Neural networks application in the aviation industry

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Abstract. Current trends in the passenger air transportation market have led to an increase in the importance of forming a stable relationship between airlines and passengers, especially through the formation of their loyalty. The purpose of this study is to substantiate the use of artificial intelligence to assess the loyalty of airline customers. The paper proposes a model of the influence of factors on passenger loyalty to the quality of airline services. It is proposed to make the loyalty program more targeted, focused on the specific needs of the passenger. Based on the information that the airline collects and stores about each passenger, it is proposed to divide passengers according to their key characteristics and to develop a system of bonuses and discounts for each cluster. To cluster passengers, a multilayer neural network with direct communication was built, the reliability of the obtained results and the possibility of their use to manage the loyalty of airline passengers was proved.

1. Introduction
The aviation industry is highly competitive in the world, as companies offer very similar products and compete for the same customers. The classic business model of air transportation involves the provision of high quality services that will be valuable to passengers. This value is expressed in the fact that in addition to the provision of basic services, ie moving from place to place, there are a large number of additional services that passengers use and for which they are willing to pay. In addition, the market for passenger air transport services is becoming more diverse and consumers are demonstrating a wider range of needs. First of all, this is due to the specifics of the air transport industry - the intensification of the struggle for customers, especially in external areas, where competition is growing rapidly. Therefore, for air carriers that offer almost a similar set of consumer properties, it is important to know the attitude to these specific characteristics of services and their individual groups of potential customers of the airline.

2. Literature review and problem statement
The world's airlines increased passenger traffic by 4.2% in 2019, according to the International Air Transport Association (IATA). Meanwhile, the congestion of passenger flights last year increased by 0.7% - to 82.6% which is the record. The previous maximum of 81.9% was set in 2018 [1].

In 2019, the market of passenger air transportation in Ukraine also continued to show positive dynamics. According to statistics, the number of passengers who used the services of Ukrainian airlines increased by 9.4% and amounted to 13,705.8 thousand people. During the year, passenger

traffic was provided by 18 domestic air carriers, among which the largest volumes were performed by Ukraine International Airlines, Azur Air Ukraine, SkyUp, Wind Rose and Bukovyna. In 2019, the five leading airlines transported in total 13,306.7 thousand people, which is 22.4% more than in 2018 and is 97% of the total passenger traffic of Ukrainian airlines [2]. The positive trend that has developed in recent years is primarily due to the successful development of the international air transportation sector. But the dynamics of increasing demand for air travel in Ukraine and abroad is uneven. (table 1) According to the State Aviation Service of Ukraine, for 5 years the number of passengers on domestic flights increased by almost 85.5 %, and on international flights - by almost 121 %. This growth is mainly due to transit traffic and flights of foreign companies, the volume of which, according to the State Aviation Service, is more than 70%. Only 4-5% of the population in Ukraine uses air transport (according to other, more pessimistic estimates, no more than 2% of the population flies) [3]. Therefore, the coefficient of aviation mobility is equal to 0.5. For comparison, in the EU it is at least 2, and in the US - more than 2.5.

Table 1. Dynamics of air travel in Ukraine [2]

Indicators	2015	2016	2017	2018	2019	2020 (the first half)
Passengers were transported, thousand people	6304,3	8277,9	10555,6	12533,4	13705,8	2009,2
international flights	5679,6	7475,4	9614,5	11450,5	12547,2	1802,3
domestic flights	624,7	802,5	941,1	1082,9	1158,6	206,9
Made flights, units	66332,0	79520,0	93042,0	100242,0	103293,0	19854,0
international flights	56066,0	67881,0	78072,0	83997,0	86654,0	16558,0
domestic flights	10266,0	11639,0	14970,0	16245,0	16639,0	3296,0
% of passenger traffic on scheduled flights	79,1	78,1	77,5	78,9	80,7	71,1

But the 2020 pandemic has brought significant changes to the aviation industry and the global economy as a whole. According to the industry research company Cirium, in March 2020 the number of flights in the world decreased by 63% compared to the same period in 2019. In the United States, passenger flights have decreased by 95% due to the COVID-19 pandemic and measures taken to combat it. [4]

According to the International Air Transport Association, this year the volume of passenger air traffic in the world will decrease by 54.7%, the number of passengers will be reduced almost twice - to 2.25 billion, and net losses of airlines worldwide will be about 84 billion dollars. For comparison, during the global financial crisis in 2008-2009, airlines lost $ 31 billion. [5]. It is expected that in 2021 passenger traffic will increase by 55%. At the same time, it will still be 29% lower than in 2019, and this means new financial losses - about $ 15 billion. Thus, in total, according to IATA estimates, due to the pandemic, airlines will totally lost $ 100 billion.

Such current trends have led to an increase in the importance of forming a stable relationship between airlines and passengers, especially through the formation of their loyalty. Therefore, in modern conditions of increasing market competition, the central place in the theory and practice of marketing is the problem of improving the relationship between the airline and the customer. As practice shows, an increase in loyalty by 2% reduces the costs of the enterprise by 10%, which, in turn, leads to an increase in its profits by an average of 16% without increasing sales and prices [65, p. 148]. Thus, today the foundation of ensuring a stable volume of passenger traffic is a positive attitude towards the airline and its services, ie the presence of customer loyalty.

3. The aim and objectives of research

The purpose of this study is to substantiate the use of artificial intelligence to assess the loyalty of airline customers.

4. The method of tandem propeller hub losses reduction

Essentially, the basis of perception or emotional loyalty is a positive experience gained by the customer in the process of buying or consuming a particular product or service. If the customer is completely satisfied with the quality of the purchased product or service, then with a high probability we can say that with other constant factors, making the next purchase, he will again make a choice in favor of this brand and will re-purchase products of this company [7, p. 20].

After analyzing the impact of factors on passenger loyalty to the airline brand, we can develop the following model of their impact on loyalty, which is presented in Figure 1.
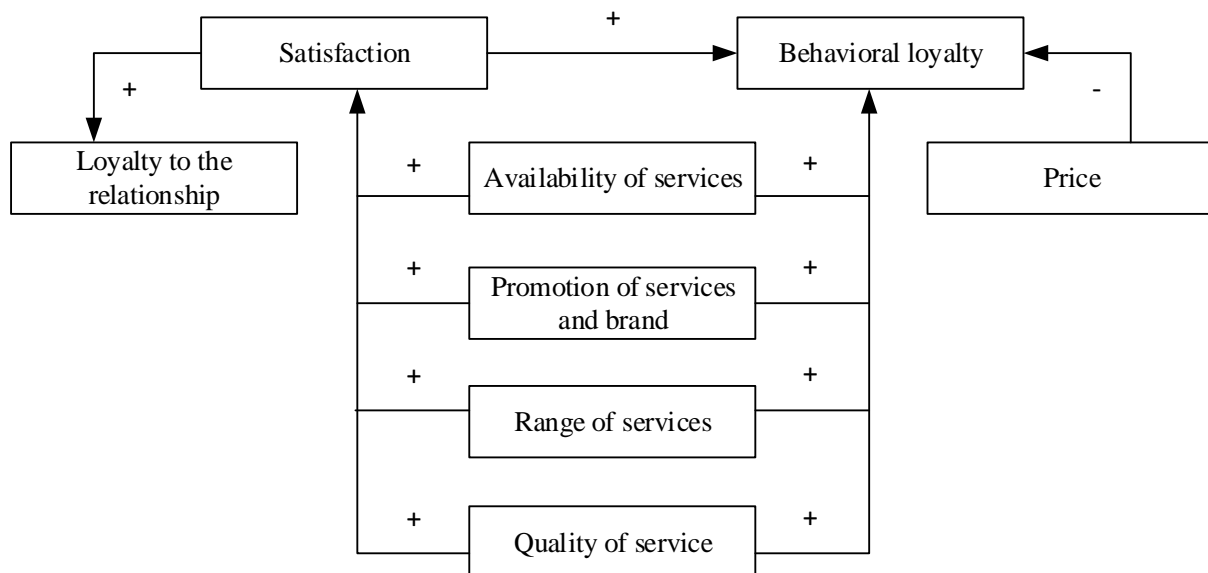

Figure 1. Process model of the influence of factors on the loyalty of airline passengers

1) The quality of service has a directly proportional effect on the attitude and behavioral loyalty of consumers through the formation of their satisfaction.

2) The price of the service has an inversely proportional effect on the attitude and behavioral loyalty of passengers through the formation of their satisfaction, as well as an inverse effect directly on behavioral loyalty.

3) The availability of services and their range has a directly proportional effect on the attitude of passengers and their behavioral loyalty through the formation of their satisfaction.

4) The promotion of the airline brand has a directly proportional effect on the attitude of passengers and their behavioral loyalty through the formation of satisfaction.

Despite the fact that the main emphasis of airlines should be on the safety of services provided, it is the level of service that allows airlines to build customer loyalty to the carrier. Airlines are creative in their marketing strategies to attract the attention of consumers. They use social media, non-traditional advertising methods and loyalty programs.

We can identify the main factors that shape the attitude of passengers to the quality of airline services: the accuracy of departure and arrival; convenience of placement in a chair; accommodation of passengers of regular flights in waiting rooms; registration at landing; interior of the aircraft cabin; privilege programs for frequent flyers; placement of landing exit; stewardess; food and related services; post-flight service [8].

The airline must also collect and store booking data, forecast demand by fare class, forecast the number of refusals and absences of passengers to the airport, set the level of booking in case of unfavorable flight loading factors and forecast the expected income. When allocating resources according to the criterion of maximizing revenue on the flight network, the airline must track the sections of the flight and segments that require special attention in terms of profitability [9].

In this aspect, it is necessary to have a clear idea of the volume of aggregate demand and the composition of target groups for the provision of services by the airline. Demand, as a necessity of passenger air transportation, is most significantly manifested in their differentiation according to the program objectives of the flight: rest, treatment, business trips, personal affairs, etc. The structure of air transportation for the program purposes of the flight of passengers is different for airlines and airlines. It largely depends on the routes of airlines and service areas, each of which has certain patterns of development of passenger traffic for the program purposes of the flight, due to external factors. Their influence is reflected in the change in the social composition of passengers: workers, employees, servicemen, students and other categories.

To assess customer loyalty to the airline, it is necessary to more fully explore the behavioral segmentation, within which the following characteristics are distinguished:
- reason for making a purchase - ordinary and special cases;
- desired benefits - quality, service, money savings, speed;
- status of the user of services - not the user, the former user, the potential user, the new user, the constant user;
- intensity of use - weak, average, high;
- degree of commitment - low, medium, strong, absolute;
- the degree of readiness of the buyer to perceive the product - not aware, informed, interested, willing to buy, going to buy;
- attitude to the product - hostile, negative, indifferent, positive, enthusiastic.

5. Numerical method and algorithm

In order to increase customer loyalty to the airline, it is advisable to make the loyalty program more targeted, focused on the specific needs of the passenger. To do this, it is proposed to cluster passengers and develop a system of bonuses and discounts for each cluster.

Data clustering is the task of dividing a given sample of objects into disparate subsets, called clusters, so that each cluster consists of similar objects and the objects of different clusters differ significantly.

The classification task was set: based on the available information about potential customers of the airline, most accurately to divide them into clusters, ie to create clusters of customers in accordance with their key characteristics. For example, it has become possible to differentiate between passengers who occasionally use the services of airlines when going on vacation, and business passengers who fly every week. This clustering alone can bring airlines significant additional revenue, contributing to the growth and success of the airline industry as a whole.

The business task is to group customers into homogeneous groups based on customer data, flight history and other attributes. Business analysts will be able to analyze each cluster to better understand the group of customers identified by the model.

A multilayer neural network with direct communication should be built to cluster passengers. The choice of such an architecture is due to the fact that direct communication networks are a universal means of approximating functions, which allows them to be used in solving classification problems. As a rule, neural networks are the most efficient way of classification, because they actually generate a large number of regression models (which are used in solving classification problems by statistical methods).

Questionnaires were processed and the classification problem was solved using the STATISTICA Neural Networks (SNN) package. A classification task was set: based on the available information about the airline's passengers, to divide them into clusters in the most accurate way. Neural network

modeling was performed in several stages.

1. Preparation of initial data. The airline collects information about passengers who have made at least one trip. Accordingly, a system of customer loyalty signs was selected and a database of 1230 events was compiled. The initial data are divided into two sets: training (861 events), on the basis of which the training was conducted, and test set (369 events) for verification.

Pre-processing of available data, conversion for supply to the input of the neural network. It is desirable to have hundreds or thousands of observations for analysis - the more observations used the better results will be. The solution of this problem determines the structure of the neural network: the input layer consisted of 13 neurons (indicators), and the output - of one neuron (cluster to which the passenger belongs): gender, income level, marital status, education, profession, age, destination, channel sales, the total amount of miles of flight of the passenger, the option of check-in for the flight, additional services, luggage, food on board.

The business challenge is to create a customer profile to explain the impact of customer characteristics on their loyalty to the airline. Using data mining methods, KPIs are modeled using two popular classification algorithms - the decision tree and support vector machine. This analysis determines which key customer attributes affect his loyalty to airlines.

The input needed to be normalized due to the need to convert the quality indicators into quantities. The initial values were divided into loyalty classes from 1 to 3.

Thus, we obtained a training sample D - a set of observations for which the values of input and output variables are defined in a next way:

$$D = \{(\bar{x}_j, VAR14_j), j = 1, \dots, n\}$$

where

$$\bar{x}_j = (Var1, Var2, \dots, Var13)$$

2. Design and training of the neural network. The task was to build a neural network based on the available data and its training. Neural network training was carried out for clients with whom the result of business relations is known. The program uses the brute-force search method to build the optimal topology of the neural network and conducts its training on a given sample.

6. Results

5 neural networks were constructed (Figure 2). Based on the value of the correlation coefficient, the best of the models for assessing customer loyalty was selected - the MLP 13-7-3 model, the architecture of which is called a multilayer perceptron. Rosenblatt's multilayer perceptron is a perceptron with additional layers of associative elements located between the corresponding sensitive (sensory) elements and the reacting elements. All layers of this multilayer perceptron will not necessarily be able to learn, some of them, for example, can be selected quite randomly and fixed. The information processing in the multilayer perceptron model consists of the interaction between the layers of neurons in the system, as a result of which the neurons of the source layer transmit the result of the interaction to the external environment. Thus, designing connections between neurons is equivalent to programming the system to process the input and create the desired output.

Index	Net. name	Training perf.	Test perf.	Validation perf.	Training error	Test error	Validation error
1	MLP 21-13-1	0,986945	0,984440	0,978792	0,033267	0,037854	0,029931
2	MLP 21-13-1	0,981218	0,987519	0,973027	0,048565	0,028413	0,035778
3	MLP 21-15-1	0,985197	0,986536	0,978767	0,037688	0,028695	0,030235
4	MLP 21-13-1	0,986267	0,974371	0,975852	0,035114	0,033975	0,038043
5	MLP 21-16-1	0,984101	0,988442	0,982275	0,040463	0,031224	0,028731

Figure 2. Analysis of neural network models for the formation of passenger loyalty clusters

3. Diagnosis and verification of the adequacy of the neural network. To set the image of the passenger change the scales in accordance with the required and actual values of the output of each polarity for both continuous and binary inputs and outputs. Comparison of the obtained results of the conducted neural network modeling and the actual result of customer loyalty allows to draw a

conclusion about the possibility of further use of neural network modeling. After saving the received network the efficiency of its work on test data is checked.

Conclusions

A comparison of the result provided by the airline with the forecast showed that the overlap occurs in 98.38% of cases. This allows us to conclude that the resulting network can be used to determine the loyalty of passengers and divide them into clusters.

The high results of the neural network are due to the following properties:

1) the ability to fully process information. Most of the known problems are solved using a neural network. This is achieved through network associativity, the ability to classify, generalize and abstract;

2) self-organization. In the process of neural network independently or under the influence of the external environment it learns to solve various problems. The neural network forms the rhythm of its activity, refining and complicating it over time;

3) ability to learn. In the process of learning the neural network reveals nonlinear relationships between variables and on the basis of such knowledge builds its forecast;

4) parallel information processing. Each neuron forms its output only on the basis of its inputs and its own internal state under the influence of some activation function.

Thus, theoretical developments in the field of neural networks have shown the possibility of their use as a reliable and effective tool for analysis and forecasting of socio-economic phenomena, including in the field of assessing the loyalty of airline passengers.

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