Proceedings of the Hamburg International Conference of Logistics (HICL) – 25

Partha Kumar Pandit, M. Ahsan Akhtar Hasin

Business Model of Aircraft Fleet Planning using ANN

Published in: The Road to a Digitalized Supply Chain Management
Wolfgang Kersten, Thorsten Blecker and Christian M. Ringle (Eds.)
ISBN 9783746765358, September 2018, epubli

Business Model of Aircraft Fleet Planning using ANN

Partha Kumar Pandit[1], M. Ahsan Akhtar Hasin[2]

1 – Bangladesh Airlines Training Center BATC

2 – Bangladesh University of Engineering and Technology

The purpose of Aircraft Fleet Planning is to provide the number and type of aircraft for acquisition, its time of acquisition, and trade-in or phase out of fleet. Airlines select a particular type of aircraft from the manufacturer on the basis of optimum cost, considering a number of constraints. Because of existence of several conflicting criteria, the solution approach becomes an NP-hard problem. As such, a traditional linear programming approach cannot optimize the system in a reasonable time frame. This paper aims at developing a model for selecting aircraft using Artificial Neural Networks. Key inputs have been obtained from the major areas of aircraft design characteristics, aircraft physical performance, maintenance needs, operating economics, acquisition cost, operating cost and customer satisfaction. The input values are fuzzy in nature. However, several methods for combined use of fuzzy logic systems and neural networks have been suggested. Experience, which is conventionally used for selecting a particular type of aircraft, has been used for training of the proposed network. Single-layer ANN model provided a good solution with optimality in cost, without sacrificing time constraint and algorithmic complexity. The airline business will be immensely benefited from the solution procedure.

Keywords: Aircraft Fleet Planning; ANN; Fuzzy

First recieved: 24.May.2018 *Revised:* 04.Jun.2018 *Accepted:* 22.Jun.2018

1 Introduction

Aircraft Fleet planning process determines type of aircraft the airline should buy and their numbers, in order to achieve organizational goals. Corporate planning deals with the need of the airlines, current resources, corporate objective, projected industry environment and marketing strategy. Specific requirement of the airlines is then identified through marketing research and analysis on the basis of the set company objectives.

Given a flight schedule, which is a set of flight segment with specified departure and arrival times and a set of aircraft, the fleet assignment problem is to determine which aircraft type should fly each flight segment (Clark et al., 1996). The objective is to maximize revenue minus operating cost. In the basic fleet assignment problem considered by Clark et al.(1996) a daily, domestic fleet assignment problem is modeled and solved with up to eleven fleets and 2500 flight legs.

Satisfied customers usually return back and buy more, they tell other people about their experiences. Customer Satisfaction is one of the most important processes in airline industry and is recognized as the key to the success of business competition. Like any other industry, airlines first measure the expectation of its passenger, analyzes the consumer behaviour, prepares a customer satisfaction program to provide a set of standard customer services, identifies the service gap and tries for continual improvement.

This research considered the issues of aircraft cost and customer satisfaction in selecting aircraft and developing models integrating these two separate issues – cost estimation and customer satisfaction. Solution methodologies of Fuzzy Logic and Artificial Neural Network have been adopted.

1.1 Aircraft Selection Process

Air transportation offers both passenger and freight services that are essential for economic growth and development. In a highly competitive environment, airline companies have to control their operating costs by managing their flights, aircraft, and crews effectively.

Fleet assignment involves the optimal allocation of a limited number of fleet types to flight legs in the schedule subject to various operational constraints (Jacobs and Johnson, 2008). Airlines typically manage their annual business cycle by subdividing the year into a sequence of scheduling periods that span about a month each (Ahmad, 2000).

Aircraft selection process is a dynamic function, coordinated by a number of group functions including corporate planning. The life cycle starts with the corporate objective of acquisition of new aircraft in the fleet. The planning life cycle is shown in Figure 1.

Data acquisition is the next step. Information related to any kind of lease or purchase of aircraft and making comparative statements, relevant information is required. Then evaluation of data is the logical sequence.

The next step is the purchase negotiation and finally acquisition of the aircraft. Many sections of the airlines will be involved when aircraft is going for its operation. Continuous updating/modifying the aircraft will be going on until the aircraft is disposed off.

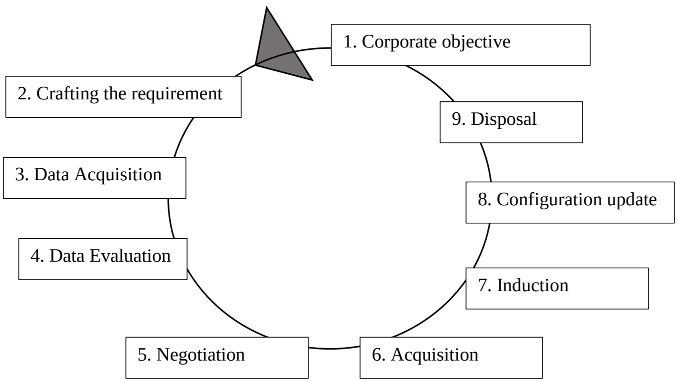

Figure 1: Fleet planning life cycle

1.2 Cost Consideration of Airline

In order to maximize anticipated profit, cost is a vital area for all business. Costing is also important for pricing of its product. The price of average revenue per passenger mile must be sufficient to cover average cost per passenger mile flown. Airline operating cost is categorized in two areas – direct operating cost or variable costs and indirect operating cost or fixed-overhead costs.

A flight sequence or route is built for each individual aircraft so as to cover each flight exactly once at a minimum cost while satisfying maintenance requirements. Finally, in the crew scheduling or pairing optimization problem, a minimum cost set of crew rotations or pairings is constructed such that every flight is assigned a qualified crew and that work rules and collective agreements are satisfied. In practice, most airline companies solve these problems in a sequential manner to plan their operations, although recently, an increasing effort is being made to develop novel approaches for integrating some of the airline operations planning problems while retaining tractability.

The cost categories (Swan and Adler, 2006) include pilot, cabin crew, fuel, Landing fee, airframe maintenance, engine maintenance and the ownership costs of the aircraft. The flight crew costs include all costs (Ssamula and Mistro, 2004) associated with the flight and cabin crew including allowances, pensions, salaries, etc.

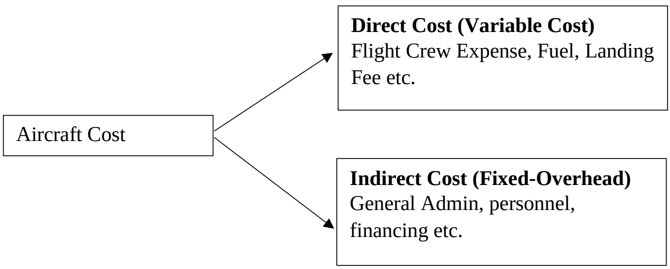

Figure 2: Types of cost

The costs of an airline incurs in producing available seat miles (ASM) depend upon the type of adjustments it is able to make in the amounts of the various resources it employs. The quantities of many resources used – labour, fuel and so forth-can be varied relatively quickly in the short run. But amounts of other resources demand more time of adjustment.

1.3 Customer Satisfaction - a primary Paramater

Introduction of wide body service in the early 1970s marked the climax of production –sales orientation in the air transport industry. Excess capacity and shortage of customer changed the marketing concept to a customer –oriented approach.

The industry entered into its matured stage since 1960s. Weaker competitors left the industry. The remaining competitors have become well entrenched, and the marketing policy and images are well known. Customer loyalties and market shares became stabilized.

Evaluation of customer satisfaction differs from one study to another. Studies have been differing with their focus and coverage. Most of the studies focused on evaluating factors influencing customer satisfaction or associated customer satisfaction and quality of services (Josephat and Ismail, 2012). Logistic regression was used to develop customer satisfaction model for Precision Air.

Customers' satisfaction degree is customers' comparative evaluation between expectation and perceived value for the products and the services after making relevant payment for their proceeds. Satisfaction or dissatisfaction after the purchase, depends not only on the difference between performance that customers actually feel and expected, but also upon their costs that they pay in order to get the profits, that is to make customers obtain the maximum discount. Customers' delivered value means the difference between the total value of customers and the total cost of customers.

Service encounters that do not meet expectations should have a bigger impact on customers than service encounters that exceed expectations. Furthermore, if customers are concerned about the possibility of service encounters that do not meet expectations, future sales and profitability may be negatively influenced (Shaun et al., 2005).

2 Theoretical Background

The flying performance of different aircraft model is different, for example, range of aircraft, flying altitude ceiling, maximum takeoff weight, maximum zero fuel weight, available cargo space and many more. So a particular route is not suitable for all models of the aircraft to perform. In addition, different models have different seating capacity, layout and their operating costs are not same (Li, and Tan, 2013). Profit maximization is the primary goal of an airline whereas customer satisfaction is considered to be the secondary goal through which strategic advantage can be achieved.

Conventionally, a computer operates through sequential linear processing technologies. They apply formulas, decision rules, and algorithms instructed by users to produce outputs from the inputs. Conventional computers are good at numerical computation. But ANNs improve their own rules; the more decisions they make, the better the decisions may become.

ANN can determine the optimal solution to an NP-complete (nondeterministic polynomial) problem, such as the travelling salesperson problem. This is equivalent to linear and integer programming in management sciences, where the objective functions are optimized using a heuristic search procedure. there is no doubt that ANNs are feasible for business applications. Many phenomena that are difficult to describe can be modeled by ANNs, if carefully designed.

Artificial Neural Networks have emerged as a very popular area of research, both from the design and the usage points of view. There is considerable research emphasis on designing better and more efficient neural networks, more powerful ”learning algorithms”, better transfer functions etc. On the other hand there is a great amount of academic interest in the applications of neural networks. Disciplines as diverse as the biological sciences and finance have applications that use neural networks. There is a significant volume of research on neural networks in the engineering and science literature. There also exists a reasonable body of neural network research as related to business.

2.1 Profit Maximization Model

Considering the features of a particular route and flight plan, under constraints of pre-announced flight schedules, not considering the flight stopovers and having enough airport capacity, the model (Pandit et al., 2010) which considers matched flying area, as well as the traffic match conditions can be proposed as follows:

$$\text{Max} \sum_{i=0}^{m} \sum_{j=1}^{n} P_{ij} x_{ij} \tag{1}$$

$$\sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} = m \tag{2}$$

$$\sum_{j=1}^{n} x_{ij} = 1 \tag{3}$$

$$x_{ij} d_j \geq D_j \qquad i = 1, 2, 3 \ldots, m; \; j = 1, 2, 3 \ldots, n \tag{4}$$

$$x_{ij} s_j \geq S_j \qquad i = 1, 2, 3 \ldots, m; \; j = 1, 2, 3 \ldots, n \tag{5}$$

$$x_{ij} r_j \geq R_j \qquad i = 1, 2, 3 \ldots, m; \; j = 1, 2, 3 \ldots, n \tag{6}$$

Where,

$i = 1, 2, 3 \ldots\ldots, m\, m$	is overall flight number
$j = 1, 2, 3 \ldots\ldots, n\, n$	is the number of aircraft model
P_{ij}	the revenue of aircraft model j to perform the flight i
	E_{ij} Revenue earned from model j to flight i
$P_{ij} = E_{ij} - F_{ij} - V_{ij}$	F_{ij} Fixed operating cost of model j to flight i
	V_{ij} is the variable operating cost of model j to fly flight i
x_{ij} { 0	flight i is performed by the aircraft model j
1	else otherwise
d_j	is the range of the aircraft model j
D_i	is the distance of the flight i
s_j	is the seating configuration of the aircraft model j
S_j	is the required traffic of the flight i
r_j	is the flying requirement (ETOPS, TCAS,..)of the model j
R_j	is the flying requirement (ETOPS, TCAS,..) of the route
g_j	is the cargo space available in model j
G_j	is the cargo space requirement in flight i

The objective function (1) means that the total income of all flights is largest, after the aircraft types are assigned to all flights considering the bulk of the flights of global optimization. Constraint (2) is to ensure that an equal number of models are selected for flights. Constraint (3) is to ensure that only one model is assigned to each flight. Constraint (4) is to ensure that the model assigned to the flight meets the flight distance requirements. Constraint (5) is to ensure that the model assigned to the flight meets the traffic requirement is fulfilled by the seating capacity. Constraint (6) is to ensure that the selected model meets the technical requirements of the route.

2.2 Integrated Fleet Planning Model

As a decision making process integrated fleet planning depends on Design characteristics, Physical Performance, Maintenance Needs, Acquisition cost, operating economics (Pandit and Hasin, 2010).

In this research, the fleet planning problem (FPP) has been defined as a multi-objective optimization function with cost minimization and satisfaction maximization as follows:

$$\text{FPP} = \text{Selection}\left[\text{Min}\sum C_{ij},\ \text{Max}\sum S_{ik}\right] \tag{7}$$

Where

i = alternative aircraft

j = cost parameters

k = satisfaction parameters

The constraints are the required Design characteristics, Physical Performance, Maintenance Needs, Operating Economics and availability of Acquisition Cost.

Selection of aircraft on the basis of optimal solution is the unique goal of this research. The input values are considered as fuzzy in nature. However, in contrast to neural networks, fuzzy decision logic systems are not capable of automatic learning. To solve this problem, this research utilized combined use of fuzzy logic systems and neural networks.

In this research, fuzzy neural network approach is used, where neural network part is primarily used for its learning and classification capabilities and for pattern association and retrieval. For neural network analysis, a two-layer hidden function is used which proves sufficient for learning. The data set for learning is derived from the available business results, which are optimized using conventional linear or integer programming approach, as used typically by some airlines research organizations.

The quantitative features, considered here, are costs and expenses of acquisition for purchase of aircraft, its spares, ground support equipment, maintenance training, flight training, financing, pre-payment, maintenance, fuel, general administrative activities, sales promotion activities, passenger service and handling, cockpit and cabin crew, dispatcher, insurance and rental charges, landing and navigation fees.

The fleet planning data used in this research are – available aircraft and specific requirement of fleet planning in terms of destination, type of load to be carried, time of aircraft acquisition.

Once these features were extracted, their probable fuzzy relations were determined. It is necessary to note that fuzzy relation provides an analyzer with a rich framework within which many problems emerging from practical applications of the theory are formulated.

This research also utilized this strength of fuzzy relations. However, the great utility of fuzzy relation equations was somewhat hampered by the rather high computational demand of conventional linear programming optimization models, which is supported by the existing literatures as well (Oliver, 1997).

A sensitivity analysis was also performed for minimization of deviations from desired outputs. The desired response of the network to which each input pattern and its comparison with the actual output of the network were used in the learning algorithm for appropriate adjustments of the weights. These adjustments whose purpose was to minimize the difference between the desired and actual outputs were made incrementally.

That is small adjustments in the weights are made in the desired direction for each training pair. This is essential for facilitating a convergence to a solution (specific values of the weight) in which patterns in the training set are recognized with high fidelity.

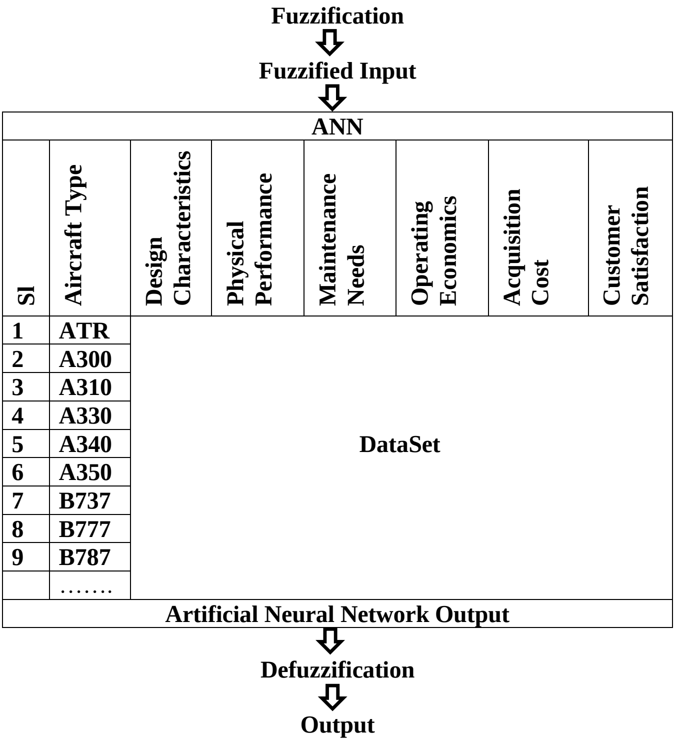

Figure 3: Detailed Model

3 Outline of Methodology

In order to carry out this research work, steps that have been adopted are mentioned below:-

3.1 Fuzzification

Uncertainties regarding all satisfaction data have been handled with the help of fuzzy membership function and finally Customer Satisfaction fuzzy ranking is prepared for different aircraft.

Passenger satisfaction data was collected from the reviews made by the passengers for different flights with different aircraft. In those reviews, they had options to give comment and make ranking on a number of issues like-seat comfort, satisfaction for Catering, satisfaction for entertainment, value for money and staff comfort.

3.2 Neural Network Design

The work flow for the general neural network design process has seven primary steps:

1. Collection of data
2. Creating the network
3. Configuring the network
4. Initializing the weights and biases
5. Training of the network
6. Validating the network (post-training analysis)
7. Using the network

Aircraft specification and data sheets have been collected from individual manufacturer and other sources. Aircraft parameters and cost related data have been collected from different airlines. Customer satisfaction fuzzy ranking is also being used as input of the ANN.

Database has been prepared and updated for all aircraft. Database has also been developed for customer satisfaction, taking into account factors like seat comfort, catering service, entertainment and overall remarks on different past flights.

Route data has been collected from flight history of aircraft. Route data have been collected for five routes- Dhaka-Bangkok, Dhaka-Dubai, Dhaka-Kathmandu, Dhaka-Kolkata and Dhaka-Kuala Lumpur. For selecting aircraft for a particular route, flight histories for five routes have been taken. The routes and the aerial distances are mentioned in Table 1.

Flight history has been taken from all these routes. Airline operating in these routes have different types of aircraft having differences in design data, performance data, seat capacity, cost data, satisfaction data. It is worthy to mention here that there are some common aircraft also being operated by different airlines.

Table 1: Routes used for flight history

Route No.	From	To	Distance KM
1	Dhaka (DAC)	Bangkok (BKK)	1533
2	Dhaka (DAC)	Dubai (DXB)	3555
3	Dhaka (DAC)	Kathmandu (KTM)	676
4	Dhaka (DAC)	Kolkata (CCU)	245
5	Dhaka (DAC)	Kuala Lumpur (KUL)	2579

Feed Forward network of Artificial Neural Network has been implemented for training, validating and finally testing. After establishment of network it was tested by different data sets to check its response.

3.3 Defuzzification

Defuzzification is the process of converting a fuzzified output into a single crisp value with respect to a fuzzy set. A common and useful defuzzification technique is center of gravity. The centroid of this shape, called the fuzzy centroid, is calculated. The x coordinate of the centroid is the defuzzified value.

4 Result

Satisfaction data is full of uncertainties. Application of fuzzy logic with a number of rules could provide a crisp result on ranking. This ranking was used as a special input for Artificial Neural Network.

4.1 Customer Satisfaction Fuzzy Ranking

The remarks given by the passengers were collected for preparing customer satisfaction fuzzy ranking. These remarks were made flight wise for a particular airline. Passengers put their recommendations on seat comfort, satisfaction for Catering, satisfaction for entertainment, value for money and staff comfort in a ranking scale of 10. Airlines wise such remarks were collected and categorized according to aircraft.

Two columns namely value for money and staff comfort have no direct correlation with the type of aircraft the airline used. So for the sake of this research, these two columns were omitted. For Seat comfort, catering and entertainment the linguistic variables are

Very Low	VL
Low	LO
Medium	MI
High	HI
Very High	VH

For final recommendations, following were the linguistic variables

Not recommended	NR
Recommended but needs improvement	RC
Highly Recommended	HR

The mode (with highest frequency) is considered. If the remarks are transferred into linguistic comments, the table becomes as follows.

Table 2: Linguistic expression of Satisfaction

ICAO Code	Seat Comfort	Catering Comfort	Entertai-nment	Satisfaction Fuzzy	Coding
A310	LO	MI	VL	1	NR
A319	MI	MI	VL	1	NR
A320	HI	HI	MI	2	RC
A333	LO	HI	MI	2	RC
A336	LO	HI	MI	2	RC
B735	HI	HI	MI	2	RC
B736	MI	LO	VL	1	NR
B737	HI	HI	MI	2	RC
B738	HI	HI	MI	2	RC
B739	HI	HI	HI	3	HR
B772	HI	HI	MI	2	RC
B77W	VH	VH	VH	3	HR
B762	LO	MI	VL	1	NR
DH8C	MI	MI	VL	1	NR
DH8D	MI	LO	VL	1	NR
E145	HI	MI	MI	2	RC
AT73	LO	HI	VL	1	NR
MD11	HI	MI	VL	1	NR

Fuzzy Inference System has been used in this situation. The system has three inputs (Seating, Catering and Entertainment) and one output (Satisfaction). 8 rules are used to setup the Inference system. The summary of the GUI system is placed here. Triangular membership function were used with the following parameters for the input variables

Table 3: Fuzzy Input Variable

Input Variable	MF	MF Definition	MF Type
Seating	VL	[0.037 0.602 1.24]	trimf
	LO	[0.7882 1.448 2.189]	trimf
	MI	[1.78 2.36 3.221]	trimf
	HI	[2.73 3.34 4.24]	trimf
	VH	[3.76 4.23 5.02]	trimf
Catering	VL	[0.0114 0.575 1.157]	trimf
	LO	[0.853 1.554 2.27]	trimf
	MI	[1.82 2.36 3.142]	trimf
	HI	[2.743 3.353 4.253]	trimf
	VH	[3.81 4.25 5.033]	trimf
Entertainment	VL	[-0.0331 0.5754 1.21]	trimf
	LO	[0.708 1.396 2.25]	trimf
	MI	[1.753 2.277 3.127]	trimf
	HI	[2.7 3.21 4.22]	trimf
	VH	[3.75 4.18 5.033]	trimf

Table 4: Fuzzy Output Variable (Triangular Membership)

Output Variable	MF	MF Definition	MF Type
Satisfaction	NR	[0.0104 0.853 2.03]	trimf
	LO	[1.52 2.44 3.485]	trimf
	MI	[3 3.909 5.01]	trimf

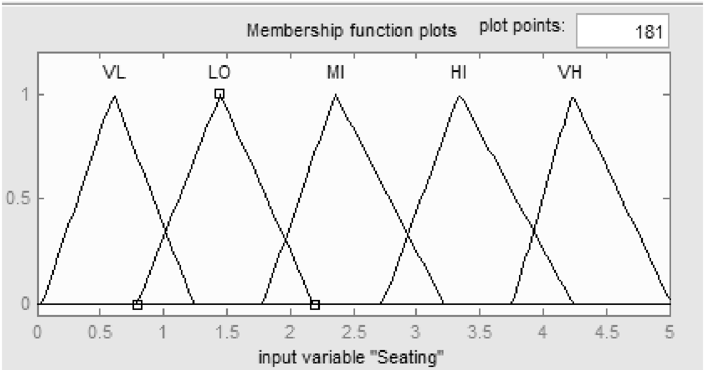

Figure 4: Membership Plot of input variable Seating

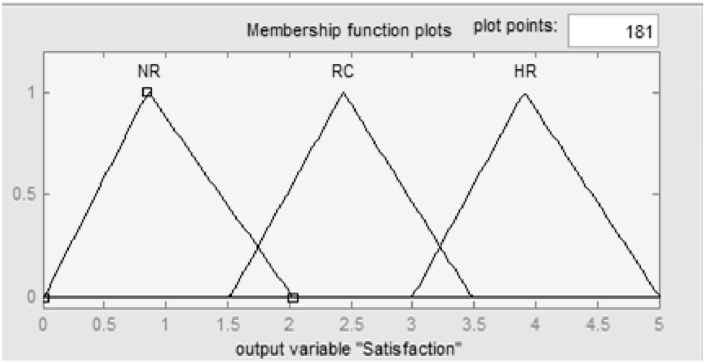

Figure 5: Membership Plot of output variable Satisfaction

The rules used in this FIS are

Rule 1. If (Seating is VL) or (Catering is VL) or (Entertainment is VL) then (Satisfaction is NR)

Rule 2. If (Seating is HI) and (Catering is not VL) and (Entertainment is not VL) then (Satisfaction is RC)

Rule 3. If (Seating is not VL) and (Catering is HI) and (Entertainment is not VL) then (Satisfaction is RC)

Rule 4. If (Seating is not VL) and (Catering is not VL) and (Entertainment is HI) then (Satisfaction is RC)

Rule 5. If (Seating is HI) and (Catering is HI) and (Entertainment is HI) then (Satisfaction is HR)

Rule 6. If (Seating is VH) and (Catering is not VL) and (Entertainment is not VL) then (Satisfaction is HR)

Rule 7. If (Seating is not VL) and (Catering is VH) and (Entertainment is not VL) then (Satisfaction is HR)

Rule 8. If (Seating is not VL) and (Catering is not VL) and (Entertainment is VH) then (Satisfaction is HR)

After fuzzification the output value is now ready to be used for Artificial Neural Network as described in the detailed model in figure 3.

4.2 Artificial Neural Network

The nftool of MATLAB is used for the Artificial Neural Network. nftool leads through solving a data fitting problem, solving it with a two-layer feed-forward network using Levenberg-Marquardt Algorithm and trained with trainlm algorithm.

4.2.1 Neural Network Summary

Input Layer :	26 Neurons
Hidden Layer:	10 Neurons
Output Layer :	1 neuron
Algorithm used:	Levenberg-Marquardt Algorithm

Table 5: Satisfaction Ranking

ICAO Code	Seating	Catering	Ent.	Sat.	Sat. Rank
A310	1.67	2.3	0.3	0.981	3
A319	1.9	3.1	0.45	1.37	6
A320	2.85	3.9	2.88	3.04	17
A333	1.1	2.9	2.8	1.8	9
A336	0.89	3.56	3	1.67	8
B735	3.12	2.9	2.87	2.99	16
B736	2.25	1.45	0.6	0.965	1
B737	2.85	3.4	2.33	2.48	11
B738	2.85	2.87	2.29	2.5	13
B739	2.88	3.4	3.4	2.93	15
B772	3.5	3.83	2.26	2.57	14
B77W	4.1	3.9	3.85	3.39	18
B762	1.2	1.9	0.45	0.969	2
DH8C	2.4	1.9	1.1	1.01	5
DH8D	1.8	1.7	1	0.995	4
E145	2.9	2.8	2.28	2.49	12
AT73	1.4	2.99	0.45	1.37	7
MD11	3.23	1.93	1.1	2.13	10

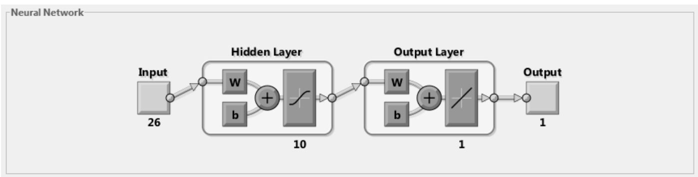

Figure 6: Neural Network Layers

After establishing the network it needs training. For that purpose developed data sets are provided to the network as data_in from a data file. Also the target was provided through another data file called data_out. 70% data (772 Samples) are used for training, 15% (166 Samples) for validation and another 15% (166 Samples) are used for testing purpose.

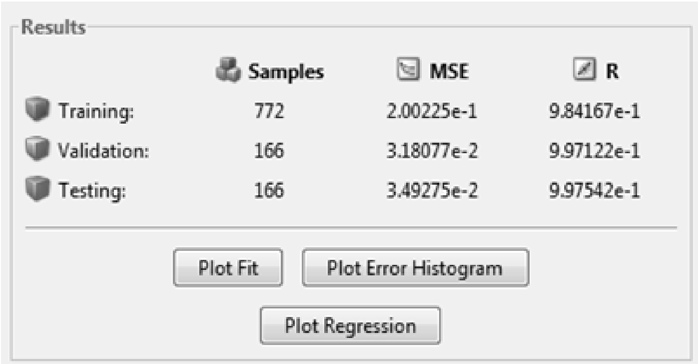

Figure 7: Training, Validation and Testing data samples

4.2.2 Training Summary

The process to train a neural network involves tuning the values of the weights and biases of the network to optimize network performance, as defined by the network performance function. The training of neural network depends on many factors - complexity of the problem, the number of data points in the training set, the number of weights and biases in the network, the error goal and whether the network is being used for function approximation (regression).

In Levenberg-Marquardt Algorithm of feed forward network, trainlm algorithm is used for training. Iteration is one step taken in the gradient descent algorithm towards minimizing the loss function using a mini-batch. An epoch is the full pass of the training algorithm over the entire training set. The training state is presented in Figure 8.

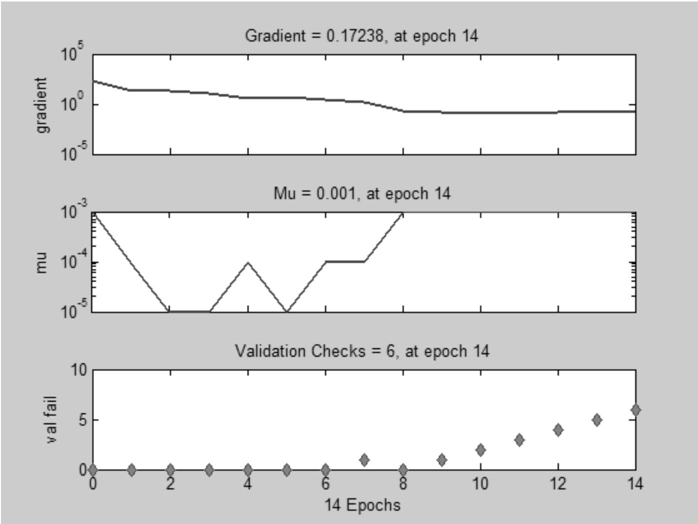

Figure 8: Training State of the network

4.2.3 Result of Regression Analysis

The neural network randomly selects data from the given data set for training, testing and validating. In each set of data the relationship between target and actual output exists which is performed by a correlation analysis to establish a linear relationship.

Regression analysis describes a relationship between target and actual output of the developed network. Regression analysis in Figure 9, presents least-squares fit for four distinct situation of Training, Validation, Testing and All samples.

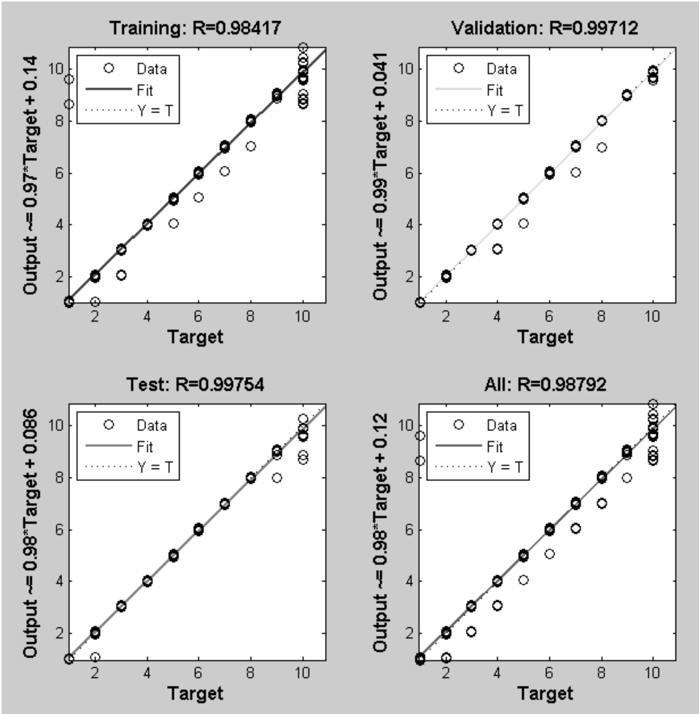

Figure 9: Regression Analysis

4.2.4 Performance of Network

When the training in is complete, the network performance is checked and determined if any changes need to be made to the training process, the network architecture, or the data sets. The performance of the network is shown in Figure 10.

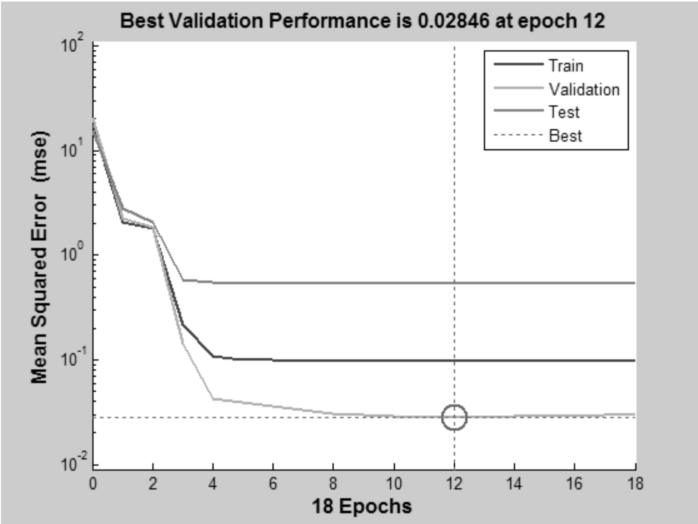

Figure 10: Performance of the network

4.2.5 Simulink

With the help of Simulink, the system is simulated interactively and viewed the results on scopes and graphical displays. The integration of Simulink and MATLAB enables to run unattended batch simulations of Simulink models using MATLAB commands.

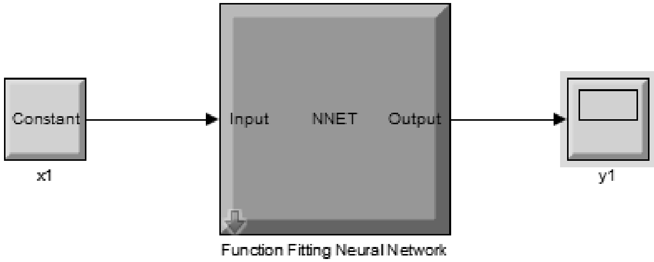

Figure 11: Simulink Diagram

5 Findings

Main objectives of this research were to develop a fleet planning model for selecting aircraft in a particular route where cost is minimized and customer satisfaction is maximum. By using fuzzy logic for customer satisfaction ranking and Artificial Neural Network for the established databases.

The Artificial Neural Network has been established with 26 neurons in the input layer, 10 neurons in the middle hidden layer and 1 output neuron. The network has been trained, validated and tested for being used by the user.

Feed Forward network using Levenberg-Marquardt Algorithm do not show always the same accuracy as the human brain. Generally it is a very good algorithm to reach its global minima when the error learning is concerned. Summary of the

Table 6: List of Sample used

Sample Type	Number of Sample
Total	1104
Training -70%	772
Validation -15%	166
Testing -15%	166

Table 7: Network Accuracy

Epoch	MSE			Regression			
	Train	Valid	Test	Train	Valid	Test	All
13	0.0736	0.0346	0.0422	0.988	0.9635	0.9976	0.985
20	0.0402	0.0278	0.0624	0.984	0.9968	0.9968	0.988
18	0.0976	0.0284	0.0536	0.992	0.9975	0.9543	0.987
14	0.2002	0.0318	0.0342	0.984	0.9971	0.9975	0.987

Mean squared Errors (MSE) and network accuracy (Regression-R) values are as follows:

The network has been tested for known and unknown inputs for recognizing the output.

Sample Input

[5; 202; 2579; 2;56000; 897; 5170; 80142; 142000; 41000; 280; 1204; 5.82; 23591.176; 940.65; 1457.43; 320; 26309.256; 1827.92; 28137.176; 280; 100.4899143; 0.981; 3; 25.7; 10]

From the Simulink output window, the output is 1 and when it is decoded for finding the real value of 1, it is found that the selected aircraft is A310.

Aircraft specification, design characteristics, aircraft performance data, power plant data, customer satisfaction data needs regular updating for correct decision making by the neural network.

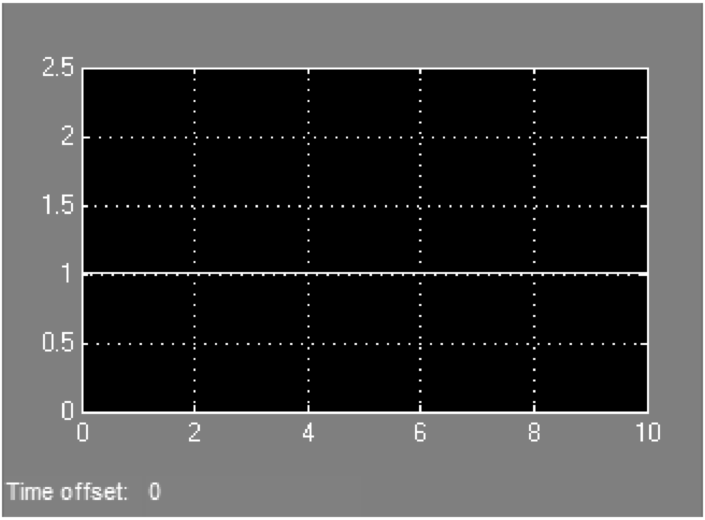

Figure 12: Simulink Output window

6 Conclusion

Airline industry is suffering from lack of integrated fleet planning mechanism, considering multiple input factors, along with uncertainties in different forms and at various stages. This research developed a mathematical model with dual objectives of minimizing operating costs and maximizing customer satisfaction. In this perspective the model developed by the researcher and its implementation through fuzzy logic and artificial neural network has given good results with respect to both objectives. Computer simulation has provided useful sensitivity with respect to varied input data sets. With slight modifications and updating of data on a regular basis, the model can serve the purposes of other regions of the world.

For specific optimization problem, other optimization algorithms may find better solutions than Fuzzy Neural Network combination (given the same amount of computation time). In this particular fleet planning problem, future research potential lies in the area of using other algorithms like evolution strategies, evolutionary programming, simulated annealing, Gaussian adaptation, hill climbing and swarm intelligence and methods based on integer linear programming.

References

Clarke, L. W., C. A. Hane, E. L. Johnson, and G. L. Nemhauser (1996). "Maintenance and crew considerations in fleet assignment". In: *Transportation Science* 30.3, pp. 249–260.

Jacobs, T. L., B. C. Smith, and E. L. Johnson (2008). "Incorporating network flow effects into the airline fleet assignment process". In: *Transportation Science* 42.4, pp. 514–529.

Jarrah, A. I., J. Goodstein, and R. Narasimhan (2000). "An efficient airline re-fleeting model for the incremental modification of planned fleet assignments". In: *Transportation Science* 34.4, pp. 349–363.

Josephat, P. and A. Ismail (2012). "A logistic regression model of customer satisfaction of airline". In: *International Journal of Human Resource Studies* 2.4, p. 197.

Li, Y. and N. Tan (2013). "Study on fleet assignment problem model and algorithm". In: *Mathematical Problems in Engineering* 2013.

Mcquitty, S., M. Hyman, R. Oliver, P. Sautter, and A. Stratemeyer (2005). "Service variability and its effect on consumer perceptions and intentions". In: pp. 264–294.

Oliver, R. (1997). *Satisfaction: a behavioral perspective on the consumer*.

Pandit, P. K., M. A. A. Hasin, and M. A. Sharif (2010). "Aircraft Fleet Planning Under Varying Demand using Aggregate Resource Planning Concepts". In: *International Journal of Logistics and Transport*.

"Pioneering Solutions in Supply Chain Management: A Comprehensive Insight Into Current Management Approaches" (2010). In: Erich Schmidt Verlag, Germany. Chap. Integrated Aircraft Fleet Planning using Fuzzy Logic and Artificial Neural Network Approach.

Ssamula, B. and R. F. Del Mistro (2004). *Developing a cost model for running an airline service*. Citeseer.

Swan, W. M. and N. Adler (2006). "Aircraft trip cost parameters: A function of stage length and seat capacity". In: *Transportation Research Part E: Logistics and Transportation Review* 42.2, pp. 105–115.