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A FUZZY APPROACH FOR SHOW-UP FORECASTING IN AIRLINE REVENUE MANAGEMENT

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LIST OF SYMBOLS

RM	**:** Revenue Management
YM	**:** Yield Management
HDI	**:** Humand Development Index
BOAC	**:** British Overseas Airways Corporation
LF	**:** Load Factor
OW	**:** One Way
RT	**:** Round Trip
AP	**:** Advance Purchase
AT	**:** Advance Ticketing
DOW	**:** Day of Week
TOD	**:** Time of Day
TOY	**:** Time of Year
BP	**:** Bid Price
OnD	**:** Origin and Destination
TAIEX	**:** Technical Assistance and Information Exchange
EU	**:** European Union

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ABSTRACT

In work life in which competition increases day by day, Revenue Management is faced as a field whose importance becomes more and more important. Revenue Management logic had been firstly used in aviation and then hotel sectors has still had big place in airlines' strategies increasing their revenue. Airline companies enabling market segmentation via Pricing and Yield Management methodologies aim to enlarge the number of passengers reached and obtain the maximized revenue.

Overselling which is one of the foremost points of Yield Management is a very important income tool for airlines whose product is perishable and meaningless after departure. The possible loss revealed because of no-show passengers is compensated by overbooked customers. Show-up rates of the passengers are investigated in this thesis via six factors; fare, number of direct flights between origin and destination points, difficulty of having visa from destination country, human development index of destination country, distance and temperature and a forecast model is offered.

There are six-month data instead of one whole year and the data is comprised of eight destination points, fuzzy linear regression method which is better in uncertain conditions and human perception is opted rather than statistical linear regression. At the end of application, possibility of show-up of a passenger is determined between a minimum and maximum value for each line with respect to its characteristic.

Main aim of the forecast model offered is to decrease the error in determination of number of overbooked passengers and have true calculation of it by predicting rate of show-up passengers in a realistic way as much as possible for a newborn airline. Therefore, airline companies would accept extra passengers for the seats which are

possible to stay empty because of no-show passengers. In addition to this, the airlines can control the number of overbooked passengers via the forecast model and prevent to have denied boarding passengers who cannot board the flight because there is no empty seat and would take compensation from the company. As a result, airline companies will have the possibility to increase their revenue while they can control some cost items like spilled passenger cost and denied boarding cost.

Key Words: Revenue Management, Fuzzy Linear Regression, Forecasting, No-show, Show-up, Airline Transportation

ÖZET

Rekabetin her geçen gün daha fazla hissedildiği iş dünyasında gelir yönetimi, önemi her geçen gün artan bir alan olarak karşımıza çıkmaktadır. İlk olarak havacılık, sonrasında otelcilik sektöründe denenen ve günümüzde çok sayıda sektör tarafından kullanılan gelir yönetimi mantığı, halen hava yolu şirketlerinin gelirlerini artırma stratejilerinde çok önemli bir yer tutmaktadır. Ücretlendirme (Pricing) ve verim yönetimi (Yield Management) yöntemleri ile pazar sınıflandırması yapan hava yolu şirketleri böylece ulaştığı yolcu portföyünü mümkün olduğunca genişletmek ve bu sayede maksimum geliri elde etmeyi amaçlamaktadır.

Verim yönetimi yönteminin önde gelen araçları arasında yer alan fazla koltuk satma (overselling) ürünü bozulabilir olan ve uçağın kalkışından sonra anlam ifade etmeyen hava yolu şirketleri için önemli bir gelir kapısıdır. Rezervasyonu olduğu halde uçuşa gelmeyen (no-show) yolcuların oluşturacağı muhtemel maliyet, fazladan satılan biletlerle azaltılmaktadır. Bu çalışmada, uçuşa gelen yolcuların (show-up) durumu ve uçuşa gelme yüzdeleri ortalama ücret, kalkış ve varış noktası arasındaki direkt uçuş sayısı, varış ülkesinden vize alma zorluğu, varış ülkesinin insani gelişmişlik endeksi, uzaklık ve sıcaklık faktörleri üzerinden incelenerek bir tahmin modeli oluşturulmuştur.

Tahmin modelinin oluşturulmasında kullanılan verinin tüm sene yerine 6 aylık bir süreyi kapsaması ve 8 varış noktası içermesi sebebiyle belirsizlik ve insan algısı faktörlerinin bulunduğu verilerde görece iyi sonuçlar veren bulanık doğrusal regresyon yöntemi tercih edilmiştir. Uygulama sonunda karakteristiğine göre her hat için, bir yolcunun uçuşa gelme oranı bulanık sayılarla minimum ve maksimum olmak üzere iki değer arasında hesaplanmaktadır.

Ortaya çıkan modelin hedefi, yeni kurulacak bir hava yolu için, herhangi bir uçuşa gelecek olan biletli yolcu oranının doğru tahmin edilmesini sağlayarak, uçuşa kabul edilecek fazla yolcu sayısındaki hatayı azaltmak ve doğru bir şekilde hesaplamaktır. Bu sayede hava yolu şirketleri bileti olduğu halde uçuşa gelmeyen yolcular sebebiyle boş kalması muhtemel olan koltuklarını doldurmuş ve kapasite fazlası bilet satarken bunun adedini uygun şekilde ayarlayarak ve gereğinden fazla bilet satılması sonucu uçağa binemeyecek ve kendisine tazminat ödenecek olan yolcu durumunun önüne geçmiş olacaktır. Sonuç olarak bu tahmin modeli ile hava yolu şirketleri gelirlerini artırırken giderlerini de kontrol etme imkânı bulacaktır.

Anahtar Sözcükler: Gelir Yönetimi, Bulanık Doğrusal Regresyon, Tahminleme, Uçuşa Gelmeme, Uçuşa Gelme, Hava Yolu Taşımacılığı

1. INTRODUCTION

Revenue Management (RM) has obtained a big amount of importance in recent years and it clearly seems that its significance will keep soaring. Revenue Management can be named as an act that the products which are limited are sold in a way bringing maximized revenue by the companies. In the Revenue Management logic, the important point is to use pricing, time and product dimensions of the selling process in the most efficient way. The same product can bring more income by selling it to the same customers with different price in different time. It can also be said that Revenue Management is giving the right product to the right customer in the right time (Kimes & Renaghan, 2011).

Today, Revenue Management techniques are used in a lot of sectors in order to gain much more income. Transportation, telecommunication, energy, retail, advertisement, freight, hotels, casinos, rental, catering and aviation are the main sectors that Revenue Management has a significant role to boost the sales and the revenue (Cleophas et al., 2011). Especially, in the sectors which address larger amount of people, market segmentation and large product range may offer people to find a more convenient option for them. Due to the fact that these are two of the important points of Revenue Management, the claim that its significance will increase, sounds realistic.

In airline sector, BOAC (old name of British Airways) showed first signs of RM tools by offering cheaper fares to customer on the condition that the tickets are purchased 21 days before. In the 70's, after deregulation of airlines in US, first big steps of Revenue Management appeared. New airlines which are named also as low-cost airlines entered to the markets and their main strategy was different from what it was until that time (McGill & Van Ryzin, 1999) By decreasing cost of the operations and enabling the market segmentation, these new companies brought competition and an amount of

change for the aviation sector. Pricing is a concept that became more of an issue with its all dimensions like market segmentation; advance purchase, minimum stay and so on. After this kind of dimensions and different fare types, effective use of these also became an important point. Analysis of demand of each type of product and answering the questions like which fare type, when and how much are the underlying points of yield management (Belobaba, 2009).

While the airlines elaborated on the yield management, the new applications were also aroused in capacity management like overselling. If a seat stays empty, because of no-show of a passenger or cancelling of a reservation, it means a revenue loss for the company. So as to overcome this problem, airlines started to accept more passenger than the capacity of the aircrafts (Lim, 2009).

With the new capacity management techniques used, forecasting had a larger place in aviation sector. In order to determine the true number of overselling seats, the airlines had to forecast the number of no-shows, cancellations and the empty seats in business cabin which will be compensated with overselling of economy cabin (Subramanian et al., 1999). Over the years, many forecasting methods have been offered on these issues and today it reaches a considerable level at the present time especially with developed Revenue Management softwares.

In this master thesis, a new method which forecast rate of show-up passengers will be offered and this new method will investigate on the factors which have role on show-up condition such as; ticket price, distance, visa condition between origin and destination countries, personal development index of the destination country, weekly number of flights between origin and destination points and temperature.

Fuzzy regression method is used to examine these factors because relations between the factors are not obvious and the data set is limited. In order to decrease complexity and vagueness of all these factors, fuzzy linear regression method is preferred instead of statistical linear regression.

The rest of the thesis is organized as follows;

Chapter 2 includes a literature review which shows the works done in the past on the Revenue Management, pricing, yield management, overselling, no-show and denied boarding topics. In Chapter 3 there is information about forecasting and fuzzy logic which were used in forecasting up to now. Chapter 4 explains fuzzy linear regression concept and compares fuzzy and statistic linear regression with respect to their compatibility with the thesis topic. Chapter 5 explains the model and the factors affecting show-up rate and decision of the passengers. The results of the thesis are also presented in this chapter. Chapter 6 concludes the thesis and discusses the further works which can be done in the future.

2. LITERATURE REVIEW

2.1. Revenue Management

Revenue Management (RM) is one of the most valid tools that are used by the companies in order to increase their revenue and profit correspondingly. RM was described as the art of selling the products to the right customers at right prices at the right time (Cleophas et al. 2011). When history of RM is investigated deeply, it can be seen that the first steps were taken in airline sector and then in lodging and hospitality. Belobaba (1987) supplies detailed information about the roots of RM and gives the motivations revealing the logic and strategy underlying the reasons why the companies have chosen the ways of RM. McGill & Van Ryzin (1999) provides a huge amount of knowledge about background of RM and shows that airline and hotel sectors started to implement RM actions in 1970's.

RM has its own characteristics and conditions and these are described as fixed capacity, predictable demand, perishable product, cost and pricing structure and time variable demand. RM techniques are used by not only aviation sector. Different sectors like automobile rental, airlines, cruise lines, hotel, advertisement, broadcasting, railways, casinos, freight, energy, retail and telecommunication have been using RM tools as well with respect to all these characteristics (Cleophas et al. 2011). These sectors and revenue management applications are provided in Table 2.1.

Car rental sector uses cars which are to be rent as their product and the rent time of the car is perishable for the companies. Firms try to attract customers by applying different pricing techniques, offering opportunities that leaving the car in a different station than it was rented. The companies use car brand, duration of renting, time of reservation,

start and end point of renting as the tools of their RM strategies. The main aim is to obtain the best revenue in the unit time.

Table 2.1: RM Industries and Their Products (Cleophas et al. 2011)

Industry	**Product**	**Type of Customer Inventory Segmentation**
Passenger Transport	Ticket, seat	Time of booking, venue of booking,
Car Rental	Right to use car	Time of booking, point of sale, return behavior
Hotels	Overnight stay	Time and duration of booking, venue of booking
Cruises	Participation in cruise	Time and duration, packages
Casinos	Overnight stay	Hotel-like segmentation versus customer value
Freight	Transport or storage	Time and venue of booking, volume versus weight
Advertising	Place for an advertisement	Time of booking, placement, frequency
Telecommunication	Bandwidth in time or data	Age of customers, business versus private customers
Energy	Transport and usage of energy	Seasonality
Retail	Fashion, consumer electronics, groceries etc.	Product life cycle, seasonality

Airline sector is the first and main player of RM. Seats of the aircrafts are the perishable product of the sector. If a seat cannot be sold until time of departure, it can be accepted as rubbish by the company. Pricing and yield management strategies are determined in various ways by airlines in order to maximize the revenue. By using many factors like time of selling and start point and end point of departure, customers can be segmented. Airline sector is investigated deeply in this master thesis.

Cruise ship sector is a combination of different revenue management opportunities like ticket selling, staying and entertainment. Time of booking, place of the rooms in the

ship and tour packages preferred by the customers are the points that are used to separate the customers into different segments. In this sector, revenue is not only obtained from the bookings of the customers, an amount of money which is spent during the trip by the customers is also meaningful to be a subject of revenue management.

Hotels are one of the sectors that the earliest steps taken in revenue management. Because if a room is not sold, it loses all value and this fact makes the rooms the perishable products of hotel industry. Room types, duration of the stay, booking time, capacity of the hotels, season of the year factors are used to enable segmentation of the customers. Hotels also can separate their rooms into different levels and they make investment so as to gain stars and place in a better class of hotels.

Casinos use Revenue Management tools with hotel industry by satisfying an accommodation place and gambling area for the players. The perishable product of casinos is time and today it is still an significant point that whether a normal hotel customer or a gambling player would be accepted before for casino industry. However, the main side generally would be gambling because the money spent for gambling is more than spent for the rooms. Casinos generally apply room price discount for gambling players if they believe that they would obtain more from the play.

Advertisement is a sector that uses RM tools in different slots. To exemplify, for printed documents such as newspapers and magazines, publication date is the factor determining the perishable product. After a document published, it is accepted as perishable for an advertisement. Radio, TV and internet websites are also important areas for advertising. Broadcasting time and duration of an advertisement are determining factors of revenue management in these fields. Long and prime time advertisements are accepted as more valuable and generating value whereas short and off prime time advertisements are cheaper.

Energy which is a very competitive sector has two different aspects of revenue management. In the contracts made with corporate and private customers, the energy providers apply flexible pricing. However, for the pipelines that are generally owned by

state firms, the price is determined with respect to value of the bids. Main aim is to maximize the total obtained revenue by differentiating the price and to use the big capacity of the lines by accepting maximum number of offers.

All these sectors try to maximize their revenues by using RM tools and characteristics. Kimes (2000) gives the characteristics in a detailed manner. Revenue Management is more important for the companies which have constrained capacity to offer their customers. The main aim is to gain the most from the capacity which is generally measured physically with numbers or timely with hours. The products of the companies benefiting from RM are generally perishable. Due to the fact that the products are perishable, the companies try to obtain maximum before the products perish. Demand generally varies from time to time and it is predictable to some extent. These require the companies to apply different tactics and pricing – yield management strategies to maximize the revenue. Cost and pricing structure is an important characteristic of RM and has a big role in RM strategies. RM using firms generally prefer high fix costs but low variable costs as much as they adjust because this helps the firms to have more flexible pricing strategies.

Revenue Management has three different levers; price, time and space (Kimes & Renaghan, 2011). Price is the first tool helping to make segmentation of the customers. The same product can be sold to different customers for different prices with respect to selling time, selling point, number of buyers and conditions of use of the product. This allows the companies to determine whether a customer is acceptable at that moment or not in order to obtain maximized revenue.

Time is an important lever for the companies and corresponding to the type of product, time can be offered to customers in two different ways; implicitly or explicitly. When the time is offered explicitly as minute, hour or a day, the planning period is easier for the planners and the companies. Hotels and car rental firms are some of the company types that offer time explicitly. If the time period is offered implicitly by the company, the planning process is a little more complex because time of use of the product is determined by the customers. For example, airlines offer their products with respect to seats and duration of the flights becomes time of use of the product and it is offered

implicitly. However, in that case it can be assumed that time is determined by the company. In restaurants, the products are offered with respect to portions or grams and time of use is determined by the customers. For that kind of companies, management of time and reaching revenue maximization are more difficult.

Space is a very strategic lever of revenue management. Like time, space can also be sold implicitly or explicitly. Interplay of time and space is important in use of revenue management and it is given in Table 2.2 (Kimes & Renaghan, 2011). If the products are sold as volume, shelf, line or inch it means that the space is sold explicitly. Companies sometimes change their capacity into different types like rooms, seats, cars and sell their space implicitly. Because one of the main logic underlying revenue management is effective use of constrained capacity, firms try to use the capacity in the best way and obtain maximized revenue by using all the tools of space.

Table 2.2: Interplay of Time and Space (Kimes & Renaghan, 2011)

		Time	
		Implicit	**Explicit**
Space	**Implicit**	Restaurants Golf Courses, Stadiums	Hotels, Rental Car, Spa
	Explicit	N/A	Gas Pipelines, Retail Space

2.1.1 Airline Revenue Management

Aviation is the field that the first steps of revenue management applications were seen after deregulation of US aviation sector at the end of 70's and new airline brands revealed. After deregulation, effect of governments on the sector started to decrease and new airlines were born in addition to the airlines which were unique in their country and today are still named as legacy airlines. With deregulation process in USA, new airlines were founded and penetrated to the market at first in USA and then gradually in the rest of the world (Belobaba et al, 2009).

This new type of airlines which is today called as low-cost airlines increased the competition in airline sector and gave the opportunity to the passengers to have a flight in an easier and cheaper way. The number of passengers using airlines clearly increased and low cost and legacy airlines were in a big and strategical contest to convince the passengers to use their own brands. Table 2.3 shows foremost legacy and low-cost airlines of today.

Table 2.3: Foremost Legacy and Low-Cost Airlines

Airline Type	Airlines
Legacy Airlines	American Airlines, Lufthansa Airlines, Turkish Airlines, Air France, Alitalia, Singapore Airlines, Korean Air, Qatar Airways, Emirates, KLM,
Low-cost Airlines	Ryan Air, Easy Jet, Wizz Air, Pegasus Airlines, Norwegian, Wirgin America, Fly Dubai,

After deregulation and competition became the real fact of aviation market, airlines looked for new paths that find new passengers which would increase the load factor (LF) of the flights and lead them close to be full. Finding new passengers constitutes the customer pool of an airline as a marketing activity and it is not the final step in the revenue and profit maximization procedures of the airlines. After constituting the customer pool which can be named as demands of the airlines, airlines accept or reject

the customers to the flights in order to have the maximized revenue. This choice and elimination of the nominee passengers are made by applying pricing strategies, yield management techniques and all the elements of revenue management. McGill & Van Ryzin (1999) give and explain the elements of revenue management.

Pricing is the most tactical ways that airlines use in order to enable market segmentation and obtain more passengers offering different levels of fare values. Airlines have different cabins which have quality differences and different fare classes offering passengers different price for the same flight and different trip conditions like cancelling the tickets, changing the dates of the flights or being able to buy a ticket for a flight while there are a few days left to departure.

Yield management can be named as the art of using fare classed produced under the roof of pricing. Airlines decide how much revenue per passenger they obtain by using high valued or low valued fare classes more. If an airline can manage to sell tickets from high valued fare classes they gain more revenue whereas if the tickets are sold from low valued fare classes the revenue would become less for the airline. Type of the aircraft also affects the yield management strategies because capacity of a flight changes with respect to type of its plane. Pricing and yield management will be investigated deeply in the following subheadings.

Today lots of airlines prefer to use new systems which control their pricing and yield management in order to have the maximized revenue and profit because number of flights, aircrafts and destination points really increased. There are the numbers of aircrafts and destination countries of some of the foremost airlines of the world in Table 2.4.

Since there are a lot of network airlines which aim to carry passengers from one point to another via their hubs, control of revenue management is not easy and requires computerized systems that are able to answer desires of the companies. If it is thought that airlines open the sales of a flight approximately one year before the flights and there are more than 10 different fare classes in only economy cabin, necessity of this kind of computerized programs can be understood easily. In addition to these, some

airlines have more than a hundred of destinations and their computation and system of revenue management is more and more complex (Belobaba et al, 2009).

Table 2.4: Aircrafts and Destination Countries of Some Airlines

Airline	Aircraft	Destination Country
Turkish Airlines	300	118
Lufthansa Airlines	616	83
Emirates	245	83
Qatar Airways	167	74
Pegasus Airlines	57	37
Air France - KLM	572	78
Aeroflot Airlines	162	52
American Airlines	1494	60
Singapore Airlines	109	66
Qantas Airways	131	14
RyanAir	321	31

New computerized revenue management systems include past data of airlines and try to learn the behaviors of the passengers. In this way, they try to make forecast about future demand and sales of the airlines by using their own mathematical models to generate optimized revenue.

Computerized revenue management systems works with two different logics: leg based and origin & destination based. Leg based logic is more convenient for small and regional airlines which generally have point-to-point flights. However, the big and legacy airlines which have a lot of destination points, a lot of aircrafts and try to send passengers from one airport to another via a hub airport are to be use O&D based systems. O&D based advanced systems make their computations by regarding two different beyond flights like a local flight and POS and POC points of the passengers are taken into account as well whereas leg based systems optimize the flights separately and then enable the integration of these flights for beyond passengers.

These systems also decide overbooking, decrement, upgrade, denied boarding strategies of the airlines. Because the system is fed with historical data, it produces a forecast for all these concepts and airlines shape their overselling, no-show and denied boarding passenger strategies with respect to model of computerized revenue management system which is used. Therefore, it can be said that revenue management systems have a big role on the actions that airlines have taken in order to maximize the income and profit (Belobaba et al, 2009).

2.1.1.1 Pricing

Pricing has an important role to enable the equilibrium between supply and demand. Supply side of aviation sector, airlines and demand side of the sector, passengers get together if willingness to pay of the passengers is enough for the fare level determined by the airline of a seat. Because the competition level increases especially after number of low-cost airlines pricing becomes a port for airlines to convince and segment the passengers.

For each flight there is a demand which may buy a ticket if suitable fare is found and this demand can be named as unconstrained demand. However, airlines generally cannot manage to reach this demand because of capacity constraints or fare levels are not enough to convince some passengers to buy a ticket. Because this general demand is comprised of various segments of customers, airlines differentiate their products, fare levels and fare rules in order to offer attractive options. One-way (OW) or round trip (RT) fares are produced in order to satisfy the desire of the passengers. OW fares are generally determined more than half of the same fare class RT prices.

While making this differentiation, airlines prefer one of three different pricing strategies: cost-based pricing, demand-based pricing and service based pricing. In practice, airlines may use hybrid forms of these theoretical pricing strategies. Even in some markets, some low cost airlines applies price-based costing being a new technique that tries to reduce cost so as to have profit with prices determined before (Simpson and Belobaba, 1992).

Cost-based pricing is generally used by low-cost airlines or other airlines whose first aim is LF than revenue yield. There are fixed costs and variable costs of an airline and fixed cost are about to be fixed in the short run. Airlines produce their price levels which allow them to operate effectively by calculating these cost in a true way if they have chosen this kind of pricing strategy. However, in some competitive markets that there are a lot of flights and different airlines, fare levels are determined before and the companies works for decreasing the costs.

The main point of demand-based pricing strategy is price-demand curve of the markets. In this approach which is different from cost-based, determining factor is willingness to pay of the passengers. Some passengers may have willingness to give high amount of money whereas some do not have. In order to make all the customers happy and maximize the revenue by having lots of passengers as much as they can, airlines differentiate their fares and offer to customers with respect to the conditions of the markets. Sometimes even in the same origin-destination market, different fare values and sales conditions can be provided via fare rules.

Service-based pricing is traced to level of the quality of the services presented by the airlines. Generally, airlines offer different cabin options for the passengers like economy, premium economy, business and first class. Because services, seat conditions, meal options are all different in these cabins, differentiated pricing is easier to apply while it would be more difficult to get the passengers paying different prices to have a seat next to each other in the same cabin.

There are some factors that have effect on pricing decisions of the airlines. Some of the factors are intra-firm whereas some of them are not exactly related to company. Intra-firm factors can be organized and kept under control for a long time but extra-firm factors may change in a short time and the airlines have to be ready for this kind of quick changes.

Airlines shape their pricing strategies and present fares to the markets via fare classes. Fare classes are generally expressed with a letter and symbolize a price. These fare levels are regulated by the airlines by applying rules and restrictions. In the Table 2.5, there are fare rules applications of American Airlines on a fare produced in June 2015.

Fare rules are the elements that regulate the fare conditions and then some restrictions are applied to the regulated fares then they are presented to customers. Selling period, travel period, blackout dates, minimum stay, maximum stay, stopovers, mileage programs, buy option, baggage options, change options of the tickets and penalties, advance purchase, advance ticketing, flight number restrictions, day of week based restrictions are the most preferred fare rules and restrictions by the airlines.

Table 2.5: Fare Rule Application Example of American Airlines[1]

Rule Type	Fare Rules
Fare Basis Code	All Business Class fares booked on J, D, C & R inventory
	All Main Cabin fares booked on Y, B & H inventory
Selling period	From 18 June – 31 August 2015 included
Outbound travel dates	Between 18 June to 31 December 2015
Travel blackout Dates	No blackout dates
Minimum stay	May vary based on fare selected. Specific fare rules are available during booking
Maximum stay	May vary based on fare selected. Specific fare rules are available during booking
Child / infant discounts	Infants under 2 years of age without a seat: Charge 10% of the adult fare.
	No discount applies to taxes, fees, or fuel surcharge.
Fare rules	May vary based on fare selected. Specific fare rules are available during booking
Stopovers	May vary based on fare selected. Specific fare rules are available during booking
AAdvantage upgrade	These fares qualify for AAdvantage mileage accrual

Selling period shows the dates that the passengers can make a reservation for a fare level. Low cost carriers generally keep this period short because they offer very low promotion fares whereas legacy and emerging airlines' selling period is shorter. Selling period can be kept larger for a fare if the fare is desired to penetrate the market deeply. In this way, more and more customer may know and prefer that price. Travel period rule regulates the flight dates of the passengers. Return date is sometimes restricted while it is sometimes left open. Because it is directly related to trip of the passengers travel period restriction has the potential to affect the level of the sale of a fare level. In

[1] aa.com, (2016). Fare Rules. [online] Available at: http://www.aa.com/intl/ie/specialOffers/FSTandC.jsp [Accessed 16 Nov. 2015]

addition to selling and travel period rules, for travel periods airline may apply blackout dates when the passengers cannot fly in these date days.

Minimum stay rules shows that the number of days that the passengers have to stay in destination points. It is used in round trip fares and for example, if minimum stay rule is determined 4 days for a fare class, a passenger using that class cannot return before 4 days than his/her first flight. This restriction is used in order to exclude short time visitors like businessmen from low promotion fares. Maximum stay which is a time restriction like minimum stay, restricts the time spent in destination point of a passenger. For a promotion fare which is produced for the passengers on vacation can be restricted with maximum stay rule because the vacation time generally does not excess 3 months.

Mileage programs, stopover conditions and buy options can be named as consumer friendly fare rules when the passengers know the details of the restrictions determined by the airlines before. Passengers gain lots of miles if they are member of loyalty programs of airlines and they can fly free on account of the flights in the past. Table 2.6 shows the loyalty program rules of Ukraine International Airlines. The program's name is Panorama Club.

Table 2.6: Panorama Club Loyalty Program[2]

Service class	Booking class	Mileage factor
Business	C, D	150%
Business	Z	120%
Business	A	No
Premium Economy	S, Y, P	110%
Economy	E, H, K, L, O, Q, R, W, V	100%
Economy	B, G, J, M, N	50%
Economy	T	10%
Economy	U, X, F	No

[2] flyuia.com, (2016). Collect Miles - Ukraine International Airlines (UIA). [online] Available at: http://www.flyuia.com/eng/club/panorama-club/collect-miles.html [Accessed 10 Nov. 2015].

If a passenger continues the trip after spending more than 24 hour at a point then this is called as stopover in aviation. Stopover can be free for some fare classes which are generally expensive ones whereas it can be directly blocked or can be allowed with a specific extra payment. Buy option is a time given to customers by the airlines to purchase the ticket after making reservation. This period is kept larger for high fare classes while it is short for low prices like promotion fares.

Baggage allowance and ticket change options are the rules highly regarded by the customers and because they are given importance by the target mass they can affect the market share of airlines. Airlines have different baggage strategies from each other. If there is business cabin, its baggage allowance is generally greater than economy cabin. Ticket change and penalty is also a changeable issue with respect to value of fare. Airlines generally do not allow change of promotions fares, allow the change of middle level fares with a penalty payment and change the high level fares without a penalty.

Advance purchase (AP) and advance ticketing (AT) rules regulates that how much time before departure the ticket is reserved and bought by the passengers. These help the airlines to plan its inventory in a more clear way and they are generally used for low fare classes in order to finish the sales of these fares early and have a time to plan the rest of the aircraft. AP and AT sometimes are used together with minimum stay and maximum stay rules in order to produce very restricted fares (Belobaba et al, 2009).

Flight number and day of week (DOW) based restrictions are preferred by the airlines so as to support empty days flights and prevent demanded days and flights from low fare level sales. For instance, if an airline observes that weekends generally have higher LF than weekdays, the airline most probably produces its promotion fares for Tuesday, Wednesday and Thursday and for the flights whose departure time is on less preferred TOD.

While competition level is rapidly increasing, the companies which want to have profit and maintenance seek that how they satisfy the customers and make them loyal (Hacıoglu, 2011). Pricing is one of the most important tools of the airlines that touch the customers and determines the market conditions. In addition to this, the fare levels

produced via pricing procedure are used as vital elements of yield management which is another significant point of airline revenue management process.

2.1.1.2 Yield Management

Yield Management is one of the most elaborated fields of Revenue Management and there are a lot of work, literature survey and suggested model which offers new and different ideas to refresh the logic and maximize the revenue of the companies. Smith et al. (1992), Belobaba (1987), Shumsky (2002), Subramanian et al. (1999), Belobaba & Wilson (1997) give valuable works to put yield management theory forward and improve.

Yield Management and Pricing which are important tools of Revenue Management have similar and different aspects. As in pricing applications, Yield Management tools are used by the airlines in order to determine the position in the competitive markets. However, pricing analysts produce the fare levels by analyzing the market structure of previous periods whereas yield management analysts who are responsible from controlling of demands and flights analyze instant and actual conditions of the market.

Yield Management has been used since 1970's after deregulation of US aviation sector and American Airlines began first works on this subject began in early 1960's. Implementation of Sabre which is a computerized tool for inventory control in 1966, first use of super-save fare levels in 1977 and completion of US aviation deregulation in 1979 were the big motivations to start and improve yield management concept (Smith, 1992).

The reasons and places that airlines use yield management tools are explained by Shumsky (2002) in a detailed way in his article which provides information about yield management in terms of airline, hotel and car rental sectors. Table 2.7 shows the situation of these sectors with respect to yield management applications. According to him, companies prefer yield management because it is difficult and expensive to store the products, demands in the future are uncertain, companies should divide the customers into different segments and the same capacity unit can be evaluated for different type of customers. Due to the fact that the companies have constrained capacity, the main aim of yield management is to obtain more revenue from the same capacity.

Table 2.7: Comparison of Yield Management Applications (Shumsky, 2002)

Parameter	Airline	Hotel	Car Rental
Unit of Capacity	Seat	Room	Car
Number of resource types	2-3	2-10+	5-20+
Capacity (Fixed or variable)	Fixed	Fixed	Variable
Mobility of capacity	Small	None	Considerable
Umber of possible prices per unit	Many	Few	Many
Duration of use	Fixed	Variable	Variable
Corporate discounts	Occasional	Yes	Yes
Capacity management (Local or central)	Central	Central/local	Central/regional/local

Revenue Management tools are generally used for perishable products which cannot be stored to be used in the future. For example, a seat in a flight cannot be kept for a passenger who would fly the following day. Because of this reason, selling a seat from cheaper value when there is a little time to departure instead of making it perished would be preferred by an airline. The airline should produce the fare firstly via pricing and then adjust the selling that fare via yield management. However, this decision is a trade-off for a company because the passengers can be directed to buy their tickets late if they think that it would get cheap right before the departure. Legacy airlines generally cannot prefer that option whereas it is a common action for low cost airlines. Figure 2.1 shows the logic whether an airline accepts low fares or waits for the full fare customers.

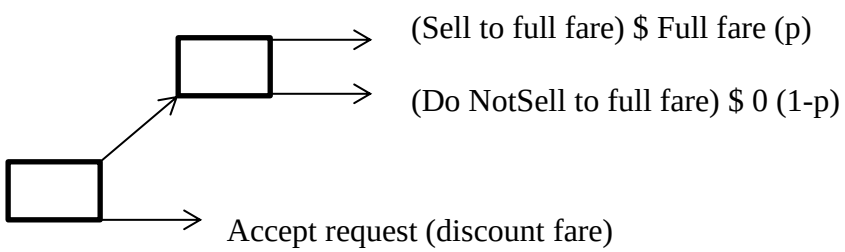

Figure 2.1: Low – Full Fare Deciding Logic

Airlines may use the same volume as differentiated product to reach different types of customers. Legacy airlines offer different cabin options like economy, business and first class in that logic while low cost airlines generally use one type product type. Applying yield management in the same cabin is more general use but differentiated product step can be thought as the first stage in customer segmentation.

Although the airlines use different cabin options, the main capacity is presented to customers in economy cabins. For example, Lufthansa Airlines uses 14 fare classes for economy cabin, 5 fare classes for business cabin and only 2 fare classes for first class cabin in its intercontinental flights. Hence, airlines give the highest importance to yield management of economy cabins.

Airlines present the capacity to the customers via nested fare class logic in order to make segmentation of the customers and maximize the revenue. In that logic, each fare class has bigger or equal capacity than the previous fare class. In Figure 2.2, the practical use of nested fare class logic can be seen.

Figure 2.2: Nested Fare Class Logic

However, nested fare class logic is generally used in leg based yield management systems. In these systems, capacity of fare classes of each flight is calculated as independent from each other. Beyond passengers using more than one flight via the hub airport of the airline can be affected badly in that logic. Despite the fact that one flight of the passenger is about to be empty and selling price is from lower fare classes, if the

other flight of the passenger is sold from higher fare classes, the passenger has to pay the value of fare class of higher flight. To exemplify, for a passenger going to Milano from Beijing via Baku, if Beijing-Baku flight is sold from the highest class (Y) and Baku-Milano flight is sold from the lowest fare class (W), the passenger pays Y class value of Beijing-Baku fares.

The airlines which have a lot of destination points and a lot of beyond passengers generally use origin and destination (OnD) logic in their yield management applications. In that logic, the system determines a bid price (BP) which shows the minimum sale value of a seat and if the trip has more than one flight, BP of the trip will be equal to total of the BPs of the different segments. In this way, fare of the passenger can be calculated in more fair way than leg based yield management logic. If previous Baku-Milano example is thought with OnD logic, the passenger's payment can be lower than Y fare class.

Yield management applications are up to demand and capacity levels of the airlines. If demand is high, airlines direct the passengers to buy their tickets from higher fare classes. In order to locate the demand to the capacity in the best way and optimize the revenue, aircraft types and number of seats has a big significance. For example, for a flight which a narrow body aircraft is assigned, the lower fare classes can be closed but if the type of aircraft is changed to large body aircraft, lower fares would be opened in order to reach more customers and increase LF of the flight. Most of the leading airlines prefer Airbus or Boeing aircrafts and Table 2.8 shows body type and capacity of Boeing and Airbus aircrafts.

There are many tools of Yield Management such as different cabin options, nested fare classes, overbooking, movable curtain, upgrade, aircraft capacity changes. Because the factors affecting no-show condition is investigated in this research, no-show and overbooking which is a precaution for no-show possibility would be put an emphasize more.

Table 2.8: Type and Capacity of Boeing and Airbus Aircrafts

Brand	Aircraft Type	Capacity	Max. Capacity
Boeing	B737	85	215
	B747	467	605
	B767	180	375
	B777	301	550
	B787	210	330
Airbus	A300	228–254	361
	A310	187	279
	A318	107	132
	A319	124	156
	A320	150	180
	A321	185	236
	A330	246-300	406–440
	A340	239–380	380-440
	A350	270–350	550
	A380	555	853

2.1.1.3 No-Show

The passengers who do not come to flight without cancelling their bookings even though they have a ticket, the passengers are named as no-show in aviation sector (Zhang et al., 2014). Because the product of the sector, seats are perishable, airlines accept extra passengers in order not to lose money and get the maximized revenue. Airlines try to analyze and forecast no-show condition so as to take precautions and prevent having seats which cannot be sold after departure.

Gorin et al. (2006) prepares a research about no-show forecasting by investigating on cost based and PNR based forecasts of no-show and offers a model which is a hybrid of these two old approaches. Figure 2.3 shows this blended approach. In that research it is given that no-show possibility of the customers dramatically decreases because of the increasing existence of low-cost carriers. Low cost carriers offer low fares and these fares are generally restricted in terms of showing up to flights. Because of all these reasons, passenger bookings are shifted to closer to departure time, LF of airlines increases and no-show rate of passengers diminishes.

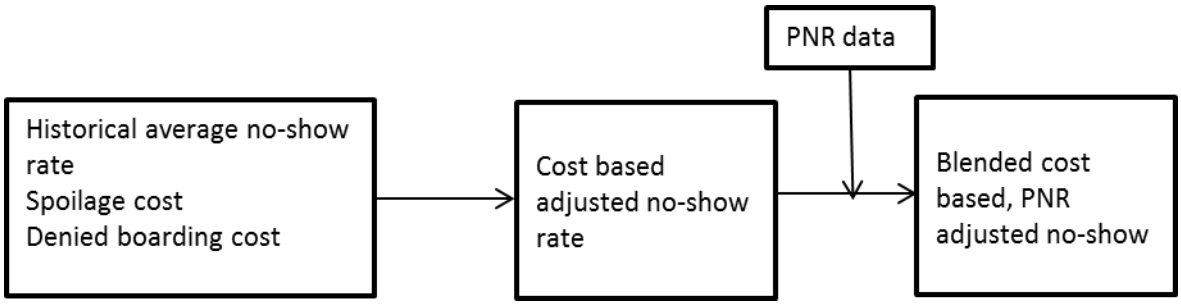

Figure 2.3: Blended no-show forecast

Airlines have a forecast for no-show rate and adjust their capacity with that rate with respect to the following formula. AU means the authorization level that is the number of seats airline sells;

$$AU = \frac{Cabin\ Capacity}{(1 - \text{NoShowR}ate)} \quad (2.1)$$

With the right forecast and calculation of no-show rate, AU value would be true and meaningful yield management actions are taken by the yield management analysts of the airlines.

No-show habits and rates of passengers may change region by region and year by year. For example, in USA where the businessmen have a trip too much, no-show rates are generally higher. It is generally between 10 - 15% and may be higher than %20 in the peak seasons (Belobaba et al., 2009). The flights going to coming from Africa region also have high no-show rates.

If no-show rate is forecasted well by an airline, it helps to do overbooking in a true manner. In this way, airlines can sell all the seats of the aircrafts and prevent the seats to get perished. In addition to this, denied boarding compensation which is given to the passengers who cannot be accepted to the flights because of extra overbooking is also decreased. In the following parts of the thesis, no-show and show-up concepts are investigated deeply.

2.1.1.4 Overselling

Overselling that is generally known as overbooking is a procedure that extra seats which exceed number of capacity are sold to passengers (Lim, 2009). The aim is to eliminate or decrease the effects of no-show, cancellation and empty seats in the upper cabins of the aircraft. In a different saying, overselling is sum of overbooking, decrement and upgrade which are precaution of no-show, cancellation and empty seats in the upper cabins respectively.

Overbooking has a big significance in terms of revenue because the product is perishable and there is no chance to compensate the lost revenue. Smith et al. (1992) gives that if overbooking was not preferred 15 percent of the seats would be stayed empty and the net revenue obtained via overbooking was more than $225 million in 1990 in USA.

There are many works on this important topic and Subramanian (1999), Suzuki (2006), Aydin (2009), Lim (2009), Amaruchkul & Sae-Lim (2011), Zhang (2014), Sierag et al. (2015) give information and offer their model in this large field. These models are generally about practice of overbooking applications by evaluating customers' uncertain choice behaviors.

Overbooking applications change airline to airline. Some low cost airlines like Ryanair do not accept overbooked passenger whereas legacy airlines like Turkish Airlines, Lufthansa Airlines, British Airways, and American Airlines have overselling applications at different rates that changes with respect to lines and regions. Legacy airlines generally have a lot of beyond passengers and because these passengers continue their trips after reaching hub airport of the airline, it is so important for them not to be denied boarding. Because of this kind of critical points for passengers, legacy airlines which have large destination network generally separate their overselling actions into three parts overbooking for no-show, decrement for cancellations and upgrade for empty seats in the upper cabins. These procedures are generally realized by computerized yield management system of the airlines.

After having a no-show forecast, overbooking rates are determined in order to fill the seats which would stay empty because of the no-show passengers. To be successful to give true overbooking rate, no-show should be forecasted realistically as much as possible. In this thesis, the factors affecting no-show rate of passengers are investigated in a detailed manner and a general equation is offered to forecast no-show.

Reservations are changed to tickets or are cancelled by the customers in the option to buy time given by the airlines. Cancellation process is named as decrement by the airlines and it directs airlines to accept more passengers than the number of available seats they have. It is shown that there may be 20 percent revenue loss if decrement is not be taken into account by airlines (Sierag at al., 2015). Decrement is also forecasted by the airlines like no-show and it has a forecast model but it differs with respect to passenger type. Passenger type is regarded as group if there are 9 or more people in the ticket and else it is individual. Decrement models and forecasts of these two passenger type are different and airlines accept extra passengers by regarding this difference.

Upgrade is another overselling element that airlines accept extra passengers for the empty seats of the upper cabins of the aircraft. There is a forecast for demands of cabins and if it is estimated that demand of upper cabins is less than capacity and there will be empty seats, airlines try to minimize their loss by carrying some passengers from lower cabins to uppers. For example, when there are 4 empty seats in business cabin according to forecasted model, the airline increases number of available seats in the economy cabin if unconstrained demand of economy cabin is larger than capacity.

2.1.1.5 Denied Boarding Passengers

When the number of arrival passengers is more than the capacity of the flight, it may cause that some passengers cannot be accepted to the flight. These customers are named as denied boarding passengers. In that case, airlines need to compensate this part of passengers with compensation which lead to losses on both social reputation and profits of airlines (Zhang et al., 2014).

Having a denied boarding passenger has some costs, not only the compensation but also different aspects that the passengers may demand can be in front of the airlines. Belobaba et al. (2009) give a detailed explanation in their book and summarize the elements as cash compensation, free travel vouchers, meal and accommodation costs, space on other airlines to place denied boarding passengers and cost of passengers' lost goodwill.

Passengers can be denied by the airlines voluntarily or not and there are some rules that regulate the compensation airlines have to pay to the passengers. Table 2.9 shows the compensation if the passenger prefers refund and Table 2.10 shows the compensation in case of passenger prefers re-routing. They are all determined by European Parliament in 2004.

Table 2.9: Refund Compensation Table[3]

Type of flight	Compensation
Flights of 1500 km or less	250 €
Flights of over 1500 km within the EU and other flights between 1500 and 3500 km	400 €
All other flights	600 €

The main logic that leads airlines to overbook and have denied boarding passengers is to gain more revenue than the compensation that they pay to customers. If an airline increases overbooking rates, spilled passenger and spoilage cost risk decrease but

[3] http://ec.europa.eu/transport/themes/passengers/air/doc/neb/questions_answers.pdf_reg_2004_261.pdf

denied boarding compensation risk increases. In terms of revenue maximization, as long as revenue coming from overbooked passengers is higher than denied boarding compensation, overbook can be preferred. However, the goodwill of passengers and customer satisfaction are also be regarded and the aim should be the condition that there is no seat perished and denied boarding passenger in the airport.

Table 2.10: Re-Route Compensation Table[4]

Type of flight	**Delay**	**Compensation**
Flights of 1500 km or less	2 hours or less	125 €
Flights of 1500 km or less	More than 2 hours	250 €
Flights of over 1500 km within the EU and other flights between 1500 and 3500 km	3 hours or less	200 €
Flights of over 1500 km within the EU and other flights between 1500 and 3500 km	More than 3 hours	400 €
All other flights	4 hours or less	300 €
All other flights	More than 4 hours	600 €

[4] http://ec.europa.eu/transport/themes/passengers/air/doc/neb/questions_answers.pdf_reg_2004_261.pdf

3. FORECASTING

3.1 Preliminaries

Forecasting is generally accepted as a tool that helps predicting the future by using information in the past. Figure 3.1 shows the bridge function of forecasting between previous data and future data.

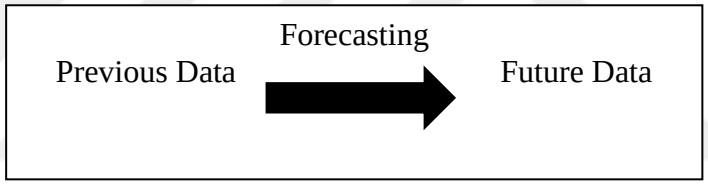

Figure 3.1: Function of Forecasting

There are a lot of detailed works and practices on forecasting field. Winklhofer et al. (1996), Green (2001), Makridakis & Wheelwright (1989) and Armstrong et al. (1987) provide large amount of information about general view of forecasting, literature and forecasting types and methods. In the article whose title is Research Needs in Forecasting (Armstrong, 1987), almost all the literature about forecasting up to that date is presented.

Because forecasting shapes the vision and future of the organizations by understanding their history, importance of it increasingly becomes high. Companies apply forecasting by designing, selecting/specifying and evaluating the issues. Figure 3.2 displays a organizational practice of forecasting (Winklhofer et al., 1996). The factors assisting improvement of importance are:

- organizations' complexity which makes difficult to have a decision;
- more systematic decision making that has proofs is preferred by organizations;
- last developments of forecasting methods allows not only decision makers but also the managers to use these methods (Makriadis et al., 1983).

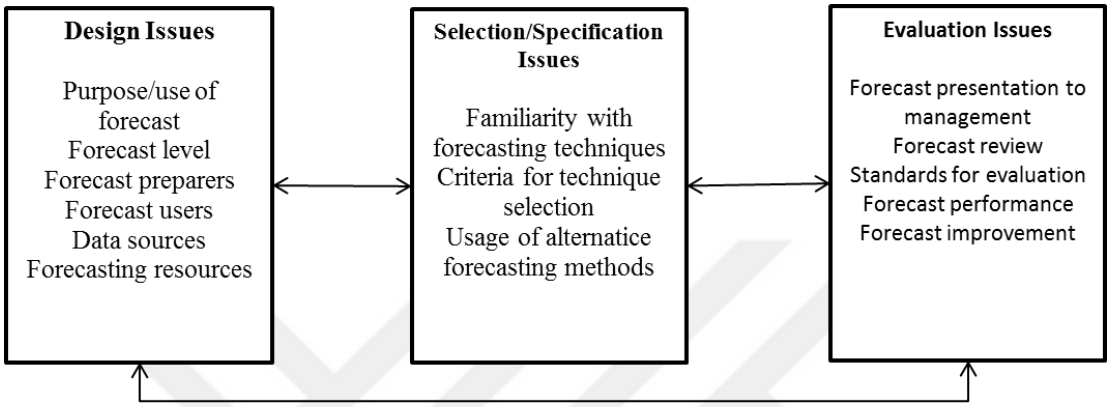

Figure 3.2: Organizational Forecasting Practice (Winklhofer et al., 1996)

Forecasting planning horizon can be divided into three different categories. The terms which are less than three months are named as short term forecasts. The periods which last between three months and two years are called as medium term forecasts and the times which are longer than two years are named as long term forecasts. Long term forecasts are generally determined as company strategies whereas short time forecasts are evaluated as daily operations of the companies (Green, 2001).

Forecasting is divided into two different types, qualitative and quantitative methods. Quantitative model are investigated as time series and causal techniques whereas qualitative model include judgmental techniques. Table 3.1 gives these techniques in a detailed way.

In this thesis, fuzzy logic is used to forecast no-show data. Fuzzy logic in forecasting and fuzzy linear regression are examined in a large perspective.

Table 3.1: Forecasting Techniques (Green, 2001)

Quantitative Techniques	Techniques
	Regression analysis
	Neural networks
	Expert systems
	Simulation
	Life-cycle analysis
	Straight-line projection
	Decomposition
	Trend line analysis
	Box-Jenkins
	Moving average
	Exponential smoothing
Qualitative Techniques	Jury of executive opinion
	Sales force composite
	Customer surveys
	Naïve model
	Delphi model

3.2 Fuzzy Logic in Forecasting

Almost every issue exists in daily life has some uncertainties. Sales forecasting, economic forecasting, weather forecasting, daily time forecasting are all parts of the daily life and they have approximation, semi-truth, imprecision, uncertainty, vagueness, nonlinearity and complexity (Dostal, 2013). Fuzzy logic is required to deal with complexities of real world (Chen & Chang, 2009). Chen & Chang (2009) present a detailed overview of fuzzy logic in forecasting in the paper which they offer a new multi-variable fuzzy forecasting method to forecast temperature and TAIEX.

Fuzzy set theory was offered by Zadeh in his paper "Fuzzy Sets" (Zadeh, 1965). The idea was then developed by Black and fuzzy logic was originated from fuzzy set theory. Primary aim of fuzzy logic is to cope with uncertainty. Fuzzy name is used in order to show that it is different from crisp sets (Frantti & Mahonen, 2001).

Li (2002) supplies that exactly defining and modeling complicated systems are so difficult fuzzy logic can manage to achieve it in a way. In addition to this, fuzzy logic is much more successful to model real world data than classical statistical and mathematical methods. Due to the fact that it models the real world events including complexity and vagueness, fuzzy logic has a big amount of support by the researchers working with real world datas (Jarrett & Plouffe, 2011).

One of the most important aspects that putting fuzzy logic to forward is its simplicity. Not only the logic represents the real world in a better way but also it achieves it in a simpler way. Fewer rules and fewer variables exist in fuzzy logic and it is the main factor lies behind its simplicity. Fuzzy logic allows the researchers to exclude tough mathematical and statistical modeling with its simple side.

Fuzzy logic also outperforms probabilistic modeling because fuzzy logic assist to tackle different type of vagueness like people judgment and subjectivity whereas probabilistic modeling can have a result only in stochastic uncertainty. Because of this advanced feature of fuzzy logic, supporters of it see as different from the other logics. Zadeh

(1992) and Kosko (1993) give the different character of fuzzy logic than probability and it is not a replacement of it (Azadegan et al., 2011).

4. FUZZY LINEAR REGRESSION

4.1 Overview of The Fuzzy Regression Methodology

Regression being one of very important fields of statistics is generally used to be investigated of relations between variables and determination of coefficients of the variables in the function. In regression analysis, to what extent the dependent variable is affected from independent variables is researched. The main aim is to express dependent variable as a function of independent variables. In fuzzy regression field, Tanaka et al. (1982), Celmins (1987 a, b), Diamond (1988) Lee & Chen (1998), Kazemi et al. (2012) give significant works and put it forward clearly.

Fuzzy regression methods can be divided into two different categories; using linear programming and using least square method. Tanaka et al. (1982), Tanaka (1987), Ozelkan (2000) and Hojati et al. (2005) offer the methods using linear programming basis. All of these methods are originated from Tanaka et al. (1982) method. However, Diamond (1988) method uses least square method. In this thesis, Tanaka et al. (1982) method is investigated.

Fuzzy regression is revealed due to the fact that classical regression can be insufficient in some cases. The cases that the data set is small, the relations between the variables cannot be given in a function clearly, the variables are as fuzzy as they cannot be changed to numerical data are some of the reasons helping the emergence of fuzzy regression idea. Use of fuzzy regression is unavoidable in some cases that:

- dependent and independent variables are fuzzy,
- relation between variables are fuzzy,
- both variables and relation are fuzzy.

Fuzzy regression, in a fuzzy environment which the limits cannot be determined clearly, shows the relations between the dependent variable and independent variables by basing membership functions. Membership functions have a value between 0 and 1 and are shown by μ (x).

General structure of fuzzy regression model is;

$$\tilde{Y} = \tilde{A}_0 + \tilde{A}_1 \tilde{X}_{11} + \tilde{A}_2 \tilde{X}_{21} + \ldots + \tilde{A}_j \tilde{X}_{ji} \quad \text{I=1,2,…n} \quad \text{J=0,1,2..k} \qquad (4.1)$$

I is the number of observation and j is the number of independent variables in that equation. A variables are the fuzzy coefficients that are the parameters of the model.

The equations shape membership functions of $\tilde{A}_j$ and a_j is the center value of this function. b_j demonstrates the radius of the function. Figure 4.1 shows the membership function of $\tilde{A}_j$. In this work, left and right spreads are taken as equal and the membership function is symmetric for simplicity. Because of this condition, the variables are not expressed as left and right and they are shown as $\tilde{A}_j = (a_j, b_j)$

Then the model is expressed;

$$\tilde{Y}_{\text{İ}} = (a_0, b_0) + (a_j, b_j) X_{11} + (a_j, b_j) X_{21} + \ldots + (a_j, b_j) X_{ji} \quad \text{İ=1,2,..n} \quad \text{J=0,1,2..k} \qquad (4.2)$$

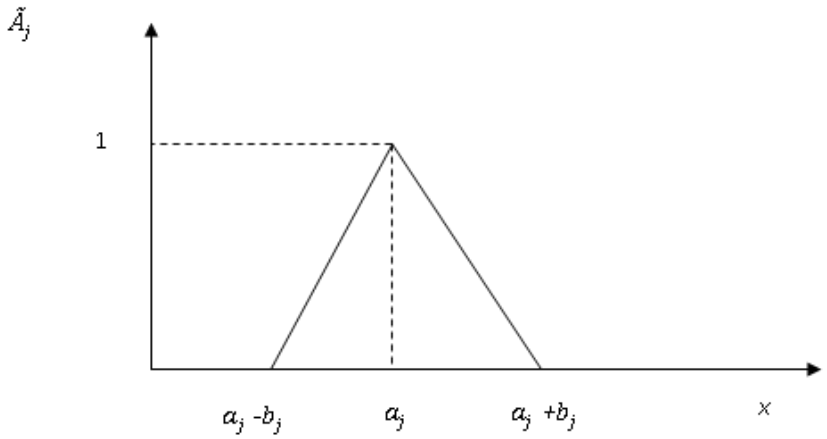

Figure 4.1: Membership function of $\tilde{A}_j$

Y_i value is expressed (y_i, e_i). y_i shows the center value of fuzzy forecast and e_i is the spread value of y_i . Minimum and maximum limits of $Y_i$fuzzy value are;

$$y_i - e_i = \sum a_j . X_{ji} - \sum b_j . X_{ji} \quad (4.3)$$

$$y_i + e_i = \sum a_j . X_{ji} + \sum b_j . X_{ji} \quad (4.4)$$

i = 1, .., n j= 0,..,k

In these equations, $e_i = \sum b_j . X_{ji}$ value shows the error term. In the optimization stage, this level is desired to minimize in the objective function. In the optimization procedure, fuzzy model is obtained by solving the equations below (Tanaka et al.,1982)

Min (b_0+ … + b_k) (4.5)

Subject to

$a_j X_i + (1-h) \sum b_j X_{ji} \geq y_i + (1-h) e_i$

$a_j X_i - (1-h) \sum b_j X_{ji} \leq y_i - (1-h) e_i$

i = 1, .., n j= 0,..,k

b ≥ 0

After the equations solved with respect to the constraints, the optimized results which minimize the error values are obtained (Hojati et al., 2005).

In classical regression, it is assumed that error terms contain the place of the variables are not included in the function but have the possibility to explain the dependent variable. In fuzzy regression, error is distributed to all the variables and the variables are forecasted with fuzziness to some extent. This extent can be named as h value and this value is between 0 and 1 (Kim & Moskowitz, 1993). If h value is equal to zero it means that forecasted models and observed values are not coherent while it is equal to one it means that they are totally coherent. While h value approaches zero, width of fuzzy variables increases whereas it decreases while h value goes to 1. When the value is equal to 1, it means that there is no fuzziness. Generally, h value is offered as 0.5 and in this work it is assumed 0.5 (Kaya, 2010). H value is also deterministic factor for distribution of fuzzy parameters. Figure 4.2 shows fuzzy regression algorithm's interpretation (Kim et al., 1996).

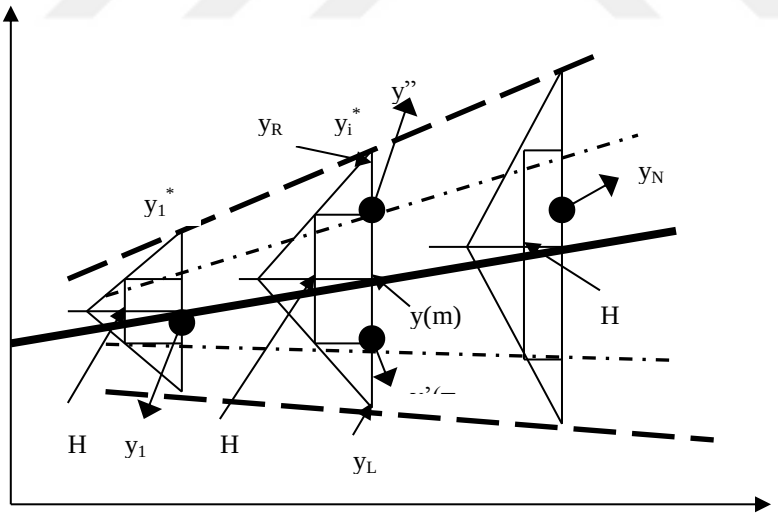

Figure 4.2: Fuzzy Regression Algorithm's Interpretation (Kim et al., 1996)

4.2 Fuzzy vs Statistical Linear Regression

Fuzzy and statistical linear regressions are used to explain a condition showed as dependent variable with different factors which are named as independent variables. Kim et al. (1996) provide a general information and comparison between these regression types and show that statistical linear regression is preferred in order to describe a phenomena and model the relationship among the variables and it is advantageous in non-fuzzy environment where the relationship is clear. Fuzzy regression which is not a statistical method is used to model and explain imprecise, vague and uncertain conditions.

Fuzzy and statistical regressions have been developed from different perspectives; possibility theory and probability theory respectively. In statistical regression, it is assumed that the deviations reveal because of omitting of relevant factors from the model and measurement errors in observation and the error term has random distribution. In fuzzy regression, error term is attributed to uncertainty of system structure, vagueness of human perception and knowledge of the model (Kim et al., 1996).

The main aims of regression analysis are to make forecasting and describe the conditions, phenomena. In terms of forecasting, statistical regression outweighs fuzzy linear regression whereas fuzzy regression replies better in describing the phenomena according to conducted experiments. However, in the case that sufficient data is not available which is often the case in practice fuzzy linear regression outperforms statistical linear regression not only in describing the condition but also predicting the phenomena as well (Kim et al., 1996).

In this work, data is comprised of 6 months, from July to September and the factors which are thought as influential for show-up decision of the passengers and therefore show-up rate are determined by human perception and knowledge.

In order to decrease the effect of hypothetical data and human perception in the project and describe the general show-up condition with 6 months-data, fuzzy linear regression

is preferred in this thesis. Explanation and optimization of the data are realized by applying fuzzy linear regression rules of Tanaka et al. (1982).

5. FORECASTING MODEL IN AIRLINE REVENUE MANAGEMENT USING FUZZY REGRESSION

Table 5.1: Airlines Having Operation in Ataturk Airport[5]

Adria Airways	Aegean Airlines	Aeroflot Airlines	Afriqiyah Airways
Air Astana	Air Canada	Air France	Air Moldova
Alitalia	Ariana Afghan Airlines	Asiana Airlines	Ata Airlines
Azerbaijan Airlines	Belavia	British Airways	Buraq Air
Delta Airlines	Lufthansa	Dniproavia	Donavia
Emirates	Etihad Airways	Ghadames Air	Gulf Air Company
Iran Air	Iran Aseman Airlines	Iraqi Airways	Jazeera Airways
Korean Air	Libyan Arab Airlines	Polish Airlines	Mahan Air
Meraj Airlines	Middle East Airlines	Onur Air	Pegasus Airlines
Qeshm Air	Rossiya Airlines	Royal Air Maroc	Royal Jordanian
Scat Air Company	Singapore Airlines	Somon Air	Swiss International
Tajikistan Air	Tarom Airlines	Transaero Airlines	Tunis Air
Turkmenistan Airl.	Ukraine International	Uzbekistan Airways	Zagros Airlines
Air Algerie	China Southern	Klm Airlines	Saudi Arabian
Air Serbia	Egypt Air	Malaysia Airlines	Taban Airlines
Atlas Jet Airlines	Iberia	Qatar Airways	Turkish Airlines

The forecasting model offered in this thesis, is revealed in order to determine the conditions of some of the factors affecting no-show and show-up behaviors of airline passengers for an airline which is newborn. A newborn airline has to make forecast in

[5] http://www.ataturkairport.com/en-EN/preflight/Pages/Airlines.aspx

order to apply overbooking strategy and because there is no historical data in its memory, it should benefit from a general model.

In this project Istanbul is selected as center and the flights to different cities in different countries are investigated. Many factors that are thought as influential on show-up rate as average fare, number of flights per week, difficulty of getting visa of the countries, human development index of destination countries, distance and temperature values are used. Regression analysis is applied with all these factors to show-up rate and the results show how show-up rate is shaped with respect to these factors. Fuzzy regression method is preferred and there was a comparison between fuzzy and statistical linear regression in previous heading.

In this work, the flights whose origin city is Istanbul and airport is Istanbul Ataturk Airport were preferred because Istanbul has one of the most populated airports of the world and Ataturk Airport serves to 65 different airlines as of December 2015. Table 5.1 shows the airlines having operation in Ataturk Airport.

Istanbul Ataturk Airport was the 13th busiest airport of the world in 2014 and it is the airport whose number of passengers increased the most. Table 5.2 demonstrates the list of first 20 airports and their information served by Airport Council International.

Turkish Airlines which is the biggest airline in Turkey and it flies to the most countries worldwide as of December 2015. Turkish Airlines contributes to improvement of aviation in Turkey and increases number of destination year by year. Turkish Airlines is selected as the best airlines in Europe by Skytrax five times in a row from 2011 to 2015. With the existence of this airline, Turkish aviation sector continues to grow.

Table 5.3 shows revenue and profit of Turkish Airlines as USD in the last years and this table also reflects improvement of Turkish aviation sector.

Table 5.2: The List of First 20 Airports[6]

Rank	Airport	Country	Total Passengers	Passanger Change
1	Hartsfield–Jackson Atlanta International Airport	United States	96,178,899	1.9%
2	Beijing Capital International Airport	China	86,130,390	2.9%
3	London Heathrow Airport	United Kingdom	73,408,442	1.4%
4	Tokyo Haneda Airport	Japan	72,826,862	5.8%
5	Los Angeles International Airport	United States	70,665,472	6.0%
6	Dubai International Airport	United Arab Emirates	70,475,636	6.1%
7	O'Hare International Airport	United States	70,015,746	4.4%
8	Paris-Charles de Gaulle Airport	France	63,808,796	2.8%
9	Dallas/Fort Worth International Airport	United States	63,523,489	5.1%
10	Hong Kong International Airport	China	63,148,379	6.0%
11	Frankfurt Airport	Germany	59,566,132	2.6%
12	Soekarno-Hatta International Airport	Indonesia	57,005,406	-4.8%
13	Istanbul Atatürk Airport	Turkey	56,767,108	10.7%
14	Amsterdam Airport Schiphol	The Netherlands	54,978,023	4.6%
15	Guangzhou Baiyun International Airport	China	54,780,346	4.4%
16	Singapore Changi Airport	Singapore	54,091,802	0.7%
17	John F. Kennedy International Airport	United States	53,635,346	6.4%
18	Denver International Airport	United States	53,472,514	1.7%
19	Shanghai Pudong International Airport	China	51,651,800	9.5%
20	Kuala Lumpur International Airport	Malaysia	48,932,471	3.0%

[6] Wikipedia, (2016). List of the world's busiest airports by passenger traffic. [online] Available at: https://en.wikipedia.org/wiki/List_of_the_world%27s_busiest_airports_by_passenger_traffic#2014_statistics [Accessed 11 Nov. 2015].

Table 5.3: Revenue and Profit of Turkish Airlines as USD[7]

Year	Revenue	Net Profit
2010	5,468,831,169	185,714,286
2011	6,251,322,751	9,523,810
2012	8,375,842,697	636,516,854
2013	9,826,000,000	357,000,000
2014	11,070,000,000	845,000,000

[7] http://investor.turkishairlines.com/en/financial-operational/financial-statements/1/2014/all-period

5.1 Defining Influential Factors

Data of the thesis is comprised of monthly information of the flights which are from Istanbul to 8 different cities in different countries. Departure month, origin and destination are information columns of the flight while show-up rate, average fare, weekly number of flights between the origin and destination points, difficulty of having visa, human development index (HDI), distance and temperature are the variables of regression. While show-up rate is dependent variable, the others are independent variables which have a role in determination of show-up role.

Origin point is Istanbul Ataturk Airport (IST) for all flights and destination points are New York John F. Kennedy Airport (JFK), Sao Paulo-Guarulhos International Airport (GRU), Belgrad Nikola Tesla Airport (BEG), Dubai International Airport (DXB), Addis Ababa Bole International Airport (ADD), Paris Charles De Gaulle Airport (CDG), Shanghai Pudong Airport (PVG) and Tokyo Narita International Airport (NRT). Departure month shows the month when the flights are realized between origin and destinations. Datas are average values of flights in concerning month.

Show-up rate shows how many of 100 passengers having reservation comes to the flight and board. This rate is affected from different factors and it changes from line to line. It generally takes values between 90 and 100 but show-up rate sometimes may decrase below of these values. At the end of the model a general idea will be revealed in order to have a clear forecast for show-up rate of an airline. Show-up rates of the lines are hypothetical values which are provided by Revenue Management analysts of concerning lines.

Weekly number of flights between two points is important because it is expected that the more direct flights exist in a line the more chance for a passenger to reach destination point. If there are a small number of direct flights in a line, passenger may have to go to indirect flights. Because of this, the number of total flights realized by all the airlines in the line is included in the project. Table 5.4 shows the weekly number of direct flights between origin and destination points.

Table 5.4: Weekly Number of Direct Flights Between Origin and Destination

Origin	**Destination**	**Weekly Direct Flights**
Istanbul Ataturk Airport	New York, USA	28
Istanbul Ataturk Airport	Sao Paulo, BRE	7
Istanbul Ataturk Airport	Belgrad, SER	15
Istanbul Ataturk Airport	Dubai, UAE	22
Istanbul Ataturk Airport	Addis Ababa, ETH	7
Istanbul Ataturk Airport	Paris, FRA	49
Istanbul Ataturk Airport	Shanghai, CHI	7
Istanbul Ataturk Airport	Tokyo, JPN	14

If there is no visa freedom between two countries including origin and destination points, it means that a travel between this kind of countries is relatively different than a trip between two countries having visa agreement. Difficulty of having a visa is a coefficient demonstrating how much effort a passenger spends while having the visa of destination point from Turkey. The coefficients in the project are hypothetical and are offered by Revenue Management analysts of concerning lines.

Human Development Index (HDI) shows the development coefficient of destination country. Human Development Index is also a sign for economic and cultural development of the countries so it can be regarded as development of aviation sector, airlines and airports of a country. Because of these reasons, it may have an effect on show-up rate of the passengers going to that destination country. HDI Index is determined by United Nations.

Distance shows how much the origin and destination points are further from each other. Distance between origin and destination points may change length and aircraft type of the flight. Because airlines have different destination point in different continents and

with different distance, this factor is really important in shaping of show-up rate of the customers. Distances of the points were obtained from GreatCircleMapper.net website.

Seasonality is also important in aviation sector because load factor and customer type of the lines and airlines may change with respect to seasons. It may result that show-up rate also differ from time to time. In order to add the seasonal factor which can be evaluated as a fuzzy variable, the temperature values of the months in origin city, Istanbul were used. Temperature value is the average of all the lowest and highest values of each day of the months. These values were obtained from Accuweather.com website.

Average Fare shows the price value that each passenger leaves for the flight. Because there are local and beyond passengers in the same flight, it is calculated with the pseudo fare of each flight. Local passengers leave all of their fare for local flights but some of the payments of beyond passengers are separated for the other flights of the customers. After this calculation, average fare of each flight is found. In this thesis, average fare demonstrates the average of the average fares of each flight in a month. This factor is hypothetical value and they are provided by the Revenue Management analysts of concerning lines of Turkish Airlines.

5.2 Application and The Results

In order to apply the fuzzy regression steps, the fuzzy regression equation is written at first.

$$Y = (a_0, b_0) + (a_1, b_1)X_1 + (a_2, b_2)X_2 + (a_3, b_3)X_3 + (a_4, b_4)X_4 + (a_5, b_5)X_5 + (a_6, b_6)X_6 \quad (5.1)$$

All the variables in the model are like that;
Y: Show-up rate
X_1: Average fare
X_2: Number of weekly flights in that line
X_3: Difficulty of having visa in that line
X_4: Human Development Index in destination country
X_5: Distance
X_6: Temperature

a and b values are the center and spread values of variables.

Objective function is to minimize the product of spread values, H value (0.5) and total of each independent variable.

$$\text{Min} \quad \sum b_i \sum X_{ij} \qquad \text{i} = 0,1,2,..,6 \qquad \text{j}= 1,2,..,48 \quad (5.2)$$

There are 96 many different conditions because there are 8 lines, 6 months and 2 less or more condition. It means that there are 48 different data and their less or more condition to determine the optimized values. The objective function and 2 of the datas with less or more conditions are given as example below. Table 5.5 shows an example with two data points.

Table 5.5: Example With Two Data Points

Dept Date	Orgn	Dstn	Show-up	Avg Fare	Weekly Flight	Visa	HDI	Distance	Temperature
07.2014	IST	JFK	97.72295	471	28	80	0.914	8072	26.21
07.2014	IST	GRU	95.77496	492	7	15	0.744	10,536	26.21

Min $Z = 48\ b_0 + 15807\ b_1 + 918\ b_2 + 2805\ b_3 + 38\ b_4 + 286887\ b_5 + 919.12\ b_6$

subject to

$a_0 + 471\ a_1 + 28\ a_2 + 80\ a_3 + 0.914\ a_4 + 8072\ a_5 + 26.21\ a_6 + (0.5\ b_0 + 235.5\ b_1 + 14\ b_2 + 40\ b_3 + 0.457\ b_4 + 4036\ b_5 + 13.105\ b_{6)} \geq 97.72$

$a_0 + 471\ a_1 + 28\ a_2 + 80\ a_3 + 0.914\ a_4 + 8072\ a_5 + 26.21\ a_6 - (0.5\ b_0 + 235.5\ b_1 + 14\ b_2 + 40\ b_3 + 0.457\ b_4 + 4036\ b_5 + 13.105\ b_{6)} \leq 97.72$

$a_0 + 492\ a_1 + 7\ a_2 + 15\ a_3 + 0.744\ a_4 + 10536\ a_5 + 26.21\ a_6 + (0.5\ b_0 + 246\ b_1 + 3.5\ b_2 + 7.5\ b_3 + 0.372\ b_4 + 5268\ b_5 + 13.105\ b_{6)} \geq 95.77$

$a_0 + 492\ a_1 + 7\ a_2 + 15\ a_3 + 0.744\ a_4 + 10536\ a_5 + 26.21\ a_6 - (0.5\ b_0 + 246\ b_1 + 3.5\ b_2 + 7.5\ b_3 + 0.372\ b_4 + 5268\ b_5 + 13.105\ b_{6)} \leq 95.77$

$b_{1,}\ b_{2,}\ b_{3,}\ b_{4,}\ b_{5,}\ b_6 \geq 0$

Fuzzy regression method is applied with respect to these objective function and constraints via Excel Solver.

After solving the problem, the results are given in Table 5.6.

Table 5.6: The Results

Center Values		Spread Values	
a_0	89.301402	b_0	2.014592
a_1	-0.000427	b_1	0.000253
a_2	-0.040502	b_2	0.000000
a_3	0.012980	b_3	0.000000
a_4	7.712456	b_4	0.000000
a_5	0.000098	b_5	0.000186
a_6	0.052025	b_6	0.000000

According to these results three of six variables including average fare and distance have fuzziness and this results demonstrates the values that show-up rate will have as minimum and maximum. Center values of average fare and number of flights are negative. It means that while fares and connectivity between two cities increases, show-up rate of passengers decrease. The other factors have positive relation with show up rate. While distance, HDI of destination country, difficulty of having visa and temperature increase, show-up rate also increases. It means that show-up rate is expected to be higher in summer season and in the flights between far cities. In addition to these, the flights between countries having higher HDI is expected to have higher show-up values like the flights whose destination countries giving visa relatively more difficult.

Lower bound of the predicted show up rate ;

$$89.301402 - 2.014592 + (-0.000427 - 0.000253)\ X_1 + -0.040502\ X_2 + 0.012980\ X_3 + 7.712456\ X_4 + (0.000098 - 0.000186)\ X_5 + 0.052025\ X_6 \quad (5.3)$$

Upper bound of the predicted show up rate ;

$$89.301402 + 2.014592 + (-0.000427 + 0.000253)\ X_1 + -0.040502\ X_2 + 0.012980\ X_3 + 7.712456\ X_4 + (0.000098 + 0.000186)\ X_5 + 0.052025\ X_6 \quad (5.4)$$

As a result, show-up value which is out of 100 is determined with respect to 6 different factors by applying fuzzy regression methodologies. Because there are very large and different characteristics of lines in the project, these results can be evaluated as descriptive and predictive to determine show-up rate forecasts for the airlines. Airlines may arrange their overbook policies by benefitting from this work.

6. CONCLUSION

Revenue Management is a very large field that is used by a lot of companies from different sectors in order to increase their revenue and profitability. Airlines, hotels, car rental companies, restaurants, casinos, energy firms all try to evaluate their capacity in the best way and obtain the maximized benefit.

In order to reach all the customers whom the companies can convince market segmentation logic is applied in aviation sector. With this logic, companies vary their products and try to become buyable by more and more customers. Pricing and Yield Management are the most prominent points enabling market segmentation for customers in Revenue Management applications.

By applying pricing and yield management tools, airlines try to do their utmost in this competitive sector. Yield Management has different tools and one of these tools is overselling which provides airlines to sell extra tickets exceeding the capacity. Airlines sell these tickets by regarding no-show and cancellation possibility of the passengers and empty seats in the upper category cabins. Overbooking which is a field of overselling can be thought as a precaution taken by airlines in order to decrease the effect of no-show passengers. In this way, it is prevented that a seat stays empty because of no-show passengers.

In order to apply overbooking in an effective manner, forecasting no-show passengers has a significant role. There are many factors influencing show-up decision of the passengers and the characteristic of each line is different. Because the factors shaping show-up (and no-show) values are not certain, forecasting of this value is difficult and it has fuzziness.

In this work, fuzzy linear regression is preferred to describe and predict show-up phenomena because of the vague relationships among independent variables.

At the end of the execution of fuzzy regression to the data which is comprised of 8 different lines and 6 months, it is seen that while fare and number of flights increase diminish the show-up rate whereas difficulty of having visa, distance, human development index and temperature increase get show-up rate higher. Because the data points are selected from the lines having different characteristics, this forecast can find a large field of application in aviation sector.

As further works, this project can be developed by adding cost of the spilled seats which stay empty after departure, cost of denied boarding passengers and the revenue obtained by airlines from overbooked passengers. With an objective function which maximizes the profit or minimizes the cost after forecasting show-up (and no-show) rate would be more beneficial for airlines.

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