercial spaces in the arrival area, while commercial space requirements in the departure area are 5899 m<sup>2</sup> if relaxing the constraints of the maximum total available commercial space of 4400 m<sup>2</sup>. The results also show that if banks, insurance services, and duty-free shops are located within an average 10 m extra-walking distance in non-controlled area and controlled area, and moreover if the remaining space for restaurants and general shops is secondly allocated following order of increasing extra-walking distance, then the model will identify NT\$ 3,020,226 per day as the maximum possible concession.

The results of the model in case studies indicate that the locations of some stores are different from present location. That is, to maximize total concession revenue, some profitable stores should be moved to more accessible locations to attract more consumers. Since current passenger volume is just 22% of the designed capacity of Terminal 2, the commercial space required to satisfy current passenger demand is significantly less than the originally designed space. The utilization of commercial space in the departure and arrival areas is 30% and 13%, respectively, and all of the used space is located within an average 10 m of average walking distance. The time budget available to passengers decreases with each commercial activity they complete. The results show that airport operators should locate stores with the large concession revenue per square meter per unit time in the more accessible positions with higher passenger flow. Such a configuration can maximize total concession revenue.

Departure passengers in Terminal 1 for commercial activities must wait because space for commercial activities is insufficient during the peak hour. Furthermore, passengers arriving late may have insufficient time to consume due to additional walking time to reach stores in distance positions may mean passengers with time constraints are unable to consume. Therefore, the average concession revenue from each passenger in Terminal 1 is seven dollars less than that in Terminal 2. Accordingly, if airport operators encouraging more airlines to move to Terminal 2 not only can reduce the peak hour jam at Terminal 1, but also can improve service quality and increase commercial concession revenue. Likewise, where two or more terminals exist, this study assigns passenger volume to each terminal according to number of passengers following a general consideration of space for various public facilities, space available for commercial activities, and the location of commercial space in each terminal, so as to maximize total concession revenues.

Based on the data on current passenger volume and the maximum commercial space presently available in the two terminals, this study finds that the models produce optimal results when Terminal 1 has 42–49% of total passenger volume, rather than the current 78%. Moreover, such an allocation of passenger volume maximizes total concession revenue, increasing by

Table 4  
Optimal square meters, positions, and concessions for all types of commercial activities at Terminal 1

Commercial activity ( <i>k</i> )	Space demand (m <sup>2</sup> )	Allocated space (m <sup>2</sup> ) at departure area						Space demand (m <sup>2</sup> )	Allocated space (m <sup>2</sup> ) at arrival area						Concessions (NT\$/day)
		Non-controlled			Controlled				Non-controlled			Controlled			
		(Walking distances, m)							(Walking distances, m)						
		<10	10–50	>50	<10	10–50	>50		<10	10–50	>50	<10	10–50	>50	
Banks	20	20	0	0	0	0	0	7	7	0	0	0	0	0	42,637
Insurance	17	17	0	0	0	0	0	0	0	0	0	0	0	0	104,552
Restaurant	1536	463	800	0	0	273	0	220	93	69	0	0	58	0	87,445
Shops	377	0	0	235	0	142	0	14	0	14	0	0	0	0	44,834
Duty-free	1485	0	0	0	1200	285	0	543	0	0	0	400	143	0	1,533,716
Total	3435	500	800	235	1200	700	0	784	100	83	0	400	201	0	1,813,184
Capacity	4400	500	800	700	1200	700	500	1800	100	100	200	400	600	400	
Difference	965	0	0	465	0	0	500	1016	0	17	200	0	399	400	

<sup>a</sup> 1NT\$  $\cong$  0.029US\$.

Table 5  
Optimal square meters, positions, and concessions for all types of commercial activities at Terminal 2

Commercial activity ( <i>k</i> )	Space demand (m <sup>2</sup> )	Allocated space (m <sup>2</sup> ) at departure area						Space demand (m <sup>2</sup> )	Allocated space (m <sup>2</sup> ) at arrival area						Concessions (NTS <sup>a</sup> /day)
		Non-controlled			Controlled				Non-controlled			Controlled			
		(Walking distances, m)							(Walking distances, m)						
		<10	10–50	>50	<10	10–50	>50		<10	10–50	>50	<10	10–50	>50	
Banks	25	25	0	0	0	0	0	8	8	0	0	0	0	0	52,110
Insurance	21	21	0	0	0	0	0	0	0	0	0	0	0	0	127,779
Restaurant	1877	254	838	0	0	785	0	268	92	106	0	0	70	0	107,141
Shops	461	0	162	149	0	0	150	17	0	17	0	0	0	0	54,780
Duty-free	1815	0	0	0	1600	215	0	663	0	0	0	600	63	0	1,875,446
Total	4199	300	1000	149	1600	1000	150	956	100	123	0	600	133	0	2,217,256
Capacity	5700	300	1000	700	1600	1000	1100	2800	100	500	800	600	500	300	
Difference	1501	0	0	551	0	0	950	1844	0	377	800	0	367	300	

<sup>a</sup> 1NTS  $\cong$  0.029US\$.



116,723 dollars per day and balancing the use of the two terminals. Tables 4 and 5 list the optimal square meter area, positions, and concession for all kinds of commercial activities at the two terminals at CKS when the passenger volume at Terminal 1 is reduced to 45% of total passenger volume. Decisions of airlines to move their operations to a new terminal are likely depend on operational procedures and operating costs. Likewise, with two or more terminals exist, allocating traffic more or less proportional to the total space available to public facilities and commercial activities will maximize commercial revenues. Airline operating cost and procedural efficiency also depend on whether allocated space distribution is proportional to their traffic. Therefore, the results are consistent regardless of whether space is allocated to maximize efficiency of airline operating costs and procedures, or allocated proportionally based on airline traffic.

#### 4.2. Relationship between public facility service level and concession revenue

Available time budgets and store location influences demand for commercial space from departure passengers, and demand for commercial space thus decreases with increasing passenger processing time and walking distance. The case study presented here further considers how to distribute terminal space between commercial activities and public facilities related to departure passenger processing. This study analyzes the relationship between maximizing concession revenue and public facility service levels.

Table 6 lists the results of this investigation regarding the concession revenue and total square meters for commercial activities in the departure areas, under different service levels of public facilities defined by IATA (1995) and under assuming that Terminal 2 passenger volume is approaching its design capacity. Total square meter area of public facilities is estimated using the approach suggested by IATA (1995) for different service levels. The average passenger processing time is also estimated for each service level. The results show that to maximize concession revenue, the ratio of commercial space to public facility space increases with decreasing levels-of-service. The reason is due to departure passengers will increase their procedure time when the level-of-service decreases and the decreasing rate of the space demand for commercial activities due to the increased procedure time is less than the reduced public facility space due to the reduced level-of-service. Table 6 also shows that concession revenue is

Table 6  
Largest obtained concession and the total commercial space under different service levels

	Level-of-service				
	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>
Departure procedure time (min)	10.5	12.2	14.4	17.6	23.1
Departure public area (m <sup>2</sup> )	20,039	17,347	14,655	11,964	9122
Commercial activities area (m <sup>2</sup> )	7760	7654	7512	7289	6860
Commercial/public	0.387	0.441	0.513	0.609	0.752
Largest concessions (NTS <sup>a</sup> /day)	3,360,834	3,313,746	3,233,190	3,131,946	2,937,815

<sup>a</sup> 1NT\$  $\cong$  0.029US\$.

Table 7

Concessions obtained under different passenger volumes and service levels unit: (NT\$<sup>a</sup>/day)

Passenger volume	Largest concession	Original designed	Level-of-service				
			A	B	C	D	E
Equal capacity	3,268,654	3,189,656	3,042,784	3,196,000	3,233,190	3,131,946	2,937,815
Over capacity 10%	3,529,133	3,414,738	2,399,310	3,307,330	3,493,005	3,458,862	3,249,776
Over capacity 20%	3,783,981	3,655,089	0	3,299,305	3,670,286	3,773,178	3,554,438

<sup>a</sup> 1NT\$  $\cong$  0.029US\$.

maximized under service level *A*. However, this service level requires more space for both public facilities and commercial activities than other service levels, and thus incurs tremendous construction costs.

International airports currently are facing a highly competitive environment and moreover increasingly are required to be self-financing. As for the space allocation of the terminal building, public facilities must maintain a certain level-of-service to be competitive. To determine which level-of-service for public facilities maximizes concession revenue, this study applies three future levels of passenger volume, that is, equal to the designed capacity, and over the designed capacity with 10% and 20%, respectively, on Terminal 2 of CKS International Airport. When passenger volume and designed capacity are the same, that is, 17 million persons per year, the level-of-service is between *B* and *C*, and the ratio of space for commercial activities to that of public facilities is 0.475 in the departure area. Maximum concession revenue is 3,268,654 dollars per day, and is obtained when the average departure passenger processing time is 13.2 min. Concession revenue increases by up to 78,998 dollars per day in this scheme compared with the original scheme, as listed in Table 7.

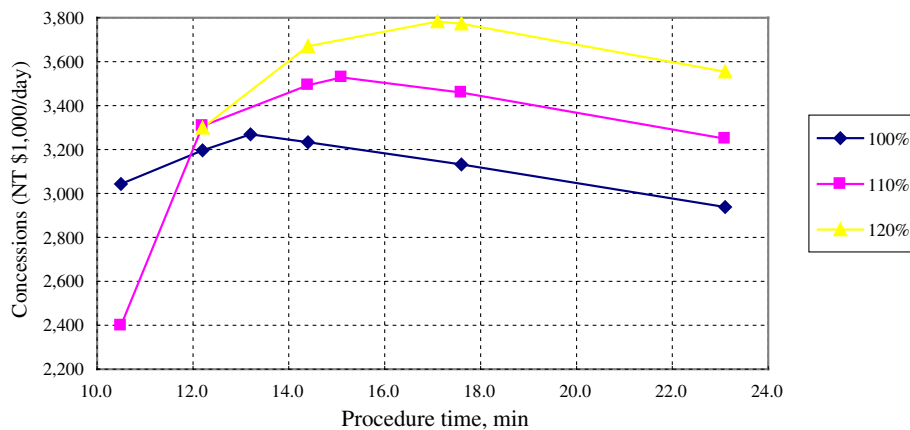


Fig. 2. Concession revenue versus public facility procedure time under different passenger volumes.

Aiming to increase level-of-service in allocating space for public facilities will result in a shortage of commercial space; on the other hand, reducing level-of-service will result in idle commercial space. However, to maximize concession revenue, level-of-service considerations in allocating space for public facilities should be adjusted according to passenger volumes. The level-of-service that should be applied to maximize concession revenue decreases with increasing passenger volume, as shown in Fig. 2. The results indicate that, due to original design space for public facilities adopting the higher level of service, when passenger volume increases, concession revenue can be increased by reducing service level. That is, this study increases commercial space while reducing public facility space, yet the extent of these increases and decreases should be controlled to maintain the level of service required for an International Airport.

## **5. Conclusions**

Previous studies on space allocation in terminal buildings have mainly focused on public facilities. Most of these previous studies dealt with the problem from architectural and/or operations research perspectives. However, the main issues in airport management studies have previously been airport pricing and airport productivity or performance. This study explores the relationships among concession revenue, passenger service level and space allocation for public facilities and commercial activities at international passenger terminals. This study aims to develop a new space allocation model that can be used in practice to allocate space for various commercial activities and maximize the concession revenue under different passenger volumes or service levels.

The results show that total commercial revenues can be maximized by allocating the stores with more concession revenue per square meter per unit time in the more accessible positions in the terminal building. In the case study presented here, the results related to the optimal square meter measures and locations for every kind of store at every region of the two terminals could provide references for use in terminal planning and lease management. The analytical results also show that if the operators of CKS International Airport allocate 42–49% of passengers to use the Terminal 1 instead of current 78%, it will balance the use of two terminals and obtain the maximum concession revenue.

On the other hand, the result of the this study shows that to maintain the same public facility service level, the space required for commercial activities increases proportionally with passenger volume, while the concession revenue does not increase by the same proportion, and instead depends on the allocated locations. To maximize concession revenue, even given constant passenger volume, the required commercial space is not the same and its ratio to public facility space also differs for different public facility service levels. The ratio of commercial space to public facility space increases with reducing public facility service level. This finding provides a new reference for airport designers who used to adopt the same ratio without further considering changes in the service level of public facility. For the established passenger terminal, if the operators

of airports aim at maximizing commercial concession then they may lower public facility service level in response to increased passenger volume due to the limitation of the original space.

This study suggests that if the airports that incorporate a high public facility service in their original design may reduce public facility space while increasing commercial space, thus increasing commercial concession revenue. However, this study also suggested that the service level should not be reduced below the standard required for an International Airport to preserve competitive advantage. Passenger arrival time depends not only on passenger estimates of the time required to reach the airport and terminal processing time but also on air trip types (such as group or individual, business or leisure) and trip length. The cumulative probability function of departure passenger time budget differs among airports due to different passenger compositions. Future studies of other airports should investigate and calibrate passenger time budget function to apply the model to reduce error.

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### Appendix A. Level of service measures by IATA

	Level of service standards (sq. meter/occupant)					
	A	B	C	D	E	F
Check-in queue area	1.8	1.6	1.4	1.2	1.0	BREAK- DOWN SYSTEM
Wait/circulate	2.7	2.3	1.9	1.5	1.0	
Hold room	1.4	1.2	1.0	0.8	0.6	
Bag claim area (excl. claim device)	2.0	1.8	1.6	1.4	1.2	
GIS	1.4	1.2	1.0	0.8	0.6	

A Excellent level of service; condition of free flow; excellent level of comfort.

B High level of service; condition of stable flow; very few delays; high level of comfort.

C Good level of service; condition of stable flow; acceptable delays; good level of comfort.

D Adequate level of service; condition of unstable flow; acceptable delays for short periods of time; adequate level of comfort.

E Inadequate level of service; condition of unstable flow; unacceptable delays; inadequate level of comfort.

F Unacceptable level of service; condition of cross-flows, system breakdown and unacceptable delays; unacceptable level of comfort.

Source: IATA (1995).

## Appendix B. Public facilities at CKS airport

Item	Terminal 1	Terminal 2
Construction type	Three stories construction with one level basement	Four stories construction with one level basement
Total floor area	169,500 m <sup>2</sup>	208,000 m <sup>2</sup>
Building height	25.7 m	47.6 m
Handling capacity	12 million per year	17 million per year
Peak hour capacity	6300 passengers	5000 passengers
Boarding gates	21	20
Checking-in counters	10 (240 desks)	8 (158 desks)
Departure immigration counters	48	42
Security inspection	8	10
Passenger aircraft aprons	28	27
Arrival immigration counters	36	58
Baggage conveyers	6	6
Baggage inspection	23	34
Parking stalls	2207	4133

Source: CKS International Airport Office.

## Appendix C. Cumulative probability function of departure passengers with time budget $\theta$

Hsu (1993) investigated the distribution of airport arrival time for departure passengers, using passengers from eight departure flights departing from CKS airport as a sample. The cumulative probability function of passenger arrival time at the airport from the beginning time of check-in to the designated departure time was calibrated as:

$$F(t) = [68.1565 + 0.0896 \cdot t^2 + 0.0023 \cdot t^3 + 14.4944 \cdot (t - 50) \cdot J - 0.8918 \cdot (t - 50)^2 \cdot J] / 2005 \quad (\text{C.1})$$

where  $J$  is a binary variable, and  $J = 0$  if  $0 \leq t \leq 50$ ,  $J = 1$  if  $50 < t \leq 130$ . The total study period is 150 min and random variable  $t$  denotes passenger arrival time elapsed from the beginning of check-in time,  $t = 0$ . Furthermore, let the duration from the arrival time of any passenger to designated departure time is  $\theta$ , that is, passenger time budget at the terminal, in which the cumulative probability function of  $\theta$  can be further obtained by transforming the cumulative passenger probability function  $F(\theta)$  as:

$$F(\theta) = 1 - [68.1565 + 0.0896 \cdot (150 - \theta)^2 + 0.0023 \cdot (150 - \theta)^3 + 14.4944 \cdot (100 - \theta) \cdot J - 0.8918 \cdot (100 - \theta)^2 \cdot J] / 2005 \quad (\text{C.2})$$

where  $J$  is a binary variable, and  $J = 1$  if  $20 \leq \theta \leq 100$ ,  $J = 0$  if  $100 < \theta \leq 150$ . Since only 3.4% passengers arrived at the airport earlier than 150 min before the flight departure time, and since these passengers usually have enough time for any commercial activities, the cumulative probability for the arrival time of these passengers can be simply expressed as  $F(\infty) - F(150) = 0.034$ .

### Appendix D. Model results for square meters, positions, and concessions for all kinds of commercial activities at Terminals 1 and 2

Commercial activity ( <i>k</i> )	Space demand (m <sup>2</sup> )	Allocated space (m <sup>2</sup> ) at departure area						Space demand (m <sup>2</sup> )	Allocated space (m <sup>2</sup> ) at arrival area						Concessions (NTS <sup>a</sup> /day)
		Non-controlled			Controlled				Non-controlled			Controlled			
		(Walking distances, m)							(Walking distances, m)						
		<10	10–50	>50	<10	10–50	>50		<10	10–50	>50	<10	10–50	>50	
<i>Terminal 1</i>															
Banks	35	35	0	0	0	0	0	12	12	0	0	0	0	0	74,090
Insurance	30	30	0	0	0	0	0	0	0	0	0	0	0	0	181,475
Restaurant	2643	435	800	550	0	0	50	377	88	100	135	0	54	0	140,197
Shops	649	0	0	150	0	0	20	25	0	0	25	0	0	0	36,378
Duty-free	2562	0	0	0	1200	700	430	946	00	0		400	546	0	2,588,086
Total	5899	500	800	700	1200	700	500	1360	100	100	160	400	600	0	3,020,226
Capacity	4400	500	800	700	1200	700	500	1800	100	100	200	400	600	400	
Difference	-1499	0	0	0	0	0	0	440	0	0	40	0	0	400	
<i>Terminal 2</i>															
Banks	10	10	0	0	0	0	0	3	3	0	0	0	0	0	20,656
Insurance	8	8	0	0	0	0	0	0	0	0	0	0	0	0	50,856
Restaurant	769	282	0	0	487	0	0	111	80	0	0	31	0	0	43,944
Shops	187	0	9	0	178	0	0	7	7	0	0	0	0	0	22,529
Duty-free	738	0	0	0	738	0	0	260	0	0	0	260	0	0	755,506
Total	1712	300	9	0	1403	0	0	381	90	0	0	291	0	0	893,491
Capacity	5700	300	1000	700	1600	1000	1100	2800	100	500	800	600	500	300	
Difference	3988	0	991	700	197	1000	1100	2419	10	500	800	309	500	300	

<sup>a</sup>1NTS  $\cong$  0.029US\$.

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