Analysis of Airline Domestic Operations using Linear Programming

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Abstract

Air transportation facilitates integration of the global economy and plays a vital role in both local and global economic development through the increasing passengers and freight traffic demands. Thus, this paper aims to minimize the operational cost of a budget airline's fleet operation by selecting the most suitable aircraft type among the company's existing fleet using the analytic hierarchy process (AHP). Then, the linear programming method was used to optimize the allocation of fleet to its operations that will minimize the daily operational expenses in nineteen (19) proposed domestic destinations from Manila. The linear programming model considered the following constraints: (1) Supply of Available Seat must meet Passenger Traffic Demand (2) Minimum Flight Frequency Requirement (3) Assignment of Aircraft Type to Destination's Airport and (4) Available Fleet Operating Hours per Aircraft Type per Day. The results obtained the frequency of flights per aircraft type per route to nineteen (19) domestic destinations that meets the passenger demand at minimum cost to the airline company. In addition, it was also realized that the fleet size could be reduced based on the remaining available hours of operation. The optimal solution maximized the available operating hours of the A330-200 and A321-200 CEO aircraft type. The A330-200's high seat capacity catered to the high demand of the destination. Despite the highest operational cost among other aircraft types, it was able to transport more passengers in one flight. While only 21% of the A321 NEO's operating capacity was utilized. Therefore, the A321 NEO's fleet size could be reduced to only 1 aircraft. Both the analytic hierarchy process (AHP) and linear programming (LP) were an effective tool in supporting the decision-making process of airline domestic operations. The AHP was able to determine the most suitable aircraft. And the LP optimized the fleet operations at minimum cost. Both methods could also be further improved by considering additional factors such as aircraft operational compatibility for AHP and other factors affecting flight operations for the LP model.

Keywords
Airline domestic operation, linear programming, analytical hierarchy process

1. Introduction
Air transportation facilitates integration of the global economy and provides vital connectivity on a national, regional, and international scale (World Bank, Air Transport, 2020). Air transportation has been progressively growing in response to an increase in both passenger and freight traffic demands, which plays a vital role in both local and global economic development (Bae, 2018). According to the International Air Transport Association (IATA) World Air Transport Statistics 2019, worldwide air passenger numbers continued to rise to 4.4 billion journeys in 2018. In the United States, there is a total of 811,547,169 passengers for domestic and 241,158,082 for international travel (Bureau of Transportation Statistics, Passengers All Carriers – All Airports, 2020). In the Asia-Pacific region, the volume of air passengers and cargo has grown significantly over the past decade due to the strong impetus of economic growth as well as trade and economic integration at both the regional and global levels (Cullinane et. al, 2011). By 2035, an additional 1.8 billion annual passengers will be transported to, from and within Asia Pacific for an overall market size of 3.1 billion (IATA, Asia Pacific Leads 20-Year Passenger Demand Forecast, 2020). In the Philippines, international scheduled passenger traffic rose from 24 million in 2017 to almost 27 million passengers in 2018 and domestic scheduled passenger traffic rose from almost 25 million to 27 million in 2018.

Airlines capitalizes this growing demand by maximizing resources to provide services to as many passengers as they can. It is the planning and efficient management of these resources that determines the survival or demise of an airline (Bazargan, 2016). It is important for an airline to optimize their operations to be sustainable. Aircraft type, fuel, maintenance, and personnel are some of the operating expenses in an airline. To be able to stay in the market and be profitable, airline companies must strictly control their costs (Naimzade, 2018). And, operations research (OR) has played a critical role in helping the airline industry and its infrastructure sustain high growth rates and make the transition from a novelty that catered to an elite clientele to a service industry for the masses (Barnhart, et al. 2003).

The application of operations research is significant in the operational decisions of an airline. Some of the most significant contributions of OR to air transport are the following: aircraft scheduling, fleet planning, fleet assignment, aircraft maintenance routing, crew scheduling, airline revenue management, airside operations and air traffic flow management (Barnhart, et al. 2003). Airline companies plan their operations prior implementation (Bae,2014). The operational planning of airlines can be divided into three interrelated problems: the definition of which flights will be offered, which aircraft will be used on each flight, and which crew will perform these flights (Caetano & Gualda, 2010).

In previous years, numerous authors have presented optimization models in solving fleet planning problems. Wang (2014) utilized linear programming to minimize fleet planning costs taking into consideration the airlines operating in a hub and spoke network. The proposed model was more efficient and accurate than without the consideration of the network effects. Dozic & Kalic (2015) conducted a study focused on aircraft type selection decision using Analytic Hierarchy Process (AHP) and, concluded that AHP can be successfully used as a support tool. Another study conducted by Basligil et. al (2012) utilized a large scale integer linear programming to the daily fleet assignment problem of Turkish Airlines and found out that the determination of a fleet type assigned to a specific flight is important to minimize assignment cost while assigning the right aircraft to the right flight.

1.1 Objectives

For a budget airline, its main objective is to provide transport medium at cheapest fares to the public in today's competitive market (Patel and Ali, 2018). To be able to provide the cheapest fares, operational costs should be at its minimum. Thus, this paper aims to minimize the operational cost of a budget airline's fleet operation. The first step is to select the most suitable aircraft type among the company's existing fleet using the analytic hierarchy process (AHP). The AHP criteria consists of the following: (1) Seat Capacity (2) Maintenance Cost (3) Aircraft Price (4) Cargo Capacity (5) Maximum Take-off Weight (MTOW) and (6) Cost per Available Seat Mile (CASM). Upon determination of the aircraft type with the highest rating, the company will allocate the maximum number of that aircraft type available in its fleet. Second, the linear programming method is used to optimize allocated fleet to its operations that will minimize the daily operational expenses in nineteen (19) proposed domestic destinations from Manila. The linear programming model will consider the following constraints: (1) Supply of Available Seat must meet Passenger Traffic Demand (2) Minimum Flight Frequency Requirement (3) Assignment of Aircraft Type to Destination's Airport and (4) Available Fleet Operating Hours per Aircraft Type per Day.

2. Methods

2.1. Analytical Hierarchy Process

This paper aims to determine the most suitable aircraft to be utilized in the airline's domestic operation in the Philippines using the analytical hierarchy process as a decision-making tool. The method involves the use of pairwise comparison to determine weight of criteria and apply it in choosing the alternative aircraft types. The aircraft types considered in this study is based on the available fleet of the model company. Each aircraft type will be evaluated based on the following specifications (1) Seat Capacity, (2) Average Maintenance Cost, (3) Aircraft Price in USD, (4) Cargo Capacity, (5) Maximum Take-off Weight (MTOW), and (6) Average Cost per Available Seat Mile (CASM) in US Cents. The seat capacity of an aircraft is dependent on the seat configuration design of the airline. In this case, the airline model is a budget airline. It has a single class seat configuration. With this design, aircraft cabin space is maximized to accommodate more passengers and consequentially, generate more revenue with each flight. The seat capacity was extracted from the model company's fleet specifications list. The average maintenance cost is listed as the maintenance cost per block hour in the data provided by planestats.com (The website uses the United States' Department of Transportation data). Each airline and each aircraft type have a corresponding maintenance cost per block hour value. The average of the maintenance cost per block hour per aircraft type was taken from all the airlines included in the list. The same procedure was done to extract the average cost per available seat mile (CASM) for each aircraft type. The price of each aircraft type was based on the Airbus aircraft average list price for 2018. And the maximum take-off weight (MTOW) was taken from Airbus' aircraft product details accessible at airbus.com. Airbus SE is the original equipment manufacturer (OEM) and designer of all Airbus aircraft types.

In using AHP one needs a hierarchic or a network structure to represent the problem and pairwise comparisons to establish relations within the structure (Saaty, 1987). The pairwise comparison is used to compare the criteria and determine their importance over each other. The first hierarchy is the goal which is selecting the most suitable aircraft type. The second is the six criteria proposed in this paper that contribute towards the goal. The criteria are as follows: (1) Seat Capacity (2) Maintenance Cost (3) Aircraft Price (4) Cargo Capacity (5) Maximum Take-off Weight (MTOW) and (6) Cost per Available Seat Mile (CASM). The last level is the set of alternatives which is based on the available fleet of the airline model. The aircraft types are as follows: A320-200 CEO, A320 CEO, A321-200 CEO, A321 NEO, and A330-200. The hierarchy structure of the problem is shown in figure 1.

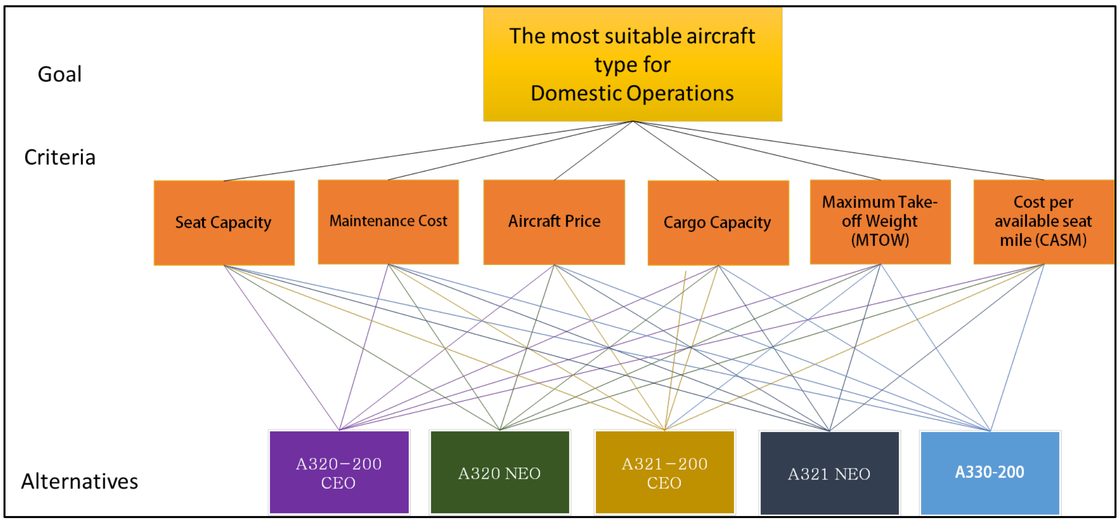

Figure 1. AHP Hierarchy Structure

2.2. Linear Programming
2.2.1. Data Gathering
The selection of the most suitable aircraft type is accomplished through the AHP method. However, the available fleet of the most suitable aircraft type will not meet the passenger traffic demand. Also, the assignment of aircraft type to airport destination needs to be considered because not all aircraft types are capable of landing on all airports in the Philippines. So, the airline company considers the 2nd and 3rd ranked aircraft type based on the results of the AHP. Considering the utilization of a fleet of three aircraft types, this paper uses the linear programming (LP) method to minimize the daily operational cost of the airline. LP is a powerful technique for dealing with resource-allocation problems (Hillier & Lieberman, 2015). The flights operate to nineteen (19) domestic routes from Manila with an operating fleet consisting of three aircraft types. The destinations were taken from the list of destinations proposed to be serviced by the company.

The linear programming model consists of a linear objective function and constraints. The objective function considers the operational cost of the aircraft. The operational cost of the aircraft is represented by the average cost per flight hour multiplied by the flight time from Manila to a destination. The list of operating costs of airlines provided by planestats.com is used to compute the average cost per flight hour per aircraft type. The firm uses historical and real-time data of airports, airlines, and the US Department of Transportation (DOT) Form 41 Traffic and Form 41 Financial. On the other hand, the flight duration in hours is based on the data extracted from airmilescalculator.com. The flight time is calculated based on great circle distance and the average airspeed of commercial airliners.

The model in this study considers the following constraints: (1) Supply of Available Seat versus Passenger Traffic Demand (2) Minimum Flight Frequency Requirement (3) Assignment of Aircraft Type to Destination's Airport and (4) Available Fleet Operating Hours per Aircraft Type per Day. (1) Supply of Available Seat versus Passenger Traffic Demand. The supply of available seat is based on the seat capacity of the aircraft type. The seat capacity is based on the airline's seat configuration of the aircraft type. The passenger traffic demand was based on the projected passenger demand traffic share of the model airline (Cebu Pacific) for the year 2020 on each route (From Manila to a Destination). The projections are based on the 2010 to 2019 passenger traffic data share of Cebu Pacific provided by the Civil Aeronautics Board of the Philippines (CAB). (2) Minimum Flight Frequency Requirement. This constraint was based on the flight frequency requirement of the airline model per destination. (3) Assignment of Aircraft Type to Destination's Airport. The assignment of aircraft to a destination is based on the historical data of the airlines' operation. The 2019 airline operations are used as basis for the airport assignment list. (4) Available Fleet Operating Hours per Aircraft Type per Day. The average operating hours of 20 was provided by the airline company. An average of 20 operating hours per day allows 4 hours of maintenance to be performed.

2.2.2. Decision Variables

The decision variable is the flight frequency per aircraft type per route. The three aircraft types with the highest priority are determined using the analytic hierarchy process.

Let, X_{ij} be the representation of the frequency of flights per route (From Manila to a Destination)

Where :

i is the subscript representing the aircraft type used. It is identified by the following numbers namely:

(1) for the1st Aircraft Type,
(2) for the 2nd Aircraft Type and,
(3) for the 3rd Aircraft Type

j is subscript representing the route from Manila to a destination. It is identified by the following letters:

(A) for Manila to Bacolod or MNL-BCD
(B) for Manila to Boracay or MNL-MPH
(C) for Manila to Butuan or MNL-BXU
(D) for Manila to Cagayan de Oro or MNL-CGY
(E) for Manila to Cauayan or MNL-CYZ
(F) for Manila to Cebu or MNL-CEB
(G) for Manila to Cotabato of MNL-CBO
(H) for Manila to Davao or MNL-DVO
(I) for Manila to Dipolog or MNL-DPL
(J) for Manila to Dumaguete or MNL-DGT
(K) for Manila to General Santos or MNL-GES
(L) for Manila to Iloilo or MNL-ILO
(M) for Manila to Kalibo or MNL-KLO
(N) for Manila to Legazpi or MNL-LGP
(O) for Manila to Pagadian or MNL-PAG
(P) for Manila to Roxas or MNL-RXS
(Q) for Manila to San Jose or MNL-SJI
(R) for Manila to Tacloban or MNL-TAC
(S) for Manila to Virac or MNL-VRC

2.2.3. Method

The linear programming (LP) is used to optimize the daily fleet operations. The LP model assigns the flight frequency per aircraft type to a certain route to minimize operational cost with consideration to operational restrictions or constraints. This model is designed with a linear objective and constraint functions that are applied repetitively to the problem. And with each repetition (called iteration), it moves the solution closer to the optimum (Taha, 2007).

The objective of this paper is to minimize the cost of fleet operations per day in nineteen (19) Philippine domestic destination with consideration to the following constraints: (1) Supply of Available Seat vs Passenger Traffic Demand (2) Minimum Flight Frequency Requirement (3) Assignment of Aircraft Type to Destination's Airport (4) Available Fleet Operating Hours per Aircraft Type per Day, and (5) Non-negativity constraint. In minimizing the daily operating costs, there are several main costs to consider. The first is the operating cost of the aircraft per flight hour which includes fuel, depreciation, labor and other service costs, insurance, and maintenance. In this study all of these costs are included in the operating cost per flight hour of the particular aircraft type.

The objective function is the cost minimization of the daily operating cost of the airline. The function equates to the decision variable which is the flight frequency per aircraft type per route sector multiplied by the cost per flight hour and the route flight time in hours.

The objective function is represented by the equation:

$$\text{Minimization of Cost, Z} = \sum (X_{ij})(Ci,\ Cost\ per\ flight\ hour)(Di,\ route\ flight\ time\ in\ hours)$$

Let, X_{ij} be the representation of the frequency of flights per route.
Where the subscripts are represented by the following:
i – aircraft type, (1) – 1st Aircraft Type; (2) – 2nd Aircraft Type; (3) – 3rd Aircraft Type
j – Route from Manila to Destination
Let, C_i be the representation of cost per flight hour.

Given the list of operating costs of airlines provided by planestats.com, the average cost per flight hour per aircraft type available in the fleet of the model airline was determined. The data used was extracted from the reports entitled "Reported Operating Cost and Utilization of Narrow-body Jets - 12 Months Ended September 2019" for the A320-200 CEO , A320 NEO, A321-200 CEO, and A321 NEO aircraft types and "Narrow-body Jet Costs and Operations - 12 Months Ended September 2019 for the A330-200 aircraft. The table 1 below presents the cost per flight hour in USD per aircraft type.

Table 1. Average Cost per Flight Hour in USD

Aircraft Type	Average Cost Per Flight Hour in USD
A320-200 CEO	4,378
A320 NEO	4,378
A321-200 CEO	4,432
A321 NEO	5,149
A330-200	6,564

The three aircraft with the highest priority determined through the AHP will be represented by the following:
C_1 for the Cost per flight hour 1st Aircraft Type
C_2 for the Cost per flight hour 2nd Aircraft Type
C_3 for the Cost per flight hour 3rd Aircraft Type

Let, D_i be the representation of the flight time in hours from Manila to a Destination.
Where the subscript i is represented by route.

The table 2 below shows the average flight time in hours from Manila to the domestic destinations from airmilescalculator.com. Data indicated is an estimate as factors affecting flight time such as weather is always changing. The website uses Vicenty's algorithm for the distance travelled by the aircraft from origin to destination. The formula calculates the distance between latitude/longitude points on the earth's surface using an ellipsoidal model of the earth. Vicenty's algorithm is considered as one of the most precise methods for the calculation of long geodesics (Pallikaris et Al, 2009). Geodesic is the shortest line between two points that lies in a given surface (Meriam Webster, 2020). Airlines utilize this distance to save fuel and reduce flight time. The International Airline Transport Association (IATA) uses a standardized form of coding system to destination airports as shown below.

Table 2. Flight time in hours from Manila to destination

Route Representation	Destination	IATA Code System	Flight time in Hours (one-way)
D_A	Bacolod	MNL-BCD	1.033
D_B	Boracay	MNL-MPH	0.850
D_C	Butuan	MNL-BXU	1.417
D_D	Cagayan de Oro	MNL-CGY	1.383
D_E	Cauayan	MNL-CYZ	0.817
D_F	Cebu	MNL-CEB	1.150
D_G	Cotabato	MNL-CBO	1.533
D_H	Davao	MNL-DVO	1.617
D_I	Dipolog	MNL-DPL	1.317
D_J	Dumaguete	MNL-DGT	1.233
D_K	General Santos	MNL-GES	1.717
D_L	Iloilo	MNL-ILO	1.017
D_M	Kalibo	MNL-KLO	0.900
D_N	Legazpi	MNL-LGP	0.883
D_O	Pagadian	MNL-PAG	1.417
D_P	Roxas	MNL-RXS	0.933
D_Q	San Jose	MNL-SJI	0.767
D_R	Tacloban	MNL-TAC	1.150
D_S	Virac	MNL-VRC	0.917

The following are the constraints considered in the model:

1. Supply of Available Seats versus Passenger Demand

The constraint is represented by the equation:

$$(\text{1st Aircraft Type } Seat\ Capacity\,)X_{1j} + (\text{2nd Aircraft Type } Seat\ Capacity\ Seat\ Capacity\,)X_{2j} + (3rd\ Aircraft\ Type\ Seat\ Capacity\,)X_{3j} \geq Passenger\ Traffic\ Demand\ per\ route$$

Where the subscripts are represented by the following:
i – aircraft type, (1) – 1st Aircraft Type; (2) – 2nd Aircraft Type; (3) – 3rd Aircraft Type
j – Route from Manila to Destination

The supply of available seat is dependent on the three most suitable aircraft identified using the AHP method. The list of seat capacity per aircraft type is based on the seat configuration of the airline model as shown in Table 3.

Table 3. Seat Capacity Per Aircraft Type

Aircraft Type	Seat Capacity
A320-200 CEO	180
A320 NEO	188
A321-200 CEO	230
A321 NEO	236
A330-200	436

The passenger demand per route is taken from the projected passenger demand using the data provided by the Civil Aeronautics Board of the Philippines (CAB) on the yearly passenger traffic from 2010 to 2019. The paper considered four demand projection methods namely arithmetic geometric curve, arithmetic straight line, statistical parabolic curve, and statistical straight line. The projection with the least standard deviation was chosen which is the statistical parabolic curve. The curve also shows a decreasing projected value which is similar to the current situation of the aviation industry. The next step is to extract the share of each route on the projected passenger traffic demand. The Civil Aeronautics Board was able to provide the traffic share per route from the year 2016 to 2019. The average value was taken, and the percent share is multiplied to the total projected passenger demand. The projected 2020 daily passenger demand is shown in table 4 below.

Table 4. Passenger Daily Demand for the year 2020

Destination	IATA Coding System	2020 Passenger Daily Demand
Bacolod	MNL-BCD	1,894
Boracay	MNL-MPH	1,206
Butuan	MNL-BXU	794
Cagayan de Oro	MNL-CGY	2,069
Cauayan	MNL-CYZ	145
Cebu	MNL-CEB	5,322
Cotabato	MNL-CBO	386
Davao	MNL-DVO	3,836
Dipolog	MNL-DPL	317
Dumaguete	MNL-DGT	821
General Santos	MNL-GES	967
Iloilo	MNL-ILO	2,357
Kalibo	MNL-KLO	1,158
Legazpi	MNL-LGP	810
Pagadian	MNL-PAG	227
Roxas	MNL-RXS	439
San Jose	MNL-SJI	60
Tacloban	MNL-TAC	1,592
Virac	MNL-VRC	83

2. Minimum Flight Frequency

The flight frequency must be greater than or equal to the minimum flight frequency required per route. It is represented by the equation:

$$\sum X_{ij} \geq Minimum\ Flight\ Frequency$$

i.e. MNL-BCD $(X_{1A} + X_{2A} + X_{3A}) \geq 1$ flight/s per day

The flight frequency must meet the minimum requirements set by the airline. Refer to table 5 below.

Table 5. Minimum Flight Frequency Requirement

To (Destination)	Route Sector	Minimum Frequency of Flights per day
Bacolod	MNL-BCD	1
Boracay	MNL-MPH	1
Butuan	MNL-BXU	2
Cagayan de Oro	MNL-CGY	6
Cauayan	MNL-CYZ	2
Cebu	MNL-CEB	3
Cotabato	MNL-CBO	1
Davao	MNL-DVO	1
Dipolog	MNL-DPL	1

Dumaguete	MNL-DGT	1
General Santos	MNL-GES	1
Iloilo	MNL-ILO	1
Kalibo	MNL-KLO	1
Legazpi	MNL-LGP	2
Pagadian	MNL-PAG	3
Roxas	MNL-RXS	1
San Jose	MNL-SJI	1
Tacloban	MNL-TAC	4
Virac	MNL-VRC	1

3. Assignment of Aircraft Type to Destination's Airport

If the destination's airport is not capable of providing airport operations to the aircraft type selected, the decision variable pertaining to that aircraft is removed from the equation of the following constraints: (1) Supply of Available Seats versus Passenger Demand (2) Minimum Flight Frequency and (4) Available Fleet operating hours per aircraft type per day.

The table below indicates the airline's operation of aircraft per airport. A330-200 aircraft type is only operated in the following routes: Cebu (MNL-CEB), Davao (MNL-DVO), and General Santos(MNL-GES). All other aircraft types including A320-200 CEO, A320 NEO, A321-200 CEO, and A321 NEO aircraft type can be operated on all 19 destinations.

Table 6. Assignment of Aircraft Type to Airports

Destination	IATA Coding System (Route)	A330-200	A320-200 CEO, A320 NEO, A321-200 CEO, and A321 NEO
Bacolod	MNL-BCD	Not Used	✓
Boracay	MNL-MPH	Not Used	✓
Butuan	MNL-BXU	Not Used	✓
Cagayan de Oro	MNL-CGY	Not Used	✓
Cauayan	MNL-CYZ	Not Used	✓
Cebu	MNL-CEB	✓	✓
Cotabato	MNL-CBO	Not Used	✓
Davao	MNL-DVO	✓	✓
Dipolog	MNL-DPL	Not Used	✓
Dumaguete	MNL-DGT	Not Used	✓
General Santos	MNL-GES	✓	✓
Iloilo	MNL-ILO	Not Used	✓
Kalibo	MNL-KLO	Not Used	✓
Legazpi	MNL-LGP	Not Used	✓
Pagadian	MNL-PAG	Not Used	✓
Roxas	MNL-RXS	Not Used	✓
San Jose	MNL-SJI	Not Used	✓
Tacloban	MNL-TAC	Not Used	✓
Virac	MNL-VRC	Not Used	✓

4. Available Fleet Operating Hours Per Aircraft Type Per Day

The available fleet operating hours per aircraft type per day is based on the number of aircraft available in the fleet and the allocated operating hours per day. The operating hours of the aircraft is represented by the summation of

$X_{ij}D_i$ which should be less than the available operating hours of the available fleet. $\sum X_{ij}D_i$ is the summation of the multiplication of the flight frequency per aircraft type per route and the route flight time.

The constraint is represented by the equation:

$$\sum X_{ij}D_i \leq \sum No.of\ \ Aircraft\ type\ Available\ x\ Operating\ Hours\ per\ day$$

Let:

$X_{ij} - Flight\ Frequency\ per\ Aircraft\ Type\ per\ Route$, i = aircraft type, j = route
$D_i - Route\ \ flight\ time\ in\ hours,\ \ \ i = Route\ Sector$

Example for the A330-200 aircraft :

$$X_{1F}D_F + X_{1H}D_H +\ X_{1K}D_K \leq 20\ hours\ x\ 1\ aircraft$$

The available fleet operating hours is the product of the fleet count and the allotted operating hours per day which is 20 hours per aircraft. See table 7 below.

Table 7. Assignment of Aircraft Type to Airports

Aircraft Type	Fleet Count	Available Operating Hours Per Day Per Aircraft Type
A320-200 CEO	7	140
A320 NEO	1	20
A321-200 CEO	4	80
A321 NEO	4	80
A330-200	1	20

5. Non-Negativity Constraint

Represented by the inequality X_{ij}, Z ≥ 0 so that no solution is a negative value.

3. Results and Discussion

3.1. Analytical Hierarchy Process

The matrix of pairwise comparisons of the criteria with the priority vector are shown in table 11. The results showed that the highest priority is given to the cost per available seat mile (CASM) with 32.13%. The priority weights of the other criteria are the following: Maximum Take-off weight (MTOW) at 17.12%, Cargo Capacity at 14.83 %, Maintenance cost at 13.37%, Seat Capacity at 12.08%, and Aircraft Price at 10.18%. The consistency ratio (CR) indicates an acceptable level of inconsistency (less than 0.1).

Table 8. Pairwise comparison matrix

	Seat Capacity	Maintenance Cost	Aircraft Price	Cargo Capacity	Maximum Take-off Weight (MTOW)	Cost per Available Seat Mile (CASM)	Eigenvector / Priority Vector
Seat Capacity	1.0000	1.0592	1.3195	0.8706	0.4251	0.4251	0.1208
Maintenance Cost	0.9441	1.0000	1.7826	0.8027	0.6598	0.5173	0.1367
Aircraft Price	0.7579	0.5610	1.0000	0.6988	0.8027	0.3299	0.1018
Cargo Capacity	1.1487	1.2457	1.4310	1.0000	1.1487	0.3196	0.1483
Maximum Take-off Weight	2.3522	1.5157	1.2457	0.8706	1.0000	0.4611	0.1712
Cost per Available Seat Mile (CASM)	2.3522	1.9332	3.0314	2.6052	2.1689	1.0000	0.3213

$\lambda_{max} = 6.0982$ $\quad CI = 0.0196$ $\quad CR = 0.0158$

Table 9. Local and Global Priority Weights

Aircraft Type	Seat Capacity	Average Maintenance Cost	Aircraft Price (USD millions)	Cargo Capacity (lbs)	Maximum Take-off Weight (Tonnes)	Cost per Available Seat Mile (CASM) (US Cents)	Final Priority Vector
A320-200 CEO	0.0499	0.1002	0.1018	0.0151	0.0552	0.2204	0.5425
A320 NEO	0.0521	0.1002	0.0929	0.0151	0.0559	0.2204	0.5366
A321-200 CEO	0.0637	0.1367	0.0869	0.0244	0.0661	0.2918	0.6696
A321 NEO	0.0654	0.0722	0.0794	0.0244	0.0686	0.2610	0.5709
A330-200	0.1208	0.0542	0.0431	0.1483	0.1712	0.3213	0.8589

According to the AHP, the A330-200 has the highest priority in terms of Seat Capacity, Cargo Capacity, Maximum Take-off Weight(MTOW) and Cost per Available Seat Mile (CASM). The A321-200 CEO was the highest in average maintenance cost. The A320-200 was highest in aircraft price. The most suitable aircraft based on the criteria is the A330-200. The overall order of priority in the selection of aircraft fleet is the following: A330-200, A321-200 CEO, A321 NEO, A320-200 CEO, and A320 NEO. The airline company selects the three highest ranking aircrafts type that will be utilized in its operations to nineteen (19) Philippine domestic destinations. The aircraft types selected is then used in the linear programming model.

3.2. Linear Programming

The decision variable, flight frequency per aircraft type per route was solved using Microsoft Excel Solver (See Appendix J). The solving method used was Simplex method of linear programming. Solution time is 0.407 seconds with 54 iterations and 0 subproblems. The minimum daily operational cost is USD 572,842.83. A solution consists a total of 96.61 flights. All of the flights in Cebu and General Santos were allocated to the A330-200 aircraft type. The A330-200 was allocated to Cebu due to the high demand of the destination and high seat capacity of the aircraft type. The A321 NEO aircraft type flights were allocated to Boracay, Kalibo, Legazpi, and Roxas. The flights to Iloilo combined the use of A321 NEO and A321-200 CEO. Flights to Davao utilized the A321-200 CEO and A330-200. This combination was due to the limited operational availability of the A330-200 which transferred the flight assignment to the next aircraft type with the lowest operational cost, the A321-200 CEO. The A321-200 CEO aircraft type was allocated to 13 out of the 19 destinations as shown in Table 10.

Table 10. Solution - Flight Frequency Distribution Table

Destination	A321 NEO	A321-200 CEO	A330-200	Grand Total
Bacolod	0.00	8.23		8.23
Boracay	5.11	0.00		5.11
Butuan	0.00	3.45		3.45
Cagayan de Oro	0.00	9.00		9.00
Cauayan	0.00	2.00		2.00
Cebu	0.00	0.00	12.21	12.21
Cotabato	0.00	1.68		1.68
Davao	0.00	14.15	1.33	15.48
Dipolog	0.00	1.38		1.38
Dumaguete	0.00	3.57		3.57
General Santos	0.00	0.00	2.22	2.22
Iloilo	3.31	6.85		10.16
Kalibo	4.91	0.00		4.91
Legazpi	3.43	0.00		3.43
Pagadian	0.00	3.00		3.00
Roxas	1.86	0.00		1.86
San Jose	0.00	1.00		1.00
Tacloban	0.00	6.92		6.92
Virac	0.00	1.00		1.00
Grand Total	**18.62**	**62.23**	**15.76**	**96.61**

Based on the table above the flight frequency distribution pie chart shows that 16 % of the flights is A330-200 CEO, 19% is A321 NEO and 65% is A321-200 aircraft type.

Constraints

1. Supply of Available Seats versus Passenger Demand

The results showed that four (4) destinations were not binding. The flights in Cauayan, Pagadian, San Jose and Virac exceeded the passenger demand. On the contrary, the solution allocated the seats equal to the passenger demand at the other routes.

2. Minimum Flight Frequency

The results showed four (4) routes are binding. The remaining 15 routes from Manila were not binding. The flight frequency solution to the 15 routes exceeded the minimum requirement.

3. Assignment of Aircraft Type to Destination's Airport

The A330-200 aircraft was only allowed to be operated in three airports. Thus, the solution allocated the majority of flights to A321-200 CEO.

4. Available Fleet Operating Hours Per Aircraft Type Per Day

The constraint was binding to the A330-200 and A321-200 CEO operations. While the solution for A321 NEO aircraft type has a slack of 63.10 hours. 100% of the operational availability of the A330-200 and A321-200 CEO was used. For the A321 NEO, there was 63 hours of available operational hours remaining which means the aircraft type utilization was at 21%.

4. Conclusion

This paper sought to model the problem of selecting the most suitable aircraft to operate and minimizing the daily operating costs. The study used the analytic hierarchy process in selecting the aircraft to be used in the daily operations. And then, the linear programming was applied to find the optimal solution to the flight frequency distribution per aircraft type per route to the proposed destinations with the goal of minimizing the cost.

From the analytic hierarchy process, we have determined that the most suitable aircraft is the A330-200. This is due to its high passenger & cargo capacity, maximum take-off weight, and low cost per available seat mile (CASM). However, not all airports in the Philippines are capable of accommodating such aircraft type. It was realized that the aircraft operational compatibility with the destinations' airports should also be considered. Ultimately, the process supported the airline in choosing the aircraft type most suitable to operate in its domestic operations considering the various criteria. This allows the airline's fleet planning and operations to choose the right aircraft from the set of alternatives. It is shown that AHP can be used as a support tool in the aircraft selection process.

After the selection process, we applied linear programming to minimize the daily operational expenses of the airline company. According to Dozic & Kalic (2014), an airline is interested in carrying out the planned traffic with the least possible number of aircraft, the lowest possible operating costs, and the highest aircraft utilization. With the use of excel solver for linear programming we were able to identify the frequency of flights per aircraft type per route to nineteen (19) domestic destinations that meets the passenger demand at minimum cost to the airline company. In addition, it was also realized that the fleet size could be reduced based on the remaining available hours of operation. The optimal solution maximized the available operating hours of the A330-200 and A321-200 CEO aircraft type. The A330-200's high seat capacity catered to the high demand of the destination. Despite the highest operational cost among other aircraft types, it was able to transport more passengers in one flight. While only 21% of the A321 NEO's operating capacity was utilized. Therefore, the A321 NEO's fleet size could be reduced to only 1 aircraft. The linear programming method was an effective tool in allocating the right aircraft to right destination while considering the operational constraints. This tool provided the company the flight frequency allocation per aircraft type per route to minimize the cost of its operations. In addition, it was also able to determine the appropriate fleet size for the given operational setting of 19 domestic destinations. For its implementation, it is realized that the model requires real-time knowledge of the potential daily demand and the actual availability of each aircraft. The model could also be further enhanced by considering other constraints such as actual crew scheduling, flight scheduling, airport traffic and many other factors affecting flight operations.

Both the analytic hierarchy process (AHP) and linear programming (LP) were an effective tool in supporting the decision-making process of airline domestic operations. The AHP was able to determine the most suitable aircraft. And the LP optimized the fleet operations at minimum cost. Both methods could also be further improved by considering additional factors such as aircraft operational compatibility for AHP and other factors affecting flight operations for the LP model.

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