PERFORMANCE EVALUATION OF INTERNATIONAL AIRPORTS IN THE REGION OF EAST ASIA

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Abstract: The performance evaluation of airport operation is an important issue for the government. In recent years, there are some research works published for the subject. However, the dimensions considered and the research methods used are not so well developed. We hope to develop a methodology for performance evaluation in airport operations by considering all the relevant criteria.

In this research, the hierarchical structure of evaluating airport performance evaluation problem will be constructed based on four aspects: supply, airline demand, passenger demand and management side.

In selecting the criteria, the gray statistics method has proven effective. In giving the weights of criteria, the FAHP (Fuzzy Analytic Hierarchy Process) will get better results than any other traditional methods. Finally, in the ranking of airport performance, we decide to adopt the TOPSIS and Fuzzy Synthetic Decision approach for the ranking of airport performance.

An empirical study is conducted to demonstrate the effectiveness of the methods proposed. In this study, we select ten major international airports in the East Asia region to rank their performance. They are: Narita International Airport at Tokyo; Kansai International Airport at Osaka; Incheon International Airport at Seoul; Beijing Capital International Airport at Beijing; Hongqiao International Airport at Shanghai; Changi Airport at Singapore; Chek Lap Kok International Airport at Hong Kong; CKS International Airport at Taipei; Bangkok International Airport and Manila International Airport.

The outcome of this study will help us better understand the relative strength and weakness of

an international airport, thus providing useful information for improving its competitive advantage.

Key words: FAHP; Gray Statistics method; TOPSIS; Fuzzy Synthetic Decision

1. BACKGROUND

The performance evaluation of airport operation is an important issue for all governments. In recent years, some research works have been done in this area. However, the dimensions considered and the research methods used for the past researches are not so well developed. We hope to develop a fine methodology for performance evaluation in airport operations by considering all the relevant criteria.

In recent years, due to the strong regional economic development, most of countries in the region of East Asia are eager to build up themselves as an international air route hub for both passenger and cargo operation by constructing their international airports. This competition can also be regarded as a competition between country's government in this region. The result of competition may also influence the development of international aviation industry in the next decade. Therefore, this paper aims to provide a total evaluation model for those international airports in the region of East Asia. The result can be a useful mechanism and information for all governments in this region to evaluate their national competitive advantage.

1.1 Purpose of the research

The aim of this research is to explore the performance evaluation and measurement criteria of airport operation. The main objectives of this research are following:

（1） Base on the literature review, this research intends to explore the factors of influencing airport operation performance and find out the evaluation criteria.

（2） In order to reveal the real operating performance of airport, this research intends to propose a comprehensive methodology of airport performance evaluation.

（3） Due to the past insufficient evaluation research, either can only evaluate parts of quantitative hardware facilities of an airport or is limited to measure the personal experience about an airport's performance, cannot measure the all facets. This research intends to provide a objective analysis by inducting a point of view of macro scope on "control economics".

（4） In differential to the traditional research method, this research intends to adopt fuzzy theory and gray theory into the work of airport performance evaluation in order to provide a better result of evaluation.

1.2 Scope and limitation of the research

（1） This research focuses its main scope on the evaluation of airport service performance and provides an empirical application of results to international airports in the region of East Asia. So, ten major international airports in this region are being selected and

evaluated.

（2） The major ten are: Narita International Airport (TYO); Kansai International Airport at (OSA); Incheon International Airport (SEL); Beijing Capital International Airport (PEK); Hongqiao International Airport (SHA); Changi International Airport (SIN); Chek Lap Kok International Airport (HKG); CKS International Airport (TPE); Bangkok International Airport (BKK) and Manila International Airport (MNL).

（3） According to the literature review, related study on this issue is very insufficient. As a preliminary study, this research may have its own insufficient as well but is still representative into certain extent. This research can also be a fundamental study for the future contingency research.

（4） As to the selection of Delphi group and decision of evaluation criteria, this research is subjective to select proper Delphi group to go on the evaluation.

（5） There are two groups of criteria will be regarded as the “language variables” base on fuzzy theory. They are, first, the qualitative criteria of passenger experience and, second, some data-lack quantitative criteria.

（6） The selection of evaluation criteria is under general consideration and not strictly divided into passenger and cargo. In order to avoid the unnecessary duplicate evaluation, the selection of evaluation criteria will base on the passenger side for its concision.

（7） Due to the insufficient data obtained from Shanghai Pudon International Airport and its shortage of operating time period, this research only selected Hongqiao International Airport instead of Pudon.

2. MEASURING AIRPORT PERFORMANCE

2.1 Evaluating airport’s facilities and services

Yeh (2003) conducted an empirical study on 14 major international airports in the Asia-Pacific region to illustrate how the fuzzy multiattribute decision making approach (Fuzzy MADM Approach) works. His empirical study was designed to evaluate the comparative level of passenger service performance among these 14 airports, and particularly to establish a service benchmark for the Chiang Kai-Shek international airport (TPE) in Taiwan to improve the quality level of its passenger services. In his study, six service attributes use for passenger service evaluation of Asia-Pacific international airports. (As shown in Table 1)

Table 1 Service attributes used for passenger service evaluation of Asia-Pacific international airports

Coding	Service attributes	Performance measures
C1	Comfort	Cleanliness, lighting and congestion level of waiting areas/lounges, and ambience of the airport as a whole
C2	Processing time	Total time required for immigration processing, customs inspection, and luggage claiming
C3	Convenience	Availability/accessibility of washrooms, shops, restaurants, money exchange, cash machines, luggage carts, and courtesy of airport staff

C4	Courtesy of staff	Helpfulness, friendliness and courtesy of airport staff
C5	Information visibility	Clearness and/or frequency of information display for flights, airport facilities, and signposting
C6	Security	Sense of security about airport safety measures and security facilities

The evaluation result of this study provides a guideline for airports to maintain passenger service standards and to identify areas for improvement in specific aspects of their service operations.

Jing (1998) hoped to achieve the following research objectives by inducting an analysis and investigation of facilities and customer satisfaction on 16 domestic airports in Taiwan:

（1） To understand passengers and airport users' expectation on airport facilities and service quality.

（2） To build up service criteria of airport.

（3） To explore the influence of airport service quality for future improvement.

（4） To enhance Total Quality Management (TQM) on each airport and set up TQM's organization culture and characteristics of leadership.

Jing's research divided passenger service quality into two parts: facilities as a hardware criteria and service quality as a software criteria. The designation of questionnaire was also based on thses two parts to investigate passenger's expectation and satisfaction on each service quality item. The hardware items cover the whole process when a passenger entering an airport until the end of leaving. The activities of this process are: entering an airport, service arrangement, waiting and queuing, and leaving. For software items are all about satisfaction: physical facilities, reliability, responsiveness, service manner, and service notion.

The insufficiency of Jin's research is, first, to select the evaluation criteria dependent on his own decision without any adoption of methodology. Second, Jin's research is over-evaluated on some detail service items, and furthermore, his research has insufficiency on evaluation criteria and ordering preference as well.

Institution of Transportation, MOTC, Taiwan, ROC (1998) revealed the study result in its final report of "An analysis of competency and development trend of international airports in the region of Asia and Pacific Rim". This study report investigated the competency of ten major international airports in the Asia and Pacific region including four main dependent variables: "competency of airport's infrastructure", "competency of airport's service quality", "competency of airport's operating strategy", and "competency of political and economic environment". This study finally conducted the research and analysis by adopting AHP (Analytic Hierarchy Process) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution).

Although its valuable information revealed of this study on its evaluation criteria, but the study just simplified the application of methodology is its main shortcoming. Therefore, this research aims to provide a better evaluation methodology and improve the past.

2.2 Modelling airport service quality

Yeh described the level of the functional quality of airport services perceived by passengers is to be assessed subjectively via a survey process. This subjective assessment process is intrinsically imprecise, due to the characteristics of airport services. Hellendoorn (1997) and Zimmermann (1996) has developed a model using fuzzy sets that has proven to be an effective way for formulating decision problems where the information available is subjective and imprecise.

2.3 Selecting evaluation criteria

There are many methods to select evaluation criteria, such as Fuzzy Delphi method, Delphi average point method, gray interrelated method, Gray Statistic method. There are all of disadvantages on themselves. For example, Delphi average point method has bias on criteria weighting. Fuzzy Delphi method is based on the concept of average number so as to be easily influenced by outliers. On the contrary, adoption of Gray Statistics method can diminish the possible influence of outliers. For this reason, this research will apply Gray Statistic method as the selection of evaluation criteria.

2.4 Weighting the criteria

Traditionally, the value of criteria weighting can be obtained not only by the provision of decision maker but also applying some other methodologies, such as mathematic planning method, multi-regression method, direct trade off method, unit weighting method, point allocation, and pairwise comparison method. The AHP method in recent years has been approved which can obtain better research result.

2.5 Total evaluation performance ordering preference

There are many ways to apply on total evaluation performance ordering preference, such as TOPSIS, ELECTRE, Promethee, CHCR fuzzy ordering, and Fuzzy Synthetic Decision. Each of them has different usage. In reviewing their advantage and disadvantage, this research is applying TOPSIS and Fuzzy Synthetic Decision as methods to conduct the total evaluation performance ordering preference.

3. PRELIMINARY SELECTION OF EVALUATION CRITERIA

In reviewing the previous research works related to this issue, most of them focused their evaluation on single facet of airports, such as passenger service quality, facility usage divided into software and hardware, or airport's management and operation. Instead, the major difference and contribution of this paper compared to those previous works is to select 21 evaluation criteria based on four major compositions. They are: supply, airline demand, passenger demand, and supervision. (As shown in Table 2)

Table 2. Preliminary Evaluation Criteria of Airport Operating Performance

Composition	Evaluation Criteria	Description
Supply	Earnings-price ratio＊	Total operating revenue / total operating cost
	Employee performance	Total passenger numbers within a year / employee numbers
	Airport land field size	Total area of airport
	Ground transportation service	Choices of ground transportation service
	Size of parking lot	Area and size of parking lot
	Intensity of passenger demand	Total passenger numbers within a year
	Potentials of passenger demand	Average growth rate of passenger demand
Airline Demand	Size of airside field	Area of airport ramp and maintenance hanger
	Distribution of landing and take off	Numbers of landing and take off within a year
	Regulated degree of airport	Daily operating time
Passenger Demand	Time spend for transit	Average spending time for passenger transit
	Congestion degree	Average meter square of passenger occupation during rush hour
	Waiting time	Average spending time in airport hall
	Walking distance	Average total walking distance in airport hall
	Seating numbers	Total seating numbers / passenger numbers during rush hour
	Comfortableness＊	Comfortableness of visual sense and service manner
	Availability of service＊	Clearness of signs and degree of informationization
Supervision	Navigation facilities	Level of ILS implementation
	Environment protection	Noise pollution during rush hour
	Flight safety＊	Ability of planning and implementation for emergency case
	Neighborhoods connection	Numbers of employee in related industry

＊ represents qualitative criteria and will be analyzed by fuzzy value.

4. A NEW APPROACH: AIRPORT PERFORMANCE MEASUREMENT

For the purpose of testing and verifying the total evaluation framework of this research, the following section will explain each steps of this empirical research including the selection of evaluation criteria, the decision of criteria weighting, and the ordinance of airport's real operating performance.

4.1 Selection of evaluation criteria of airport's operating performance

The above preliminary evaluation criteria are selected by referring related literature review (as

shown in Table 2). However, the major problem of it is short of appropriatization. In order to amend this problem, the data analysis of this research is based on the questionnaire of Delphi group and applying Gray Statistics method to select ideal criteria.

From the collection of Delphi questionnaire, although the importance degree of preliminary evaluation criteria are all being evaluated as above "rather high", this research only selects those criteria nominated with "very high" and "high" degree. The final 16 evaluation criteria (as shown in Table 3) will be applying as the performance evaluation criteria of international airports in this research.

Table 3. Final Evaluation Criteria of Airport Operating Performance

Composition	Evaluation Criteria	Criteria Code
Supply	Earnings-price ratio	C11
	Employee performance	C12
	Airport size	C13
	Ground transportation service	C14
	Potentials of passenger demand	C15
Airline Demand	Size of airside field	C21
	Distribution of landing and take off	C22
	Regulated degree of airport	C23
Passenger Demnad	Congestion degree	C31
	Waiting time	C32
	Walking distance	C33
	Comfortableness	C34
	Availability of service	C35
Supervision	Navigation facilities	C41
	Environment protection	C42
	Flight safety	C43

4.2 Application of fuzzy criteria

As described earlier, so far, there is no single conclusion on weighting performance evaluation criteria of airport. Therefore, this research selects 16 criteria to compose a Delphi questionnaire and send it to question 15 professionals in related fields. The selection of professionals is based on four compositions of evaluation criteria as described in 4.1 earlier. This research also applies Saaty's AHP (1980) method to obtain a contradictory value of weighting. Simultaneously, this research is also applying the concept of triangular fuzzy number in order to obtain the fuzzy weighting value of criteria.

Because of the difference of recognition and position, each decision maker's recognition into the same evaluation result may vary from one to another. Traditional AHP method resolves this problem by using the concept of average number to the integration. However, this can only reveal the possible weighting but showing the whole framework. Hence, this research is applying the concept of triangular function in fuzzy theory, in order to reveal the real

differential situation of objective judgments during evaluation. Table 4 has shown the triangular fuzzy weighting value of each evaluation criteria.

Table 4. Fuzzy Weighting Values of Evaluation Criteria

Criteria Code	Evaluation Criteria	Fuzzy Weighting Numbers
C11	Earnings-price ratio	(0.02, 0.06, 0.09)
C12	Employee performance	(0.02, 0.05, 0.07)
C13	Airport land field size	(0.03, 0.05, 0.09)
C14	Ground transportation service	(0.04, 0.05, 0.07)
C15	Potentials of passenger demand	(0.04, 0.05, 0.09)
C21	Size of airside field	(0.06, 0.09, 0.14)
C22	Distribution of landing and take off	(0.05, 0.08, 0.10)
C23	Regulated degree of airport	(0.06, 0.08, 0.14)
C31	Congestion degree	(0.03, 0.06, 0.09)
C32	Waiting time	(0.04, 0.06, 0.08)
C33	Walking distance	(0.04, 0.06, 0.10)
C34	Comfortableness	(0.04, 0.06, 0.08)
C35	Availability of service	(0.01, 0.06, 0.10)
C41	Navigation facilities	(0.04, 0.07, 0.11)
C42	Environment protection	(0.02, 0.06, 0.8)
C43	Flight safety	(0.05, 0.07, 0.10)

4.3 General evaluation of international airports in the East Asia region

4.3.1 Adjustment of evaluation criteria

Based on the selection of evaluation criteria using Delphi group questionnaire, and according to the definition of this research, 13 criteria of 16 (as shown in Table 2) are belonging to quantitative criteria, and the rest of 3 are qualitative criteria. Because of insufficient data on some quantitative criteria, this research will analyze those quantitative criteria as qualitative criteria in order not to cause the problem of serious bias because of excluding those quantitative criteria. They are extent of congest, waiting and queuing time and distance of steps. As a result, there are 10 quantitative criteria and 6 qualitative criteria to evaluate in this research. The data of 6 qualitative criteria is obtained from the Delphi group questionnaire. Moreover, due to the insufficient secondary data on some selective airports, this research has necessarily and appropriately adjusted partial evaluation criteria as shown in Table 5.

Table 5. Adjusted Evaluation Criteria

Composition	Evaluation Criteria	Definition	Adjusted definition
Supply	Employee performance	Total passenger numbers within a year / employee numbers	Total passenger numbers within a year
Airline Demand	Size of airside field	Area of airport ramp and maintenance hanger	Numbers of passenger aircraft landing
Passenger Demand	Congestion degree	Average meter square of passenger occupation during rush hour	Congestion degree for each passenger's experience during rush hour
	Waiting time	Average spending time in airport hall	Acceptance degree of spending time in airport hall
	Walking distance	Average total walking distance in airport hall	Acceptance degree of walking distance in airport hall
Supervision	Environment protection	Noise pollution during rush hour	Numbers of aircraft landing and take off

＊ represents qualitative criteria

4.3.2 Performance value of qualitative criteria

The qualitative criteria of this research are mainly the extent of passenger experience on "Passenger Demand" side. The analysis of those qualitative criteria is based on the response of Delphi group questionnaire and using language variables to measure the performance value. The application of those 6 qualitative criteria is described in Table 6.

Table 6. Description of 6 qualitative criteria

Composition	Code	Qualitative Criteria	Definition Description
Passenger Demand	C31	Congestion degree	Congestion degree for each passenger's experience during rush hour
	C32	Waiting time	Acceptance degree of spending time in airport hall
	C33	Walking distance	Acceptance degree of walking distance in airport hall
	C34	Comfortableness	Comfortableness of visual sense and service manner
	C35	Availability of service	Clearness of signs and degree of informationization
Supervision	C43	Flight safety	Ability of planning and implementation for emergency case

In measuring the criteria performance value, due to the influence of future uncertainty, the possible achievements of each airport's performance cannot be shown as an appropriate number. Therefore, this research is applying the concept of triangular fuzzy function to show the value of criteria performance.

This research is applying five degree of language variable: “very low”, “low”, “medium”, “high”, and “very high”. Each decision maker answers those questions according to his or her professional knowledge and objectively judges the extent of every language variable within the number scale of 0~100. This also means all the language variables are analyzed by triangular fuzzy number.（As shown in Table 7）

Furthermore, the decision maker may fail to measure all the achievements value of each evaluation criteria, the qualitative criteria value may be partially lack to some airports. Table 8 has shown the result of fuzzy performance value of each qualitative criteria for the ten major international airports in the region of East Asia.

Table 7. The Result of Five Degree of Language Variable

Professional	VL	L	M	H	VH
1	0, 0, 20	20, 30, 40	40, 50, 60	60, 70, 80	80, 100, 100
2	0, 0, 20	21, 31, 40	41, 51, 60	61, 71, 80	81, 100, 100
3	0, 0, 29	30, 40, 49	50, 60, 69	70, 77, 84	85, 100, 100
4	0, 0, 49	50, 65, 79	80, 85, 89	90, 93, 95	95, 100, 100
5	0, 0, 59	60, 65, 69	70, 75, 79	80, 85, 89	90, 100, 100
6	0, 0, 20	21, 31, 40	41, 51, 60	61, 71, 80	81, 100, 100
7	0, 0, 15	16, 26, 35	36, 51, 65	66, 76, 85	86, 100, 100
8	0, 0, 20	21, 35, 49	50, 55, 59	60, 70, 80	81, 100, 100
9	0, 0, 20	20, 30, 40	40, 50, 60	60, 70, 80	80, 100, 100
10	0, 0, 19	21, 35, 49	40, 50, 59	60, 70, 79	80, 100, 100

Table 8. Average Number of Each Airport’s Qualitative Criteria

Airport	C31	C32	C33	C34	C35	C43
CKS International Airport	67,76,84	48,56,64	47,53,63	48,56,64	49,58,67	53,62,69
Narita International Airport	35,46,55	58,66,74	48,58,66	60,70,78	68,78,85	71,82,88
Kansai International Airport	44,54,63	58,66,74	62,72,82	71,81,87	74,85,91	71,82,86
Chek Lap Kok International Airport	21,31,47	65,74,84	46,55,66	61,71,77	61,68,78	68,78,86
Bangkok International Airport	52,62,70	59,64,72	41,52,61	45,54,61	45,55,64	47,57,64
Changi International Airport	32,40,51	51,61,69	62,71,81	51,59,67	48,57,66	61,69,77
Incheon International Airport	45,54,62	51,61,69	62,71,81	51,59,67	48,57,66	61,69,77
Hongqiao International Airport	54,63,72	44,54,63	59,68,76	43,53,62	43,53,62	42,51,54
Beijing Capital International Airport	60,70,78	52,54,62	60,69,78	34,45,54	44,53,61	42,51,54
Manila International Airport	47,55,68	40,51,61	56,66,76	30,40,53	34,44,58	36,46,59

4.4 Total evaluation method Ⅰ – FSD

4.4.1 Standardization and direction modification

Before realized the total objective synthetic decision, there are two things to be sorted out -- standardization and direction modification to each criteria's fuzzy performance value. The purpose of standardization is to diminish possible bias by creating the same measurement unit for each criteria according to its characteristic qualitative or quantitative. For each qualitative criteria, this research standardizes the criteria's performance value by applying the largest number scale 100. For each quantitative criteria, this research standardizes the criteria by applying the largest fuzzy value of each selected airport.

Within all the performance evaluation criteria, some of them are positive in operating benefit; others are negative in operating cost. Therefore, before the total objective performance value can be obtained, it is necessary to modify some criteria's direction in order to acquire the same direction in its fuzzy performance value. To modify these criteria, the triangular fuzzy number（1,1,1）can be used to deduct the modified criteria. For example, if the cost criteria is （a,a,a）, it can be modified as benefit criteria（1-c,1-b,1-a）.

4.4.2 Synthetic decision

Based on the fuzzy weighting values（as shown in Table 3）and the obtained fuzzy performance value of each airport under evaluation criteria, the final fuzzy synthetic decision can be conducted. In mathematical way, the calculation of fuzzy synthetic decision includes fuzzy multiplication and fuzzy plus. In general, because the calculation of fuzzy multiplication is very complicated, the approximate value of it is popular being used.（Kaufmann and Gupta, 1988）Based on this method, the approximate fuzzy value of each airport under fuzzy synthetic decision can be obtained.（As shown in Table 9）

Table 9. Fuzzy Synthetic Decision Values of Each Airport

Airport	Fuzzy Synthetic Decision Values
CKS International Airport	0.326796, 0.586659, 0.947908
Narita International Airport	0.348909, 0.621756, 0.990362
Kansai International Airport	0.379593, 0.658368, 1.053751
Chek Lap Kok International Airport	0.376212, 0.668745, 1.063088
Bangkok International Airport	0.330336, 0.576632, 0.934538
Changi International Airport	0.421130, 0.732374, 1.159075
Incheon International Airport	0.346597, 0.591796, 0.949911
Hongqiao International Airport	0.301068, 0.533381, 0.892385
Beijing Capital International Airport	0.334634, 0.583033, 0.946282
Manila International Airport	0.283548, 0.500150, 0.832225

4.4.3 Total ordering preference

As shown in Table 8, the result of applying fuzzy synthetic decision is to obtain a fuzzy values, it is difficult to compare each other in its ordering preference. Therefore, the fuzzy ordering method must be applied in order to undergo the ordering preference to each airport

and to defuzzify（defuzzification）the obtained fuzzy value. Based on the "Gravity Rule" of fuzzy value ordering, the procedure of defuzzification can be simplified without any decision bias. So, this research applies the "Gravity Rule" to obtained each airport's defuzzified values. As to the defuzzified values D_{Fi} of fuzzy synthetic decision can be obtained from formula（1）, the result is shown in Table 10.

$$DFi = （URi + MRi + LRi）/ 3, \quad （1）$$

DFi：Defuzzification Vaule

URi：the maximum value of triangular fuzzy number

MRi：the average value of triangular fuzzy number

LRi：the minimum value of triangular fuzzy number

Table 10. The Defuzzification Vaule and Ordering Preference of Each Airport

Airport	Triangular Fuzzy Number			Defuzzification	Ordering
CKS International Airport	0.32679	0.58665	0.94790	0.293658	5
Narita International Airport	0.34890	0.62175	0.99036	0.304767	4
Kansai International Airport	0.37959	0.65836	1.05375	0.317644	3
Chek Lap Kok International Airport	0.37621	0.66874	1.06308	0.32646974	2
Bangkok International Airport	0.33033	0.57663	0.9345	0.2834996	7
Changi International Airport	0.42113	0.73237	1.15907	0.349729	1
Incheon International Airport	0.34659	0.5917	0.94991	0.28283776	8
Hongqiao International Airport	0.30106	0.53338	0.89238	0.27454333	9
Beijing Capital International Airport	0.33463	0.58303	0.94628	0.28668219	6
Manila International Airport	0.28354	0.50015	0.83225	0.25510325	10

4.5 Total evaluation method Ⅱ - TOPSIS

In this section, the TOPSIS method is applying to compare with fuzzy synthetic decision as described in 4.4.3.

TOPSIS total ordering method is different from fuzzy synthetic decision in modifying direction of negative criteria. Among these differences, the standardization and direction modification of criteria is managed in the last ordering stage at the same time with those negative criteria of quantitative criteria in order to obtain a better ordering result.

4.5.1 Defuzzification value of qualitative criteria performance

If taking the O's distance as a norm, the ideal solution of this research is as being closest the ideal solution as better. By applying TOPSIS method, it is necessary to distinguish the "Ideal Solution" and "Negative-ideal Solution". However, if taking the measurement criteria as fuzzy value, the Hamming Distance can be uses for calculation.

This research includes two kinds of criteria – qualitative and quantitative. For those quantitative criteria, it is already obvious in numbers so as no need to transform. For those qualitative criteria, the "Gravity Rule" is applied to defuzzify. Once defuzzification value of each airport's qualitative criteria is obtained, the operating performance ordering of each airport can be obtained by using the TOPSIS method's formula to calculate and standardize each evaluation criteria value. Finally, each criteria is analyzing in weighting after entering each criteria's weighting（AHP weighting value）. Table 10 shows the final result of total ordering preference of all airports.

4.5.2 Analysis and discussion of the result

（1） From supply side

Due to the newly opening of Chek Lap Kok International Airport in Hong Kong since July 6th, 1998, the airport itself and its hardware facilities possesses the leading ordering preference in supply side. The second best is Beijing Capital International Airport. Changi International Airport in Singapore is placed the third, and CKS International Airport in Taipei is the fourth due to its high ROE.

（2） From airline demand side

The composition of performance value in terms of airline demand side of each airport is the most concerned issue for every operating airline. In this composition, Changi International Airport wins the leading ordering preference. Manila International Airport is the second leading one. Kansai International Airport in Osaka is the third, and Beijing Capital International Airport is the fourth.

（3） From passenger demand side

From passenger demand side, the ordering preference of leading three is: Changi International Airport, Kansai International Airport, and Chek Lap Kok International Airport.

（4） From government supervision side

Among all three criteria of government supervision side, Kansai International Airport is evaluated as in the leading ordering preference that its performance value is the highest one (> 0.9, the full score is 1). Narita International Airport is in the second leading position. Chek Lap Kok International Airport possesses the third leading position for its brand-new facilities on airport navigation, environment protection, and flight safety.

Table 11. Final Result of Total Ordering Preference of All Airports

Composition	Evaluation Criteria	Standardization analysis for criteria value										AHP W.
		TPE	TYO	OSA	HKG	BKK	SIN	SEL	SHA	PEK	MNL	
Supply	Earnings-price ratio	1	0	0.0526	0.258	0.2768	0.141	0.1143	0.5647	0.5647	0.1403	0.0536
	Employee performance	0.3629254	0.7557	0.1459	1	0.4733	0.8803	0.3233	0.2203	0.3966	0	0.04874
	Airport land field size	0.6192434	0.21628	0.0526	0.6587	0.1431	1	0.2341	0	0.4219	0.1513	0.04918
	Ground transportation service	0	0.5	1	0.5	0.5	0	0.5	0	0	0	0.05371
	Potentials of passenger demand	0.173333	0	0.68	0.2267	0.3333	0.26	0.768	1	0.8733	0.5933	0.05787
	Composition performance weighting analysis	0.111814	0.0743327	0.1055897	0.134956	0.091105	0.114703	0.104706	0.098900	0.120911	0.049306	
	Ordering	4	9	5	1	8	3	6	7	2	10	
Airline Demand	Size of airside field	0.1607143	0.64286	0.3571	0.4464	0.3571	1	0.125	0	0.125	0.0179	0.09215
	Distribution of landing and take off	0.001795	0.20761	0.1117	0.5096	0.073	0.5822	1	0	0.2872	0.599	0.07554
	Regulated degree of airport	1	0	1	0	1	1	0	1	1	1	0.09166
	Composition performance weighting analysis	0.106604	0.074919	0.133007	0.079634	0.124008	0.227782	0.087057	0.091659	0.124872	0.138555	
	Ordering	6	10	3	9	5	1	8	7	4	2	
Passenger Demand	Congestion degree	0	0.71875	0.5156	1	0.3359	0.8125	0.6484	0.2969	0.1484	0.4453	0.05942
	Waiting time	0.3802817	0.64789	0.6479	1	0.6056	0.831	0.3099	0.1268	0.2254	0	0.0551
	Walking distance	0.1451613	0.29032	1	0.2097	0	0.8548	0.7581	0.7903	0.8548	0.7097	0.06715
	Comfortableness	0.4225252	0.70423	0.9225	0.7113	0.3662	1	0.4437	0.3521	0	0.1056	0.05464
	Availability of service	0.3333333	0.83333	1	0.6228	0.2456	0.9298	0.2018	0.193	0.193	0	0.05603
	Composition performance weighting analysis	0.091606	0.204	0.239925	0.202360	0.107101	0.285207	0.142055	0.091109	0.069455	0.079890	
	Ordering	7	4	2	3	6	1	5	8	10	9	
Supervision	Navigation facilities	1	1	1	1	1	1	1	0	1	0	0.06692
	Environment protection	1	0.71429	0.9048	0.619	0.7143	0.2857	0	0.9048	0.6667	0.9524	0.04784
	Flight safety	0.60	1	0.98	0.91	0.27	1	0.66	0.31	0.06	0	0.0704
	Composition performance weighting analysis	0.145032	0.171488	0.179193	0.160596	0.120099	0.150985	0.113381	0.065108	0.103037	0.045563	
	Ordering	5	2	1	3	6	4	7	9	8	10	
General	RC value	0.47	0.49	0.60	0.53	0.44	0.69	0.45	0.41	0.46	0.39	
	General total ordering	5	4	2	3	8	1	7	9	6	10	

（5） From total ordering preference side

This research applies the TOPSIS method to calculate the distance to its ideal solution of all airports in order to obtain the total operating performance value. As a result, the first three leading airports in total ordering preference is: Changi International Airport, Kansai International Airport, and Chek Lap Kok International Airport. The rest of ordering preference is shown in Table 11.

4.6 General analysis

Table 12 shows the comparison result of two different evaluation methods – FSD and TOPSIS in total ordering preference.

Table 12. The Comparison Result Between FSD and TOPSIS

Ranking	Fuzzy Synthetic Decision	TOPSIS
1	Changi International Airport	Changi International Airport
2	Chek Lap Kok International Airport	Kansai International Airport
3	Kansai International Airport	Chek Lap Kok International Airport
4	Narita International Airport	Narita International Airport
5	CKS International Airport	CKS International Airport
6	Beijing Capital International Airport	Beijing Capital International Airport
7	Bangkok International Airport	Incheon International Airport
8	Incheon International Airport	Bangkok International Airport
9	Hongqiao International Airport	Hongqiao International Airport
10	Manila International Airport	Manila International Airport

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From Table 13, there is no big difference between these two evaluation methods. However, the only difference is placed on Chek Lap Kok International Airport and Kansai International Airport, Incheon International Airport and Bangkok International Airport for their different ordering preference. Table 13 shows the similarity and difference between these two methodologies' application – FSD and TOPSIS.

Table 13. The Similarity and Difference of Methodologies' Application between FSD and TOPSIS

	Fuzzy Synthetic Decision	TOPSIS
Weighting	Fuzzy weighting	AHP weighting
Criteria Application	Turning all the quantitative criteria into triangular fuzzy numbers	Turning all the qualitative criteria's triangular fuzzy number into physical numbers based on the "Gravity rule"
Ordering Principle	the obtained fuzzy performance value of each airport is shown by the approximate value of it. Based on this method, the approximate fuzzy value of each airport under fuzzy synthetic decision can be obtained.	Timing AHP weighting after standardized all the criteria, taking the O's distance as a norm, the ideal solution of this research is as being closest the ideal solution as better. By applying TOPSIS method, it is necessary to distinguish the "Ideal Solution" and "Negative-ideal Solution".
Ordering Result	Based on the "Gravity Rule", the fuzzy ordering method must be applied in order to undergo the ordering preference to each airport and to defuzzify（defuzzification）the obtained fuzzy value.	Based on the RC value, all ideal solutions' preference ordering can be decided.
Recommendation	All the evaluation criteria are qualitative.	All the evaluation criteria are quantitative.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

There are many factors to influence operating performance of airports. In practice, these factors make airport's decision maker environmentally to face some uncertainty and fuzziness. This research applies gray theory and fuzzy theory to conduct the empirical study. The following section concludes the research result from deduction of methodology and application of the empirical study.

5.1.1 Deduction of methodology

（1） In order to present the real operating performance of each selected airport, this research first reviews past related literature and concludes four major compositions to develop evaluation criteria. These four major compositions cover all concerned issues related to an airport's daily operation by all beneficial groups. These four major compositions are: "supply", "airline demand", passenger demand", and "government supervision".

（2） Due to the difficulties to cover all the related issues when selecting the performance evaluation criteria, and to manage some qualitative criteria into manageable, this research applies fuzzy AHP method to avoid the possible conflict among different

criteria. The application of fuzzy theory also can manage the uncertainty during evaluation.

（3） This research applies Fuzzy Synthetic Decision and TOPSIS to analyze both qualitative and quantitative criteria simultaneously. The result of evaluation between these two methodologies shows no big difference and provides valuable reference for future further study.

5.1.2 Application of the empirical study

（1） Due to the too wide consideration on all related issues when evaluating airport's operating performance, insufficiency for past research is either selecting partial criteria or some quantitative criteria to conduct the evaluation. As a result, some serious biases are produced. This research adopts all-facet criteria based on the improvement of methodology so as the result is more valuable in reference in terms of research structure and evaluation criteria.

（2） This research can tell from the result that most of study airports are seriously insufficient to their operating facilities. When analyzing the qualitative criteria of passenger experience, the satisfaction of most airports is averagely low. The result provides valuable information to all governments to pay more attention to improve their airport's facilities.

（3） Due the limitation to improve some criteria in supply side shortly（such as size or scale of an airport）, this research recommends airport's decision maker to improve some heavy weighting criteria in passenger demand side so as to enhance its competency power and draw up passenger's satisfaction.

5.2 Recommendation

（1） The main purpose of this research is to provide a comprehensive and applicable procedure in airport's performance evaluation. However, the major limitation of this research faces to the difficulties in data searching and the different extent of data provision by different country government. Especially in passenger demand side, it is impossible to adopt traditional way to design a questionnaire to undergo an investigation at each airport. In order to obtain a better result and solution, this research applies an analysis of fuzzy theory by designing a Delphi questionnaire. The first recommendation to further study places on the investigation of customer satisfaction in detail.

（2） Due to the limitation in time and finance, this research only conducts a Delphi questionnaire and has no others, such as passenger and travel agent. The second recommendation for future study is to conduct a all-facet investigation.

（3） Although the "language variables" is being used more and more popular, the third recommendation of this research suggests that a developing and innovating qualitative research method can be designed in the future study.

（4） Factors influencing airport's operating performance are always changeable because of time and decision maker's managerial notion, the fourth recommendation of this research suggests future researcher have a good control in updated information in operating information.

（5） As to TOPSIS method, the final recommendation of this research suggests to apply fuzzy TOPSIS method in the future study in order to well analyze qualitative criteria.

（6） In China, since Shanghai Pudon International Airport has replaced Hongqiao as city's

major international air hub in October 2002, this research suggests that future researches related to this issue can consider Pudon's new role in playing as a major regional air route hub in the near future.

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