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Airline Performance Challenge: Big Data Analysis and Resource Allocation Optimization for The Eva Air

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Keywords

Importance-performance analysis
decision analysis
airline performance improvement
resource allocation

Abstract.

The purpose of this study is to provide routes layout and investment strategy for airline industry through the performance analysis of routes. It is important to assist the decision-makers in reviewing performance immediately and adjusting the resources in the case of large-scale airline business and limited resources. Five issues may be encountered in analyzing the route operations: (1) immediately present the operation status of each route, (2) figure out which routes are profitable or unprofitable, (3) figure out which routes are vital and needed to improve immediately, (4) the priorities of routes improvement, (5) the amount of money invested in routes improvement. This study establishes a three-dimensional routes visual instrument panel by important performance analysis (IPA) to review the performance of routes and evaluate the needs for investment and improvement. Furthermore, the establishment of a resource allocation model determines the order of improvement priority. This study selects EVA Air as an example and simulates three scenarios that can provide the results to airlines as a reference for upcoming planning and execution.

1. Introduction

Taiwan has an important geographical advantage in the aviation industry. After the government promulgated the "Open Sky Policy" in 1987, the civil aviation industry was opened for application. Recently, the civil aviation industry of Taiwan has performed well in the international aviation market. Skytrax's ranking of the top 100 best airlines in the world in 2021 shows that EVA Air ranked seventh in the highly competitive international market, representing that services provided by EVA Air are recognized by consumers [22].

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At the same time, Taiwan and several countries have implemented visa-free concessions. Furthermore, because of the rise of the low-cost airline industry trying to divide the market, the aviation industry has become more competitive than before. In response to changes in the environment, EVA Air joined the Star Alliance in 2013, hoping to reduce the company's overall operating costs through the alliance's resource sharing. Strategic alliances belong to the external resource allocation and integration of airlines. For the long-term development of EVA Air, there are bound to be lots of investment projects that need to be implemented. When decision-makers are facing the huge scale of airlines, they will face the following problems: (1) immediately present the operation status of each route, (2) figure out which air routes are profitable or unprofitable, (3) figure out which air routes are vital and needed to improve immediately, (4) the priorities of the air routes after closing down other routes, (5) the amount of money invested in routes improvement. Therefore, this study uses these five questions to analyze the airline's route performance and further optimize the allocation of resources.

The competitive pressure of the aviation industry is increasing sharply [12]. Huang et al. [9] believed that performance evaluation of the aviation industry is one of the most important ways to help airlines improve their operational efficiency. Feng and Wang [6] mentioned that most studies related to airline performance evaluation only consider passenger load and ignore financial indicators that affect airline survival. Yu et al. [27] pointed out that joining the airline alliance will reduce the operating performance of airlines, which is the result of the incomplete integration of resources within the alliance. It should reduce waste and strengthen internal integration and planning. Pineda et al. [19] mentioned that decision-makers in airlines need a tool that can identify, diagnose, and evaluate the performance of operations of the company and that it can prioritize assessment projects. Sakthidharan and Sivaraman [20] believed that airline operating cost is an important factor affecting the maximization of airline operating efficiency. Dincer et al. [4] pointed out that revenue capability is an important key to improving airline performance. This study believes that the most important part of performance evaluation is to provide concrete and substantial solutions for decision-makers. In addition to understanding what causes inefficiencies, how much resources should be provided to decision-makers to improve, and whether the improved operating performance has grown. Huang et al. [7] believed that airlines can improve their operational performance if they are in control of the operating costs.

Martilla and James [26] pointed out that Importance-Performance Analysis (IPA) is a low-cost and straightforward analysis technique. We can get the meaning of each attribute from a simple two-dimensional quadrant diagram, so that the company understands which attributes need to be maintained, which attributes require resource investment, and which attributes have excessive resource investment, in order to provide effective decision-making for the enterprise. Azzopardi and Nash [1] mentioned that IPA is a tool for diagnosing decisions, helping to prioritize improvements, and allocating limited resources where they are really needed to increase competitive advantage. Lai and Hitchcock [11] established three-dimensional IPA, which provides more improvement strategies to decision-makers than two-dimensional IPA. Nam and Lee [17] believed that IPA is a simple and widely used tool and used IPA for performance evaluation in the aviation industry. Rosario et al. [5] thought IPA is a tool to help decision-makers make decisions about investment allocation and also to enhance competitiveness. From the above literature, we can know that IPA is a simple and important tool for enterprises. The biggest function of IPA is to understand its own advantages and disadvantages, and it can clearly understand where urgent resources are needed to improve and whether there are excessive investments and waste in the case of limited resources.

Bieblich et al. [3] mentioned that the internal structure of each airline is different, so it was discussed how to evaluate profitability and fare allocation from the perspective of cost accounting. Kyparisis and Koulama [10] discussed how several European airlines will face the problem of seat allocation in two classes when purchasing new aircraft. Ma et al. [15] made the configuration of the aircraft model and size for each route under the multi-target situation of minimizing greenhouse gas emissions and maximizing operating income. Wang et al. [13] established a dynamic planning model, worked out the best fares, and allocated the appropriate number of sellable tickets to different sales channels. Wojahn [24] mentioned that many factors cause the aviation industry to overinvest, overcapacity, and low profitability. Airlines should review these issues and reallocate the amount of investment to maintain competitiveness. The resources are bound to be limited in every enterprise, so it is necessary to check its own resource utilization at any time. Then find out the priority of improvement and re-allocate resources to achieve greater operational performance. Pineda et al. [18] mentioned that the key point of airline management is to evaluate and use available resources. Huang [8] considered airline operating costs as the most important factor for making a resource allocation strategy for the airline. Akshara et al. [1] believed that it is more important to properly allocate resources and review operational performance in order to restore the viability of airlines.

Resource allocation has become one of the hottest topics and important issues [16]. How to enable airline decision-makers to understand the operating status of all routes in real-time under the huge scale operation, and adjust the resources to achieve the optimal resource allocation under limited resources is the problem to be solved in this research. Therefore, the purposes of this study are as follows: (1) based on all routes of EVA Air, a three-dimensional IPA is established to assist airlines in understanding the operating status of each route, (2) through the three-dimensional IPA formed by significance, passenger load, and revenue-to-cost ratio, it helps decision-makers decide which routes should be prioritized for investment improvement, (3) based on past historical data, forecast the budget demand for the next year, and help airlines find a resource allocation combination that improves the overall revenue-to-cost ratio, (4) this study proposes EVA Air's assumptions in three different scenarios as follows: (i) limited resources investment, (ii) unlimited resources investment, (iii) additional resource investment. To simulate the air routes operation under three scenarios and provide the results to airlines as a reference for upcoming planning and execution.

The remainder of this paper is organized as follows: Section 2 provides our proposed model. In Section 3, EVA Air is applied and examined according to the proposed approach. Section 4 discusses and analyzes our findings from different perspectives. Finally, the research draws conclusions in Section 5.

2. Methodology

This study collected the flight information for each year through the Civil Aviation Administration and then collected the annual cost investment situation from EVA Air's annual report and financial report. Then sorted out the above data and calculated the significance of each route and the revenue-to-cost ratio. This study established a three-dimensional IPA so that decision-makers can easily and clearly identify the operating status of each year, and then analyze the distribution of routes in different quadrants to find routes that should be improved. Meanwhile, this study established a resource allocation model based on the collected data, including a cost estimation model and a priority ranking model. The cost estimation model can find a reasonable investment portfolio for the next year, and the priority ranking model is to prioritize the routes to be improved. Finally, resource allocation is performed through three resource scenarios that are provided to decision-makers as a reference basis for decision-making.

2.1. Data collection

This study collected data from the Civil Aviation Administration from 2003 to 2019 for a total of 17 years, including flight frequency, the number of seats provided, the number of passengers, passenger load, market share, mileage, and flight time for each route on each year, as shown in Table 1.

Table 1: Flights data of EVA AIR for each route in 2019.

Route	Brisbane	Osaka	Seattle	Paris
Flight Frequency (Times)	431	3,496	884	647
Number of Seats Provided	137,271	884,862	307,132	218,781
Number of Passengers	116,858	751,126	259,155	194,941
Passenger Load	85.13%	84.89%	84.38%	89.10%
Market Share	38.35%	22.91%	100%	100%
Total of Mileage (Km)	2,910,974	5,981,656	8,618,116	6,152,970
Total of Flight Time (Minutes)	228,430	594,320	623,220	514,365

This study also collected two financial-related data of annual revenue and operating costs from EVA Air's annual report and financial statements. The operating revenue is divided by continents, as shown in Table 2.

Table 2: The operating Revenue of EVA AIR in 2019. (Unit: Million)

Revenue Category	America Line	Europe Line	Asia Line	Oceania Line	Total
Passenger Operations Revenue	39,386	11,516	48,628	1,093	100,623
Cargo Operation Revenue	16,079	2,660	6,548	92	25,379
Other Revenue	4,234	1,082	4,212	90	9,618
Total Revenue	59,699	15,258	59,388	1,275	135,620

The operating costs are expressed as total costs, as shown in Table 3. The air freight cost is including the cost of cabin crew, fuel, insurance, depreciation, and rent. The airport operation cost is including the cost of using the airport, ground crew, and other costs related to taking off and landing. The traveler service cost is including the cost of supplies and insurance for travelers. The maintenance cost is including the cost of maintainers and materials for maintenance.

Table 3: The operating costs of EVA AIR in 2019. (Unit: Million)

Air Freight Cost	Airport Operating Cost	Traveler Service Cost	Maintenance Cost	Other Cost	Total Cost
69,408	15,794	17,344	10,574	4,358	117,478

2.2. Data processing

Since it is not easy to obtain the information required by the Institute directly from EVA Air's annual report and financial statements, this study assigned each cost and revenue to each route in a reasonable way according to different proportions [21, 23]. Among them, the factor affecting the cost of air freight is the mileage of each flight; the factor affecting the cost of airport operating is the number of flights; the factor affecting the cost of traveler service is the number of passengers; the factor affecting the maintenance cost is the flight time; the factor affecting operating revenue is the number of passengers. Since other cost are defined by EVA Air, there is no basis for dividing this cost into each route, so this study assumed that the factor affecting other cost is flight time. Because it is not possible to know the ticket price for each route from operating revenue, this study assumed that the ticket price for routes that fall on the same continent are the same.

2.3. Three-dimensional importance-performance analysis

This study selected the significance, passenger load and revenue-to-cost ratio as the three dimensions of IPA. When a decision-maker wants to identify the operating status of each route, the performance of each route can be determined from these three operating indicators.

(1) Significance

This study believes that the importance of each route must consider both external and internal factors: market share and internal share of EVA Air. The formula for calculating the market share of a route is as Eq. (2.1); the formula for calculating the internal share of a route is as Eq. (2.2); the formula for calculating the importance of a route is as Eq. (2.3).

$$MS_i = \frac{TPS_i}{\sum_{k=1}^{m} TPS_{ik}} \tag{2.1}$$

where MS_i is the market share of route i; TPS_i is the total number of seats provided in the current year of route i; TPS_{ik} is total number of seats provided in the current year of airline k of route i ($k = 1, 2, \ldots, m$).

$$IS_i = \frac{TPS_i}{\sum_{i=1}^{n} TPS_i} \tag{2.2}$$

where IS_i is the internal share of route i; $\sum_{i=1}^{n} TPS_i$ is the total number of seats provided for all routes in the year.

$$\text{Significance}_i = MS_i \times IS_i \tag{2.3}$$

(2) Passenger load

The passenger load is based on statistics from the Civil Aviation Administration, which divides the number of passengers by the number of seats provided.

(3) Revenue-to-cost ratio

Revenue-to-cost ratio is the operating revenue divided by operating costs. Operating cost is defined by EVA Air, including air freight cost, airport operating cost, traveler service cost, maintenance cost, and other cost. Therefore, this study evaluated the operating status of each route of EVA Air through this formula to understand whether the route is profitable or unprofitable. The calculation formula of revenue-to-cost ratio is shown in Eq. (2.4).

$$RC_i = \frac{R_i \times TN_i}{AC_i + AOC_i + TC_i + MC_i + OC_i} \tag{2.4}$$

where RC_i is the revenue-to-cost ratio of route i; R_i is the ticket price of route i; TN_i is the number of passengers of route i; AC_i is the air freight cost of route i; AOC_i is the airport operating cost of route i; TC_i is the traveler service cost of route i; MC_i is maintenance cost of route i; OC_i is other cost of route i.

2.4. Resource allocation model

This study established a cost estimation model based on the historical operating data of EVA Air in the past, and predicted the operating costs and revenue for each route in the next year. And used Mean Absolute Percentage Error (MAPE) to check whether the estimation model established by this research is accurate and reasonable. If the airline has an additional budget for investment in the current year, this study will use the analysis results of IPA to allocate resources under the condition that the revenue-to-cost ratio of each route is maximized.

Based on the past historical data, this study established a reasonable estimation model based on past historical data. Then used the two-period moving average method to make the MAPE the minimum, and checked whether the prediction is accurate according to the meaning represented by the MAPE proposed by Lewis [14]. As shown in Table 4.

When airlines budget additional budgets, it is necessary to find out which routes are the primary investment targets. Therefore, this study divided all routes into three groups. The routes in Group 1 are already profitable, so no additional investment in resources is required. The routes in Group 2 are unprofitable currently, but the routes can be improved without too many resources and bring the routes of this group to

Table 4: MAPE criteria for model evaluation.

MAPE	$< 10\%$	$10\% - 20\%$	$20\% - 50\%$	$> 50\%$
Accuracy	Excellent	Good	Reasonable	Not Accuracy

breakeven. Therefore, this study calculated the amount of investment required for the route to achieving breakeven and displayed the change in passenger load and revenue-to-cost ratio after investment. Group 2 is the priority improvement area, and the routes of this group are improved in order of significance. The routes in Group 3 are unprofitable currently, but the difference from Group 2 is that, if the airline has successfully sold all seats, it still can't reach breakeven. The routes in this group must wait until all the routes in Group 2 have been improved, if there are still remaining funds, they will be improved in order of significance to minimize the overall loss of the airline. Here are the steps to prioritize:

Step 1. Calculate the maximum revenue-to-cost ratio for each route

In order to understand how to maximize the overall profit, how much money must be invested. This study calculated the maximum revenue-to-cost ratio for each route, and the calculation formula is shown in Eq. (2.5).

$$RC\_\max_i = \frac{R_i \times TPS_i}{AC_i + AOC_i + (UTC_i \times TPS_i) + MC_i + OC_i} \tag{2.5}$$

where $RC\_\max_i$ is the maximum revenue-to-cost ratio of route i; UTC_i is unit of traveler service cost of route i.

Step 2. Divide all routes into three groups

This study divided all routes into three groups: (1) the routes that have been balanced, (2) the routes that are not balanced yet but will be profitable after investment, (3) the routes that are not balanced yet, but will still be unprofitable after investment

Step 3. Prioritize routes that need improvement

In this study, significance is used as the basis for ranking. Therefore, the routes of Group 2 and Group 3 are ranked by significance respectively, which is the order of investment improvement.

Step 4. Calculate the amount of investment required

Calculate the amount of investment required for the route of Group 2 in order to achieve a break-even, that is, the revenue-to-cost ratio is 1. The formula is shown in Eq. (2.6).

$$NTN_i = \frac{AC_i + AOC_i + MC_i + OC_i}{R_i - UTC_i} \tag{2.6}$$

where NTN_i is the number of passengers required when the revenue-to-cost ratio of routes i is 1. Then calculate the amount of investment required when the revenue-to-cost ratio is 1. The calculation formula is shown in Eq. (2.7).

$$IC_i = (NTN_i - TN_i) \times UTC_i \tag{2.7}$$

where IC_i is the amount of investment required for routes i. For the route of Group 3, the revenue-to-cost ratio is still less than 1 when the service is maximized. Therefore, calculate the amount of investment required to reach the maximum revenue-to-cost ratio, and the calculation formula is as Eq. (2.8).

$$IC_i = (TPS_i - TN_i) \times UTC_i \tag{2.8}$$

3. Example

This study uses EVA Air as a case study. We collected data for each route from 2003 to 2019 and incorporated it into the resource allocation model established by this research. Three scenarios are discussed and analyzed: limited resource investment, unlimited resource investment, and additional resource investment. The following uses 2019 data as an example.

3.1. Three-dimensional Importance-performance analysis

EVA Air has a huge operating scale, this study converts the three-dimensional view into a three aspect of two-dimensional view so that decision-makers can easily identify whether there are problems with each route and find out which routes need to be improved immediately. The IPA of significance v.s. passenger load is shown in Figure 1. The IPA of significance v.s. revenue-to-cost ratio is shown in Figure 2. The IPA of passenger load v.s. revenue-to-cost ratio is shown in Figure 3.

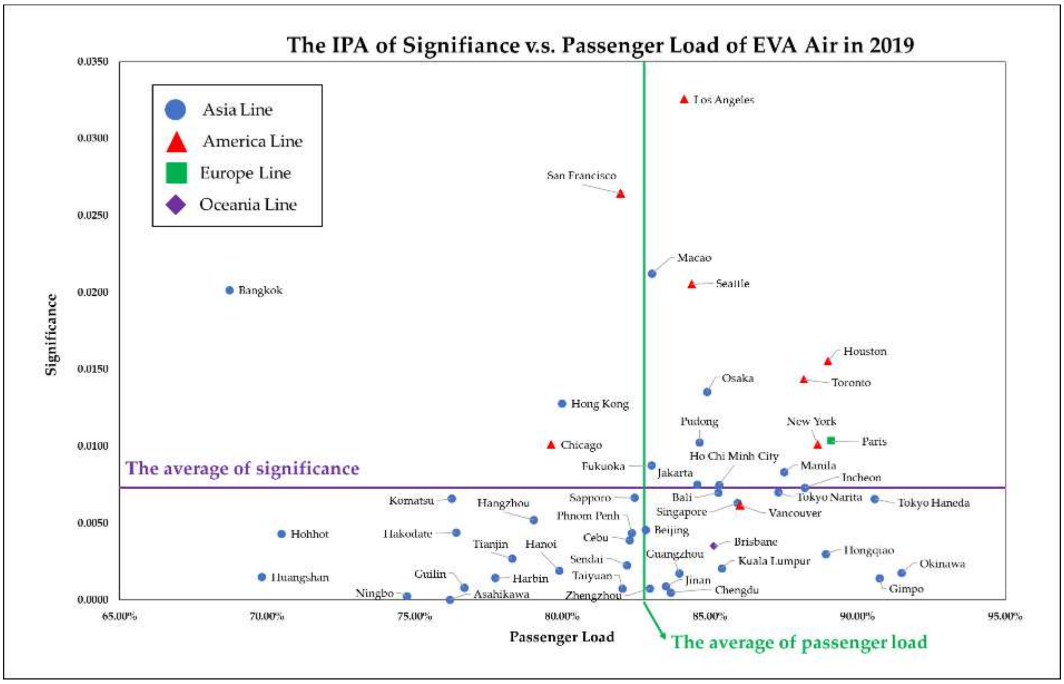

Figure 1: IPA of significance v.s. passenger load of EVA AIR in 2019.

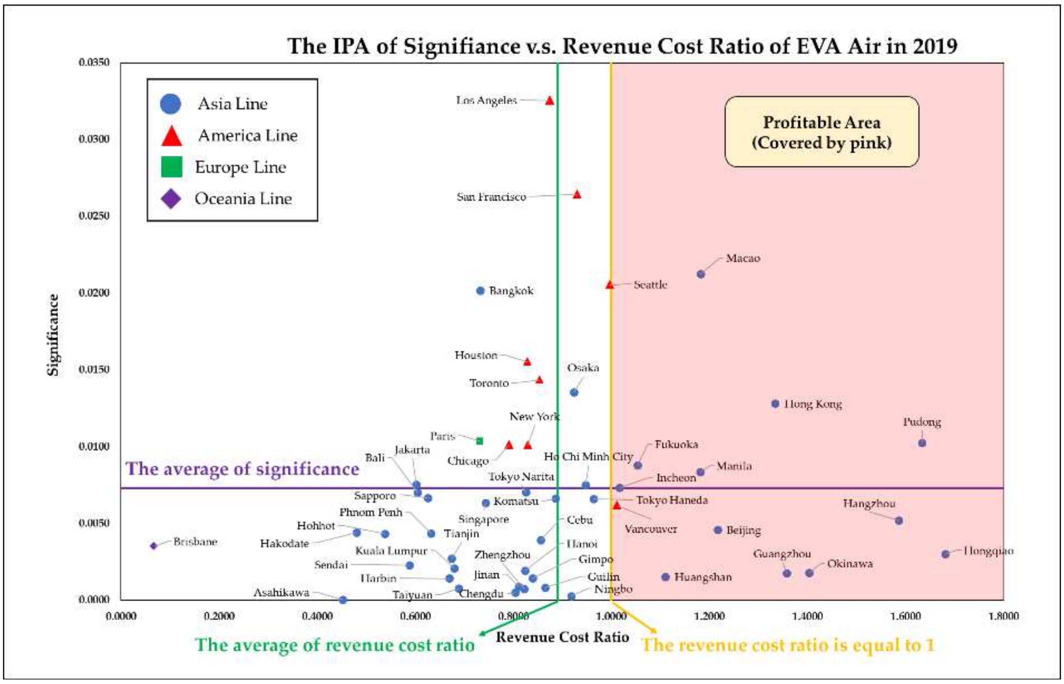

Figure 2: IPA of significance v.s. revenue-to-cost ratio of EVA AIR in 2019.

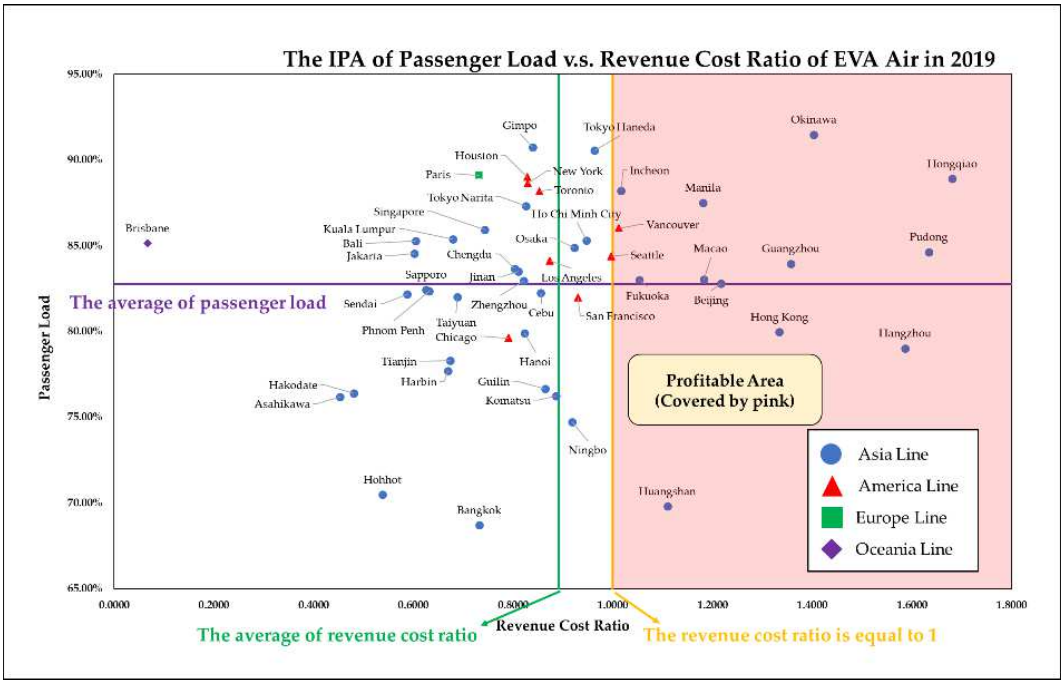

Figure 3: IPA of passenger load v.s. revenue-to-cost ratio of EVA AIR in 2019.

According to the three-dimensional IPA constructed by this research, we divided the routes into 12 clusters through three indicators of significance, passenger load, and revenue-to-cost ratio, and analyzed the results of route operations, as shown in Table 5.

Table 5: The results of route operations of EVA AIR in 2019.

Cluster	Significance	Passenger Load	Revenue Cost Ratio	Routes
A	High	High	Profitable	Macao, Pudong, Fukuoka, Manila, Incheon
B	High	High	Nonprofitable and higher than average	Seattle, Osaka, Ho Chi Minh City
C	High	High	Nonprofitable and lower than average	Los Angeles, Houston, Toronto, Jakarta, Paris, New York
D	High	Low	Profitable	Hong Kong
E	High	Low	Nonprofitable and higher than average	San Francisco
F	High	Low	Nonprofitable and lower than average	Bangkok, Chicago
G	Low	High	Profitable	Vancouver, Beijing, Guangzhou, Hongqiao, Okinawa
H	Low	High	Nonprofitable and higher than average	Tokyo Haneda
I	Low	High	Nonprofitable and lower than average	Bali, Singapore, Tokyo Narita, Jinan, Zhengzhou, Chengdu, Brisbane, Kuala Lumpur, Gimpo
J	Low	Low	Profitable	Hangzhou, Huangshan
K	Low	Low	Nonprofitable and higher than average	Ningbo
L	Low	Low	Nonprofitable and lower than average	Sapporo, Phnom Penh, Cebu, Sendai, Taiyuan, Hanoi, Tianjin, Harbin, Komatsu, Hakodate, Asahikawa, Guilin, Hohhot

3.2. Resource allocation model

This study used the moving average method of 2 to 10 periods to predict the passenger load, ticket price, air freight cost, airport operating cost, traveler service cost, maintenance cost, and other costs. This study found that the MAPE of the two-period average moving method is the smallest, indicating that the aviation industry is susceptible to short-term fluctuations. If we use the longer-period moving average method to predict, the predicted result will not be accurately estimated. The estimated MAPE of the ticket price is shown in Table 6. The MAPE of the ticket prices of four continents of the two-period moving average method is less than 10%, which are highly accurate forecast.

All other MAPE of the two-period moving average method is less than 10% except for the other cost. Because this study can't know the items made up of the other cost, we

Table 6: Estimated MAPE of ticket prices.

Continent	The MAPE of moving average of different periods (%)								
	2	3	4	5	6	7	8	9	10
America Line	5.09*	8.17	10.08	11.63	13.12	14.51	13.53	13.66	15.48
Asia Line	3.69*	5.74	7.35	8.38	9.44	9.82	9.65	9.20	8.29
Europe Line	4.99*	7.12	9.47	12.31	15.84	15.59	19.28	22.23	25.84
Oceania Line	4.20*	6.31	7.82	8.24	7.84	7.05	5.67	6.90	7.62

*minimum MAPE

assumed that it is related to the flight hours, so the predicted MAPE will be relatively large. The MAPE of other cost is 12.32%, but it is still a good prediction. The estimated MAPE of the operating cost is shown in Table 7.

Table 7: Estimated MAPE of operation cost.

Operation Cost	The MAPE of moving average of different periods (%)								
	2	3	4	5	6	7	8	9	10
Air Freight Cost	7.56*	12.36	15.80	17.20	18.46	17.96	20.62	25.10	27.60
Traveler Service Cost	3.37*	4.54	4.32	5.01	5.76	7.01	8.31	9.24	11.40
Maintenance Cost	8.18*	10.23	12.28	12.79	13.49	13.26	12.72	12.04	9.08
Other Cost	12.32*	21.86	30.44	41.71	56.42	69.60	72.91	82.23	79.09
Airport Operating Cost (Vancouver)	3.98*	6.74	9.43	11.41	12.85	13.50	15.39	19.71	23.72
Airport Operating Cost (Fukuoka)	3.49*	5.45	7.37	8.98	9.89	10.26	10.81	12.95	14.48
Airport Operating Cost (Paris)	3.70*	6.26	9.77	13.62	18.13	20.56	25.53	30.31	33.97
Airport Operating Cost (Brisbane)	3.58*	6.16	8.61	10.58	12.40	13.45	15.52	19.97	20.02
Air Freight Cost	7.56*	12.36	15.80	17.20	18.46	17.96	20.62	25.10	27.60

*minimum MAPE

The forecast results of the passenger load of the route are shown in Table 8. We found that all routes can obtain the smallest MAPE when using the two-period moving

Table 8: Estimated MAPE of passenger load.

Route	The MAPE of moving average of different periods (%)								
	2	3	4	5	6	7	8	9	10
Vancouver	2.11*	3.04	4.24	4.62	5.44	5.55	5.71	5.28	3.37
Fukuoka	3.42*	5.01	5.84	5.77	6.37	6.60	7.15	7.36	8.31
Paris	1.92	1.91	1.97	2.53	2.66	2.80	2.83	2.26	1.53*
Brisbane	2.78*	3.08	2.56	3.12	3.51	3.87	4.38	5.53	5.67

*minimum MAPE

average method except for Paris. Although the MAPE of Paris that uses the two-period moving average method is not the best prediction result, it still belongs to a highly accurate forecast, which makes the overall MAPE performance the best.

3.3. Scenario analysis

In airline industry, there may be many different limitations on flights in real-life situations, and the contract limit on the number of flights for each route is considered. Thus, this study also considered those limitations into resource allocation strategy. In the following, three resource allocation scenarios when airlines allocate resources:

(1) Resource allocation of limited resources investment: In order to continue to profit, the airline will prepare investment budgets. However, the airline has limited resources and can only find the best investment portfolio from a limited budget.

(2) Resource allocation of unlimited resources investment: An investment portfolio within a limited budget may not maximize the overall profitability. Therefore, in order to provide the airline with an idea of how to invest to achieve the best overall profitability, we proposed this scenario assumption and calculate the total amount that must be invested.

(3) Resource allocation of additional resource investment: This study assumed that the airline has planned additional investment amounts for future operating policies, but they don't know which route is the primary investment object. Therefore, according to the priority ranking model established in this study, we will sort the order of route investment and calculate what the funds will be.

Scenario 1: Resource allocation of limited resources investment

The forecast results of operating data are obtained through the cost estimation model. The MAPE results of each forecast item are shown in Table 9. In addition to other cost, the MAPE of the prediction results is all within 10%, which are highly accurate prediction. Although the MAPE of other cost is as high as 19.79%, the MAPE of the total operating cost is only 3.52%, which means that even if there is a high error in the prediction results of other cost, it will not affect the forecast results of total operating costs. Airlines can use the resource allocation model established in this study to predict the operating status of the next year and find the best investment portfolio within a limited budget.

Table 9: Estimated MAPE of resource allocation of limited resources investment.

Forecast Item	MAPE (%)	Forecast Item	MAPE (%)
Air Freight Cost	4.85	Number of Passengers	4.46
Airport Operating Cost	10.00	Passenger Load	4.46
Traveler Service Cost	4.87	Number of Passengers	4.27
Maintenance Cost	5.69	Total Operating Cost	3.52
Other Cost	19.79	Revenue Cost Ratio	5.73

Scenario 2: Resource allocation of unlimited resources investment

The purpose of unlimited resource investment is that the investment portfolio within a limited budget may not maximize the overall profitability. Therefore, in order to provide the airline with an idea of how to invest to achieve the best overall profitability, we proposed this scenario assumption and calculate the total amount that must be invested. Therefore, this study assumed that every seat provided by the airline can serve passengers. The resource allocation of unlimited resource investments allows the airline to identify if the routes can profitable when these routes reach maximum service. If the route is still unprofitable when the service is maximized, the airline should review why the route is unprofitable before investing in the route.

According to the resource allocation model established by this research, the results of resource allocation of each route in 2019 are displayed in IPA, as shown in Figure 4. This study found that the average revenue-to-cost ratio is 1.01, which indicates that the overall operating results are good and profitable.

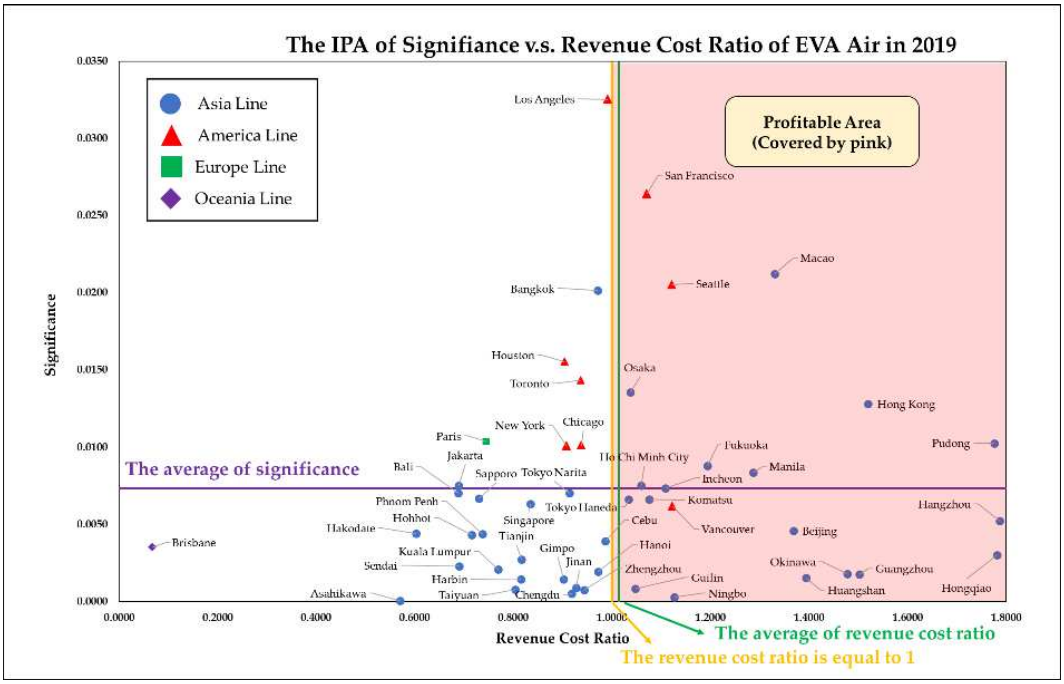

Figure 4: IPA of significance v.s. revenue-to-cost ratio in 2019 with unlimited resources investment.

This study found that there are 28 routes that can't be profitable after investment (maximization of service) in Figure 8. Therefore, this study organizes these routes in Table 10. This study divided these 28 routes into 3 groups. In Section 4, this study will be explained in terms of data (divided into three indicators: market share, actual passenger load, and revenue-to-cost ratio) and management.

Scenario 3: Resource allocation of additional resource investment

Table 10: Routes that are unprofitable after unlimited resources investment.

Group	Route	Market Share	Actual Revenue Cost Ratio	Predicted Revenue Cost Ratio	Growth Rate of Revenue Cost Ratio	Actual Passenger Load	The Rank of Passenger Load/Total Number of Airlines Serving his Route	Description
1	Hohhot	100.00%	0.5379	0.7160	33.12%	70.48%	1/1	The market share is 100%
	Houston	100.00%	0.8285	0.9040	9.11%	89.00%	1/1	
	Toronto	100.00%	0.8534	0.9367	9.76%	88.17%	1/1	
	Chicago	100.00%	0.7911	0.9384	18.62%	79.62%	1/1	
2	Paris	70.85%	0.7319	0.7456	1.87%	89.10%	1/2	The market share is between 50%-100%
	New York	62.45%	0.8296	0.9079	9.43%	88.65%	1/2	
3	Hanoi	14.05%	0.8234	0.9719	18.03%	79.89%	1/6	The passenger load is the top one of all airlines serving this route
	Gimpo	28.40%	0.8390	0.9021	7.53%	90.73%	1/4	
	Jakarta	49.65%	0.6019	0.6897	14.59%	84.55%	1/3	
	Tianjin	49.41%	0.6741	0.8164	21.11%	78.29%	1/3	
	Phnom Penh	42.85%	0.6316	0.7379	16.82%	82.35%	1/3	
	Cebu	34.98%	0.8555	0.9868	15.35%	82.26%	1/3	
	Taiyuan	32.41%	0.6884	0.8039	16.77%	82.02%	1/3	
	Zhengzhou	22.00%	0.8217	0.9441	14.89%	82.95%	1/3	

The purpose of additional resource investment is that airlines have planned plans for future operating policies, but they don't know which route is the primary investment object. Therefore, according to the priority ranking model established in this study, we will sort the order of route investment and calculate what the funds will be.

The part of results of the resource allocation of additional resources investment is shown in Table 11. It can be found that if the airline has an additional budget of NT 8,983,160,202 dollars in the current year, it can invest in the routes in Group 2. If the airline has an additional budget of more than NT 8,983,160,202 dollars in that year, it can further invest in the routes of Group 3 in sequence.

4. Discussions

4.1. Importance-performance analysis

(1) In the past, IPA relied on the questionnaire method to measure the importance and performance of the consumer perspective. This study is based on the perspective of the operator. We represented the importance of each route using the market share and internal share of each route of EVA Air. Route performance is expressed in terms of passenger load. However, for a for-profit organization, the key question is whether a route is profitable or not. Therefore, this study used a revenue-to-cost ratio to

Table 11: Resource allocation results of additional resource investment.

Group	Route	Significance	Passenger Load	Revenue Cost Ratio	Investment Sequence	Required Investment Cost	Passenger Load After Investment	Revenue Cost Ratio After Investment
1	Hongqiao	0.000176	88.91%	1.6810	The routes are already profitable, so no additional investment in resources is required.			
	Pudong	0.001923	84.64%	1.6336				
	Hangzhou	0.000171	79.01%	1.5858				
	Okinawa	0.000238	91.48%	1.4032				
2	Osaka	0.003565	84.89%	0.9231	②	156,287,000	94.88%	1.0000
	Guilin	0.000008	76.66%	0.8648	③	13,486,516	93.58%	1.0000
	Komatsu	0.000067	76.24%	0.8863	⑥	31,277,621	90.06%	1.0000
	Ningbo	0.000005	74.73%	0.9180	⑧	5,829,361	84.16%	1.0000
3	Cebu	0.000124	82.26%	0.8555	⑩	52,480,640	100%	0.9868
	Hanoi	0.000180	79.89%	0.8234	⑪	72,944,678	100%	0.9719
	Bangkok	0.003062	68.72%	0.7327	⑫	503,962,284	100%	0.9716
	Chicago	0.000098	79.62%	0.7911	⑭	228,269,671	100%	0.9384

determine the value of each route; this operating indicator adds a third dimension to the traditional IPA framework.

(2) IPA of significance v.s. passenger load (in Figure 1)

a. The first quadrant represents routes of high significance and high passenger load, which means that the routes provide enough seats and also meet the needs of passengers. These routes perform well and should be maintained.

b. The fourth quadrant represents routes of low significance with high passenger load, which means that the routes provide a sufficient number of seats.

(3) IPA of passenger load v.s. revenue-to-cost ratio (in Figure 2)

a. When the revenue-to-cost ratio is more than 1, the route is profitable. Of the 49 routes, 13 routes fall in this area of the graph (marked in pink). If these routes are also of low significance, they can be maintained with minimal input resources.

b. The second quadrant represents routes provide many seats (high significance) with a low revenue-to-cost ratio, which means that profits are unlikely to increase based on further resources input. Strategies to address this imbalance are required.

c. The third quadrant represents routes low significance with a low revenue-to-cost ratio. Most of these routes are only served by EVA Air and have strategic significance for the airline.

(4) IPA of significance v.s. revenue-to-cost ratio (in Figure 3)

a. On the right side of the revenue-to-cost ratio line equal to 1 is the currently profitable routes. Of the 49 routes, 13 routes fall in this area and should continue to be maintained. They are in the profit area and the passenger load of these routes are lower than average. The representative is the route can achieve profit with minimal input of resources.

b. On the right side of the revenue-to-cost ratio line equal to 1 is the routes that haven't been balanced. Among them, the routes in which the average revenue-to-cost ratio is higher than the average are priority areas, as they can be improved without investing too many resources. We took the perspective that airline quality can influence market competitiveness. Therefore, airline should consider how to maintain high levels of quality service even on routes with low passenger load to reduce the negative effects of fluctuations in passenger demand.

(5) IPA of significance v.s. passenger load v.s. revenue-to-cost ratio (in Table 5)

a. For profitable routes of high significance and high passenger load, the revenue-to-cost ratio and passenger load can be increased by the investment of further resources. For these routes, EVA Air has kept abreast of market demand by increasing seats and investing appropriate amount of resources at just the right time.

b. For profitable routes of high significance and low passenger load, airline can try to reduce the amount of resources invested to test whether the routes remain profitable, to maximize the benefits of the smallest investment cost.

c. For profitable routes of low significance and high passenger load, airline must keep up to date with market demand in order to achieve the highest passenger load with a minimum input of resources.

d. For unprofitable routes of low significance and high passenger load, either the routes are popular or else are exclusively marketed by EVA Air. For popular routes, it is difficult for the airline to make a profit because of the number of competitors. In order to avoid financial loss, the airline offers only a small number of seats on these routes.

e. For unprofitable routes of low significance, low passenger load, the airline can profit with minimum investment.

4.2. Scenario analysis

(1) Resource allocation of limited resources investment (in Table 9)

a. Through the cost estimation model established by this study, we can forecast operating costs and revenue. The MAPE of total operating revenue in 2019 was 4.27%, the MAPE of total operating costs was 3.52%, and the MAPE of passenger load was 4.46%. This means that our predictions are all highly accurate.

b. The proposed IPA chart forecasting operating statistics for 2019 was roughly the same as the actual operating data. Therefore, airlines can use the resource allocation model established by this study to make predictions regarding operation for the following year and determine a suitable investment portfolio within a limited budget.

(2) Resource allocation of unlimited resources investment (in Table 10)

a. This study found 28 routes that were unlikely to become profitable even following the maximization of service. We divided these 28 routes into three groups, which we discuss in term of related statistics and implications for management.
   (a) Data
      i. Some routes have a market share of 100% and the airline must maintain these routes to fill gaps in the aviation market.
      ii. When passenger load is in the top 50% of all airlines serving this route, the airline can be assured that it remains competitive. For example, there are eight airlines providing round-trip service from Taipei to Osaka, and the passenger load of EVA Air is the best of all eight airlines.
      iii. 13 of the 24 routes have a revenue-to-cost ratio of more than 0.9 after investment in unlimited resources, which means that the airline could improve these routes without financial loss.
      iv. There are 6 of the 24 routes have the revenue-to-cost ratio of increased by more than 20% after investment in unlimited resources, indicating that these routes have some areas that need improvement.
   (b) Management
      i. When routes are unprofitable, the airline may consider maintaining the service in order to boost customer confidence. If passengers know that the airline is about to close a certain route, they might question the operating capabilities of the airline, which would affect their willingness to purchase tickets for other routes. Therefore, the airline should continue to provide services with a minimum loss.
      ii. When the operations of the airline reduce due to the closure of some routes, this can reduce the advantages of economies of scale previously enjoyed by the firm. This might lead to idle aircrafts and reduced room for negotiation in the purchase of new aircrafts or component parts.

(3) Resource allocation of additional resource investment (in Table 11)
   a. The routes in Group 1 break even, so no additional resources will be invested.
   b. The routes in Group 2 are currently unprofitable but can be improved without invest too many resources to break even. These routes represent the priority for improvement and are ranked according to their significance.
   c. The routes in Group 3 are currently unprofitable and are unlikely to become so, even if significant investment is made. Once all the routes in Group 2 have been improved and if there are still remaining funds, the routes in this group can be improved according to their significance to minimize the overall losses of the airline.

5. Conclusions and Implications for Management

5.1. Conclusions

When airlines have a large scale of operations, it is not easy for managers to determine the source of problems. This study provides routes layout and investment strategy for the airline industry. It is through a three-dimensional IPA establishing. The operating statistics of each route in the current year based on the relationship between the three aspects and explain the reasons for significant changes have been examined. The contribution of a three-dimensional IPA is that the operating results of large-scale routes can be displayed so that managers can easily pinpoint the problems. In order to help the airline to find which routes are the primary investment targets, this study established a resource allocation model and chose significance as the basis for ranking because the significance is the resources invested by the airline. There are three situations assumed during the investment process, including limited resources investment, unlimited resources investment, and additional resource investment. The results can provide to the airlines as a reference for upcoming planning and execution.

5.2. Implications of management

(1) IPA can display different operational indicators in the cross quadrant, and provide managers with suggestions for future operation through the different strategic significance of each quadrant. If we only discuss the operating results from the perspective of traditional IPA analysis, we will not be able to get closer to the actual strategy. Therefore, this study established a three-dimensional IPA through three key indicators: significance, passenger load and revenue-to-cost ratio, so that airline can more easily grasp the operating results.

(2) To keep profitable for the airline in a highly competitive market, it must plan its resource allocation early for the next year. Therefore, this study used historical data and uses the two-period moving average method to minimize the overall forecast error. If the airline wants to survive in such a competitive market, using this cost estimation model established by this study can help the airline plan for the next year early.

(3) This study envisaged what may happen to the airline in their investments. Through the allocation of resources with limited resources, the airline can find the investment portfolio for the next year based on past historical data. Through the allocation of resources with unlimited resources, provide airlines to identify the total resources that must be invested to achieve the best overall profit. Through the allocation of resources through additional resource investment, when the airline has planned additional investment amounts for future operating policies, but they don't know which route is the primary investment object, it can find out the order of investment and calculate the funds to be invested.

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