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A comparative analysis of the operational performance of Taiwan's major airports

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Abstract

The paper evaluates and compares the operational performance of ten major airports in Taiwan. The measure of operational performance is based on the relationship between four factors: airport, passengers, airline companies, and fire services. To overcome the restrictions of the small sample size, grey relation analysis is used to group the initial evaluation indicators and to select the representative indicators.

Keywords: Airport; Performance evaluation; Representative indicators; Grey relation analysis

1. Introduction

The Taiwan Government has recently become interested in evaluating the performance of its airports. The role of air transport in Taiwan is under review because the high-speed railway is about to open direct passenger transportation links between Taiwan and Mainland China which are imminent, and Taiwan is an emerging logistics centre for the Asia Pacific Region. In the past, studies of the operational performance of air transportation have primarily concentrated on evaluating airline performance and the economic efficiency of routes. Much less has been done on airports with most of the focus on productivity, competitive power, service standards, and service quality. Only a few shed light on the operational performance of airports.[1]

Furthermore, previous work outside the US has tended to concentrate on comparative studies of different international airports, and thus excluding airports used for domestic or regional services. Whether the analysis of large airports is applicable to smaller airports, and the nature of heterogeneity and homogeneity between the operational performances of airports of different classes, has been explored a little. Here ten major domestic airports in Taiwan are studied for their operational performance. They are; class A airports (Chiang Kai-Shek, Kaohsiung and Taipei), class B airports (Tainan, Hualien, Taitung and Ma Kung), and class C airports (Taichung, Chiayi and Kinmen).

2. Conceptual framework

An airport is a place where the suppliers of air transportation services (airline companies) and the users of such services meet and conduct their business. The operations and management of airports are handled by their administrations that view both the airline companies and passengers as consumers. Running an airport is thus the same as running any other enterprise from the perspective of corporate ethos and operational efficiency. In doing so, airports must be cognizance of more general concerns such as safety and security which are less important in some other types of business.

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[1] Yu (2000), Hooper and Hensher (1997), Gillen and Lall (1997), and Martin and Roman (2001) on productivity, Wang (1999) and the Institute of transportation, Ministry of Transportation and Communications (1999) on competitive issues, and Yen (1995) and Ching (1998) on service quality.

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Practically, the efficiency of an airport's operations can be seen to rest on four features: the airport, airline companies, passengers, and aviation control and fire services (Fig. 1). Here the airport is evaluated in terms of its; labour force (number of employees), terminal facilities (floor area of the terminal building, number of boarding gates, and number of check-in counters), aviation facilities (size of the apron, the number of car parking places, and accommodation of traffic volume), and revenue (total revenue and non-aviation income). The airline companies cover the output of transportation (take-offs and landings, cargo tonnage, number of take-offs and landings during peak hours, and the number of routes) while passenger considerations include the total number of people served (passengers) and the number of people during peak hours. The aviation control and fire service covers police and firefighters (number of firefighters stationed on-site) and aviation control (number of aviation controllers). The evaluation of the overall operational performance is conducted by examining the productivity of employees, airline service levels, passenger service levels, and aviation and fire service levels.

In the context of this paper, an attempt has been made to ensure that indicators for evaluation purposes are meaningful, e.g., measures such as the ratio of floor area per aviation controller are excluded. Second, if data for any specific element are unavailable, items carrying similar meaning for evaluation are used as substitutes, e.g., the number of aviation controllers is replaced with the number of air traffic controllers. This leaves 28 indicators for the evaluation exercise, 6 falls under the category of employee productivity, 6 under airline service level, 7 under passenger service level, and 9 under aviation and fire service level (see Table 1).

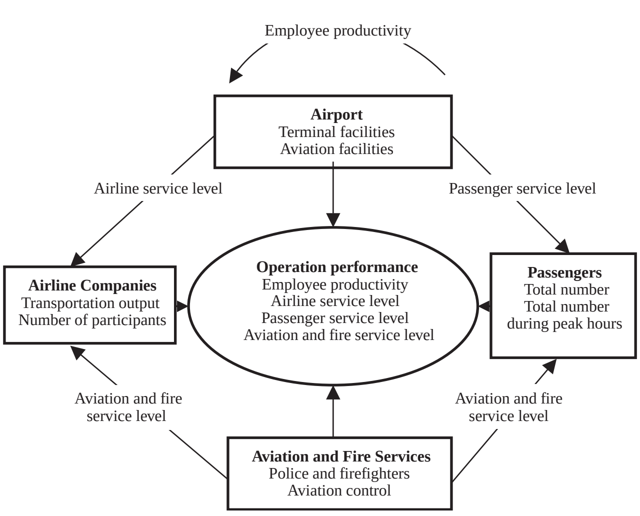

Fig. 1. Conceptual framework for evaluating airport operational performance.

3. Grey relation analysis and TOPSIS

Initially there is a need to reduce the number of indicators by selecting the most representative one. In general, these can be selected by grouping in a way that minimizes the differences within a group and maximizes the differences between those groups. If the samples are large and normally distributed, methods such as factor analysis, cluster analysis, and discriminate analysis can be used. However, if the sample size is small and the distribution of samples is unknown, grey relation analysis offers a tractable alternative. In addition, the TOPSIS method is employed in conjunction with grey relation analysis to calculate performance scores and rankings (Feng and Wang, 2000, 2001).

Grey system theory was developed by Deng (1982). The fundamental definition of 'greyness' is the information that is incomplete or unknown; thus an element from an incomplete message is considered to be a grey element. 'Grey relations' refer to the measurements of changing relations between two systems or between two elements that occur in a system over time. This method of analysis that is based on the degree of similarity or difference of development trends among elements used to measure the relation among elements is called 'grey relation analysis'. During system development, should the trend of change between two elements be consistent, it is seen to enjoy a higher level of synchronized change and can be considered as having a stronger relationship. Otherwise, the grade of relation is smaller.

Let $\mathbf{X}$ be a factor set of grey relation, $\mathbf{x}_0 \in \mathbf{X}$ represent the referential sequence, and $\mathbf{x}_i \in \mathbf{X}$ represent the comparative sequence. $\mathbf{x}_0(k)$ and $\mathbf{x}_i(k)$ represent the respective numerals at point k for $\mathbf{x}_0$ and $\mathbf{x}_i$. If the average relation value $\gamma(\mathbf{x}_0(k), \mathbf{x}_i(k))$ is a real number, then it can be defined as (Deng, 1989):

$$\gamma(\mathbf{X}_0, \mathbf{X}_i) = \frac{1}{n} \sum_{k=1}^{n} \gamma(\mathbf{X}_0(k), \mathbf{X}_i(k)).$$

The average value of $\gamma(\mathbf{x}_0(k), \mathbf{x}_i(k))$ must satisfy the following four axioms: normal interval, duality symmetric, wholeness and approachability.

Axiom 1. Norm Interval

$$0 < \gamma(\mathbf{X}_0(k), \mathbf{X}_i(k)) \leqslant 1, \forall(k),$$
$$\gamma(\mathbf{X}_0(k), \mathbf{X}_i(k)) = 1 \quad \text{iff} \quad \mathbf{X}_0(k) = \mathbf{X}_i(k),$$
$$\gamma(\mathbf{X}_0(k), \mathbf{X}_i(k)) = 0 \quad \text{iff} \quad \mathbf{X}_0(k), \mathbf{X}_i(k) \in \varnothing,$$

where $\varnothing$ is an empty set.

Axiom 2. Duality symmetric

$$x, y \in \mathrm{X},$$
$$\gamma(x, y) = \gamma(y, x) \quad \text{iff} \quad \mathrm{X} = \{x, y\}.$$

Table 1
The initial indicators

Code	Name of indicator	Equation for evaluation
Employee productivity		
OP_1	Number of take-offs and landings to number of employees	Number of take-offs and landings/number of employees
OP_2	Cargo tonnage to number of employees	Cargo tonnage/number of employees
OP_3	Floor area of terminal building to number of employees	Floor area of terminal building/number of employees
OP_4	Revenue to number of employees	Total revenue/number of employees
OP_5	Non-aviation income to number of employees	Non-aviation income/number of employees
OP_6	Number of passengers to number of employees	Number of passengers/number of employees
Airline service level		
OA_1	Floor area of terminal to number of airlines	Floor area of terminal building/number of airlines
OA_2	Size of apron to number of airlines	Size of apron/number of airlines
OA_3	Volume to number of airlines	Traffic volume /number of airlines
OA_4	Volume to number of take-offs and landings	Traffic volume/number of take-offs and landings
OA_5	Volume to the number of routes	Traffic volume/number of routes
OA_6	Service standards of runway	Traffic volume/take-offs and landings during peak hours
Passenger service level		
OC_1	Take-offs and landings to number of passengers	Take offs and landings/total number of passengers
OC_2	Number of airlines to number of passengers	Number of airlines/number of passengers
OC_3	Number of routes to number of passengers	Number of routes/number of passengers
OC_4	Number of car parks to the number of passengers during peak hours	Number of car parks/number of passengers during peak hours
OC_5	Degree of congestion	Floor area of terminal/number of passengers during peak hours
OC_6	Number of boarding gates to number of passengers	Number of boarding gates/number of passengers
OC_7	Number of check-in counters to number of passengers	Number of check-in counters/number of passengers
Aviation and fire service level		
OS_1	Number of police and firefighters to number of take-offs and landing	Number of police and firefighters/number of take-offs and landings
OS_2	Number of police and firefighters to the number of airlines	Number of police and firefighters/number of airline companies
OS_3	Number of police and firefighters to number of passengers	Total number of police and firefighters/number of passengers
OS_4	Number of police and firefighters to floor area of terminal	Number of police and firefighters/floor area of terminal
OS_5	Number of police and firefighters to number of car parks	Number of police and firefighters/number of car parks
OS_6	Number of police and firefighters to the size of the apron	Number of police and firefighters/size of the apron
OS_7	Number of police and firefighters to the number of flight routes	Number of police and firefighters/number of flight routes
OS_8	Number of aviation controllers to the number of take-offs and landings	Number of aviation controllers/number of take-offs and landings
OS_9	Number of aviation controllers to the number of flight routes	Number of aviation controllers/number of flight routes

Axiom 3. Wholeness

$\mathbf{X}_i, \mathbf{X}_j \in \mathrm{X} = \{\mathbf{X}_\sigma | \sigma = 0, 1, 2, \ldots, n\}, n > 2,$
$\gamma(\mathbf{X}_i, \mathbf{X}_j) \neq \gamma(\mathbf{X}_j, \mathbf{X}_i).$

Axiom 4. Approachability

$\gamma(\mathbf{X}_0(k), \mathbf{X}_i(k))$

decrease along with $|\mathbf{X}_0(k) - \mathbf{X}_i(k)|$ increasing.

If the four axioms are satisfied, $\gamma(\mathbf{x}_0, \mathbf{x}_i)$ is then designated as the grade of grey relation in $\mathbf{x}_i$ correspondence to $\mathbf{x}_0$.$\gamma(\mathbf{x}_0(k), \mathbf{x}_i(k))$ is said to be the grey relational coefficient of the same at point k. Deng has proposed a mathematical equation that will satisfy these four axioms of grey relation, which is

$$\gamma(\mathbf{X}_0(k), \mathbf{X}_i(k)) = \frac{\min_{i\in I} \min_k |\mathbf{X}_0(k) - \mathbf{X}_i(k)| + \zeta \max_{i\in I} \max_k |\mathbf{X}_0(k) - \mathbf{X}_i(k)|}{|\mathbf{X}_0(k) - \mathbf{X}_i(k)| + \zeta \max_{i\in I} \max_k |\mathbf{X}_0(k) - \mathbf{X}_i(k)|},$$

where ζ is the distinguished coefficient ($\zeta \in [0,1]$), the function of which is to reduce its numerical value by $\max_{i\in I} \max_k |\mathbf{X}_0(k) - \mathbf{X}_i(k)|$ getting large, so as to effect its loss-authenticity and to heighten the remarkable difference among relation coefficients.

The TOPSIS method (Hwang and Yoon, 1981) has the advantage of being simple and yields an indisputable preference order. But it does assume that each indicator takes monotonic (increasing or decreasing) utility. TOPSIS is based on the concept that the chosen indicator should have the shortest distance from the ideal solution and the farthest from the worst solution. The ideal solution is the one that enjoys the largest benefit indicator value and the smallest cost factor.

The steps involved in carrying this out are:

Step 1: *Normalization of indicator values*

Normalization aims at obtaining comparable scales. There are different ways of normalizing the indicator values. Here vector normalization is used. This utilizes the ratio of the original value (x_{ij}) and the square root of the sum of the original indicator values. The advantage of this approach is that all indicators are measured in dimensionless units, thus facilitating inter-indicator comparisons. This procedure is usually utilized in TOPSIS using

$$\mathbf{r}_{ij} = \frac{\mathbf{X}_{ij}}{\sqrt{\sum_{i=1}^{m} \mathbf{X}_{ij}^2}},$$

where i is the ith airport, j is the jth evaluation indicator, $\mathbf{r}_{ij}$ is the indicator value after vector normalization for the ith airport and jth evaluation indicator, $\mathbf{x}_{ij}$ is the original value of indicators for the ith airport and jth evaluation indicator, and m is the number of airports.

Step 2: *To determine ideal* (A^+) *and worst* (A^-) *solution*

$$\mathbf{A}^+ = \{(\max_i \mathbf{r}_{ij} \,|\, j \in \mathbf{J}), (\min_i \mathbf{r}_{ij} \,|\, j \in \mathbf{J}') | i = 1, 2, ..., m\}$$
$$= \{\mathbf{A}_1^+, \mathbf{A}_2^+, \ldots, \mathbf{A}_j^+, \ldots, \mathbf{A}_k^+\},$$
$$\mathbf{A}^- = \{(\min_i \mathbf{r}_{ij} \,|\, j \in \mathbf{J}), (\max_i \mathbf{r}_{ij} \,|\, j \in \mathbf{J}') | i = 1, 2, ..., m\}$$
$$= \{\mathbf{A}_1^-, \mathbf{A}_2^-, \ldots, \mathbf{A}_j^-, \ldots, \mathbf{A}_k^-\},$$

where $\mathrm{J} = \{j = 1,2,\ldots, k|k\}$ positively relates to the benefit criteria, $\mathbf{J}' = \{j = 1,2,\ldots k|k\}$ positively relates to the cost criteria.

Step 3: *To calculate the separation measure*

The separation of each airport from the ideal airport ($\mathbf{S}_i^+$) and the worst airport ($\mathbf{S}_i^-$) uses

$$\mathbf{S}_i^+ = \sqrt{\sum_{j=1}^{k} (\mathbf{r}_{ij} - \mathbf{A}_j^+)^2}; \quad \mathbf{S}_i^- = \sqrt{\sum_{j=1}^{k} (\mathbf{r}_{ij} - \mathbf{A}_j^-)^2}$$

$i = 1, 2, ..., \mathrm{m}$.

Step 4: *To calculate the relative closeness to the ideal solution* ($\mathbf{C}_i^*$)

This is defined as

$$\mathbf{C}_i^* = \frac{\mathbf{S}_i^-}{\mathbf{S}_i^+ + \mathbf{S}_i^-} \; 0 < \mathbf{C}_i^* < 1.$$

Step 5: *To rank the preference order according to the descending order of* $\mathbf{C}_i^*$.

4. Application

As indicated earlier, 10 class A, B, and C airports are used in the analysis. Class A airports are key domestic airports and also provide backup for the international airports. Class B airports are domestic airports with heavy domestic air traffic. Class C airports are similar to class B airports, but have lighter traffic. CKS is the only international class airport in Taiwan but for purposes of the analysis is included as a Class A airport.

The data used for 2001 are taken from a variety of studies. The sources are data from various airports and the accounting offices of the air transport branches of the Civil Aviation Administration. Based on the grey relation analysis, indicators are established for the four groupings; employee productivity, airline service level, passenger service level, and aviation and fire service level, in accordance with the coefficient of each indicator. The grouped indicators and representative indicators for class A, B, and C airports are presented in Table 2.

The values of the indicators are converted into performance scores through TOPSIS. The operational performances of class A, B, and C airports are rated according to employee productivity, airline service level, passenger service level, aviation and fire service level, and total performance (Table 3).

The analysis allows comparisons between the operational efficiency of the various airports. In terms of operations performance, class A airports are ranked, CKS, Taipei and Kaohsiung. Each has some particular operational challenges to meet. For example, the aviation and fire service level at CKS is the poorest in the class, whilst Taipei International Airport comes out the poorest in terms of passenger service. As for Kaohsiung International Airport, the employee productivity is poor.

Turning to class B airports, the airline service level in Ma Kung Airport is the poorest of the four airports in this class. Taitung Airport, on the other hand, performed fairly well when compared with the other airports. Tainan Airport has the poorest passenger service level while Hualien Airport has the poorest ratings for both employee productivity and aviation and fire service levels in this class. Taichung Airport has the poorest aviation and fire service levels of the three class C airports. The airline service level in Kinmen Airport is the worst in the group and Chiayi Airport has the worst employee productivity and passenger service level.

This analysis suggests that the various airports may find it useful to pursue a variety of measures to enhance their performance. Table 4 provides some general indications of how this may be done.

Table 5 that focuses on labour considerations show that the airports studied have high employee productivity in terms of cargo handling. Both class A and B airports are also efficient in terms of the number of take-offs and landings handled by their workers and regarding the passengers they handle. Class A and C airports obtain significant non-aviation income for the number of employees they have while as a group, class B airports tend to make good use of their floor space.

Turning to service levels (Table 6), all airport classes show operational efficiency in the way they use floor area relative to the airlines using their facilities and in the way they handle traffic volume relative to the

Table 2
The grouped indicators and representative indicators

Group		Representative indicator of each group	Indicators within each group
Class A Airports			
Employee productivity	OP-I	OP_1: Number of take-offs and landings to number of employees	OP_1
	OP-II	OP_2: Cargo tonnage to number of employees	OP_2
	OP-III	OP_5: Non-aviation income to number of employees	OP_3, OP_4, OP_5
	OP-IV	OP_6: Number of passengers to number of employees	OP_6
Airline service level	OA-I	OA_1: Floor area of terminal to the number of airlines	OA_1
	OA-II	OA_3: Traffic volume to the number of airlines	OA_2, OA_3
	OA-III	OA_4: Traffic volume to number of take-offs and landings	OA_4, OA_6
	OA-IV	OA_5: Traffic volume to number of routes	OA_5
Passenger service level	OC-I	OC_1: Number of take-offs and landings to number of passengers	OC_1
	OC-II	OC_2: Number of airlines to number of passengers	OC_2
	OC-III	OC_3: Number of routes to number of passengers	OC_3, OC_7
	OC-IV	OC_5: Degree of congestion	OC_4, OC_5
	OC-V	OC_6: Number of boarding gates to number of passengers	OC_6
Aviation and fire service level	OS-I	OS_8 Number of police and firefighters to number of take-offs and landing	OS_1, OS_8
	OS-II	OS_2: Number of police and firefighters to number of airlines	OS_2
	OS-III	OS_3: Number of police and firefighters to number of passengers	OS_3
	OS-IV	OS_7: Number of police and firefighters to number of routes	OS_4, OS_7
	OS-V	OS_6: Number of police and firefighters to size of the apron	OS_5, OS_6, OS_9
Class B Airports			
Employee productivity	OP-I	OP_1: Number of take-offs and landings to number of employees	OP_1
	OP-II	OP_2: Cargo tonnage to number of employees	OP_2
	OP-III	OP_3: Floor area of terminal building to number of employees	OP_3
	OP-IV	OP_6: Number of passengers to number of employees	OP_4, OP_5, OP_6
Airline service level	OA-I	OA_1: Floor area of terminal to number of airlines	OA_1
	OA-II	OA_5: Traffic volume to number of routes	OA_2, OA_5
	OA-III	OA_3: Traffic volume to number of airlines	OA_3
	OA-IV	OA_4: Traffic volume to number of take-offs and landings	OA_4
	OA-V	OA_6: Service standards of runway	OA_6
Passenger service level	OC-I	OC_1: Number of take-offs and landings to number of passengers	OC_1
	OC-II	OC_6: Number of boarding gates to number of passengers	OC_2, OC_6
	OC-III	OC_7: Number of check-in counters to number of passengers	OC_3, OC_7
	OC-IV	OC_4: Number of car parks to number of passengers during peak hours	OC_4
	OC-V	OC_5: Degree of congestion	OC_5
Aviation and fire service level	OS-I	OS_1: Number of police and firefighters to number of take-offs and landings	OS_1, OS_3, OS_8, OS_9
	OS-II	OS_2: Number of police and firefighters to number of airlines	OS_2, OS_5, OS_7
	OS-III	OS_4: Number of police and firefighters to floor area of terminal	OS_4
	OS-IV	OS_6: Number of police and firefighters to the size of the apron	OS_6
Class C Airports			
Employee productivity	OP-I	OP_4: Revenue to number of employees	OP_1, OP_4, OP_6
	OP-II	OP_2: Cargo tonnage to number of employees	OP_2
	OP-III	OP_5: Non-aviation income to number of employees	OP_3, OP_5
Airline service level	OA-I	OA_1: Floor area of terminal to the number of airlines	OA_1, OA_2
	OA-II	OA_6: Service standards of runway	OA_4, OA_6
	OA-III	OA_3: Traffic volume to the number of airlines	OA_3
	OA-IV	OA_5: Traffic volume to the number of routes	OA_5
Passenger service level	OC-I	OC_7: Number of check-in counters to number of passengers	OC_1, OC_3, OC_7
	OC-II	OC_2: Number of airlines to number of passengers	OC_2, OC_6
	OC-III	OC_4: Number of car parks to number of passengers during peak hours	OC_4
	OC-IV	OC_5: Degree of congestion	OC_5
Aviation and fire service level	OS-I	OS_1: Number of police and firefighters to number of take-offs and landings	OS_1, OS_7
	OS-II	OS_2: Number of police and firefighters to number of airlines	OS_2, OS_5
	OS-III	OS_9: Number of aviation controllers to number of routes	OS_4, OS_6, OS_8, OS_9
	OS-IV	OS_3: Number of police and firefighters to number of passengers	OS_3

numbers of airlines and routes that they deal with. Class A and B airports have ratios of traffic volume of their runways to the number of take-offs and landings, while class B and C airports value the service standards of the runways. No airports do well regarding the size of their runways relative to the number of airlines they serve.

Table 7 shows that all classes of airports pay close attention to the degree of congestion, which may be seen

Table 3
The ranking of airports

Class A airports

Aspects	Rank1	Rank2	Rank3
Employee productivity	CKS (0.643)	Taipei (0.357)	Kaohsiung (0.179)
Airline service level	Taipei (0.639)	CKS (0.428)	Kaohsiung (0.139)
Passengers service level	CKS (0.643)	Kaohsiung (0.632)	Taipei (0.266)
Aviation and fire services level	Taipei (0.613)	Kaohsiung (0.439)	CKS (0.356)
Total performance	CKS (0.517)	Taipei (0.475)	Kaohsiung (0.391)

Class B airports

Aspects	Rank1	Rank2	Rank3	Rank4
Employee productivity	Magong (0.860)	Taitung (0.430)	Tainan (0.189)	Hualien (0.164)
Aviation and fire service level	Tainan (0.547)	Magong (0.471)	Taitung (0.223)	Hualien (0.153)
Passengers service level	Taitung (0.930)	Magong (0.606)	Hualien (0.551)	Tainan (0.126)
Airline service level	Hualien (0.764)	Tainan (0.595)	Taitung (0.499)	Magong (0.406)
Total performance	Magong (0.583)	Taitung (0.463)	Tainan (0.399)	Hualien (0.382)

Class C airports

Aspects	Rank1	Rank2	Rank3
Employee productivity	Taichung (0.683)	Chi Mei (0.473)	Chiayi (0.061)
Aviation and fire service level	Chiayi (0.749)	Chi Mei (0.342)	Taichung (0.236)
Passengers service level	Chi Mei (0.508)	Taichung (0.458)	Chiayi (0.443)
Airline service level	Taichung (0.570)	Chiayi (0.466)	Chi Mei (0.398)
Total performance	Taichung (0.537)	Chi Mei (0.448)	Chiayi (0.398)

Note: The numbers in parentheses indicate the relative closeness to the ideal solution.

as an indicator of passenger service standards. Class A and C airports both place an emphasis on the ratio of the number of take-offs and landings and the total number of passengers they process. They also have a high ratio of the number of airlines to the number of passengers using their facilities. Both Class B and C airports have a high ratio of car parking spaces to the number of passengers during peak hours, and the ratio of the number of check-in counters to the number of passengers. In addition, Class A airports tend to offer a large the number of routes given its passenger flow.

Table 8 deals with aviation and fire services. It shows that all classes of airports have high ratios of police and firefighters to the number of airlines they serve class A and B airports exhibit high ratio numbers of police and firefighters to the sizes of their aprons. Class B and C airports have a high ratio of the number of police and firefighters to the number of takes-off and landings while class A and C airports have a high ratio of the number of police and firefighters to the total number of passengers. In addition, Class A airports put an emphasis on the number of police and firefighters to the number of routes served, and the ratio of the number of aviation controllers to the number of take-offs and landings.

Table 4
The priority strategy for improving airport operating efficiency

Class of airport	Airport	Priority recommendation strategy				
		Review the staffing conditions	Review the dispatch of police and firefighters	Increase the proportion of non-aviation income	Enhance passenger satisfaction	Review and allocate the accommodation for each runway
A	CKS		✓			
	Taipei				✓	
	Kaohsiung			✓		✓
B	Ma Kung					✓
	Taitung					✓
	Tainan				✓	
	Hualien	✓	✓			
C	Taichung		✓			
	Kinmen					✓
	Chiayi	✓			✓	

Table 5
Employee productivity indicators for different airports

Code	Name of indicator	Class A	Class B	Class C
OP_1	Number of take-offs and landings to number of employees	✓	✓	
OP_2	Cargo tonnage to number of employees	✓	✓	✓
OP_3	Floor area of terminal building to number of employees		✓	
OP_4	Revenue to number of employees			✓
OP_5	Non-aviation income to number of employees	✓		✓
OP_6	Number of passenger to number of employees	✓	✓	

Table 6
Airline service level indicators for different airports

Code	Name of indicator	Class A	Class B	Class C
OA_1	Floor area of terminal to the number of airlines	✓	✓	✓
OA_2	Size of apron to the number of airlines			
OA_3	Traffic volume to number of airlines	✓	✓	✓
OA_4	Traffic volume to number of take-offs and landings	✓	✓	
OA_5	Traffic volume to the number of routes	✓	✓	✓
OA_6	Runway service standards		✓	✓

Table 7
Passenger service level indicators of different airports

Code	Name of indicator	Class A	Class B	Class C
OC_1	Number of take-offs and landings and number of passengers	✓	✓	
OC_2	Number of airlines to number of passengers	✓		✓
OC_3	Number of flight to number of passengers	✓		
OC_4	Number of car parks to the number of passengers during peak hours		✓	✓
OC_5	Degree of congestion	✓	✓	✓
OC_6	Number of boarding gates to number of passengers	✓	✓	
OC_7	Number of check-in counters to number of passengers		✓	✓

5. Conclusions

The paper has applied the grey relation analysis in the clustering of indicators for an evaluation of the performance of a group of Taiwan's airports. The technique allows a streamlining of the number of indicators used I evaluation and helps to overcome limitations when using a small sample. The relative total

Table 8
Comparing aviation and fire service level indicators of different airports

Code	Name of indicator	Class A	Class B	Class C
OS_1	Number of police and firefighters to number of take-offs and landings		✓	✓
OS_2	Number of police and firefighters to number of airlines	✓	✓	✓
OS_3	Number of police and firefighters to number of passengers	✓		✓
OS_4	Number of police and firefighters to floor area of terminal building		✓	
OS_5	Number of police and firefighters to the number of car parks			
OS_6	Number of police and firefighters to the size of the apron	✓	✓	
OS_7	Number of police and firefighters to number of routes	✓		
OS_8	Number of aviation controllers to number of take-offs and landings	✓		
OS_9	Number of aviation controllers to number of routes			✓

scores method is applied to select the indicators for each group of airports in Taiwan. The results indicate that the total performance and the rating of the airports of all classes differ when examined in the context of several efficiency criteria.

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