Research Article
Araştırma Makalesi

Bartın University International Journal of Natural and Applied Sciences
JONAS, 6(2): 157-167 e-ISSN: 2667-5048
31 Aralık/December, 2023 DOI: 10.55930/jonas.1274797

MODELING OF AIRPORT CHECK-IN UNITS ARCHITECTURAL DESIGN AND PROCESSING TIME STANDARDS WITH FUZZY APPROACH

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Abstract

There is a number of architectural problems that airports must meet such as ensuring the circulation of passengers in terminal building quickly and shortening the time between flights. This is related to the concept of level of service (LOS) which aims to keep passengers in circulation at an affordable cost with minimum delay and maximum comfort without being exposed to congestion. LOS standards have been developed by the International Air Transport Association (IATA) for density analysis of airport terminal buildings. However, with the increase in capacities and user density, there are gradual decreases in standards with sharp boundaries, and this situation is true in the context of strict limits but does not fully reflect reality. Besides, a fuzzy assumption has been made to the issue, both due to the fact that LOS are set with different values in standards published in different years, and to allow rapid and efficient analysis of density changes in unexpected situations. Within the scope of the study, the LOS standards of the check-in areas and sub-functions which are used extensively and host a large number of passengers are modeled in matlab program by means of fuzzy logic. Four independent mathematical models were created: a design decision support model for the architectural design related to the check-in section, and three models for the check-in sub-functions, processing times and areas for business performance. In the models, output data were obtained for each input data and LOS could be determined by interpreting these outputs degree of representation.

Key Words: Fuzzy assumption, fuzzy logic, IATA, level of service, airport terminal

1. Introduction

Airports are places where arriving passengers get their first impressions of a country and departing passengers get their last. In this respect, airport terminal buildings which act as a showcase that introduces a country are exposed to the world and bring growth potential to the regions where they are located (Horonjeff et al., 2010; Kazda & Caves, 2015). Therefore, it is important for terminal buildings to provide necessary comfort conditions for passengers both in terms of obtaining positive impressions of passengers about a country and increasing user satisfaction. With the increase in flights and the decrease in air transport fares, airport terminal buildings have become places that people frequently use. Hitherto the Covid-19 pandemic in 2020 where a reported decrease of 60% in airport traffic was witnessed, other reports indicated a sustained increase in airport traffic up until 2019 and as of 2021 (ICAO, 2022; Thampan et al., 2020). Considering that airport strategic planning is made by taking into consideration the estimates ranging from 20 to 50 years, the increase in user density over time brings with it problems that need to be solved for future planning (Waltert et al., 2021).

As a result of the increase in the number of users of airport terminal buildings, there are a number of architectural problems that airport terminals must meet, such as ensuring quick circulation of passengers within the building to shorten the time between connecting flights (Tošić, 1992). It is possible to predict the overall size of a terminal building design before determining detailed calculations of the areas to be designed for specific functions. Projected total size of terminal projects are related to the concept of level of service (LOS) which aims to keep passengers in circulation at an affordable cost with minimum delay and maximum comfort, without being exposed to excessive congestion. The concept of LOS is also used in the density analysis of existing airport terminal buildings and in the decision of investment strategies (IATA, 1995; Solak et al., 2009). Therefore, one of the main problems for airport management is to be able to meet the increasing capacity while maintaining financial viability and an acceptable LOS. Airlines, airport operators and relevant government agencies strive to anticipate airport capacity and potential problems that will be caused by the increase in density (IATA, 2004). The development of LOS measurements for airport terminals has been one of the most important issues for airport operators in recent

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Geliş (Received) : 31.03.2023
Kabul (Accepted) : 04.10.2023
Basım (Published) : 31.12.2023

years (Correia et al., 2008). LOS standards have been developed by the International Air Transport Association (IATA) for density analysis of airport terminal buildings. LOS standards related to the functions of airport terminal buildings can be reached from different editions of the Airport Development Reference Manual (ADRM) published by IATA. The values corresponding to the LOS standards ranking from A (the best) to E (the worst) have changed over the last three decades and have been increased in details according to the sub-functions of the airport (such as check-in, security point or baggage claim). As understood from ADRMs, the LOS standards of airport terminal buildings are determined within the framework of definite value ranges. However, it can be predicted that the actual service perception cannot be in full correlation with the standards determined with sharp boundaries. In addition, the definition of different values for standards in different editions of ADRM strengthens the hypothesis that there cannot be strict boundaries between level of services (from A to E). Other than IATA, studies on LOS include the Airport Cooperative Research Program (ACRP) report sponsored by the Federal Aviation Administration (FAA) and the regulations of the Airports Council International (ACI) are available. However, in the documents of ACRP and ACI, in the parts related to airport terminal level of service, IATA standards are cited (ACI, 2012; ACRP, 2010).

As mentioned before, airport terminal buildings are starting to fail to meet the required LOS in the regulations due to their architectural programs that increase in capacity over time. However, with the increase in capacities and user density, there are gradual decreases in standards with sharp boundaries (e.g. a terminal with a density of C level can drop to level D as a result of adding a single person), and this situation is true in the context of strict limits, but does not fully reflect reality. Besides to this situation, the existence of different values related to standards also requires a fuzzy assumption. Within the scope of the study, the LOS standards determined by IATA for the check-in areas, which are used intensively and host a large number of passengers, due to the fact that ADRMs become more and more detailed in terms of standards, have been modeled and made flexible by means of fuzzy logic. The LOS standards in different editions of ADRM were defined as membership functions, and the data were modeled in the matlab program. Thanks to the four mathematical models built on the fuzzy approach, the uncertainty of the LOS standards in the context of different regulations and the sharpness of the level drops can be eliminated (Mcneill & Thro, 1994).

2. The LOS Concept of Airport Check-in Units

Planners and decision makers should keep in mind that travelers visit an airport for one reason: to catch a flight. Therefore, the expectations and needs of passengers should be at the center of the planning process (IATA, 2004). Passengers, airlines and other terminal users have their own ideas about the comfort, convenience and cost, and therefore evaluate the terminal's performance in terms of such factors (Lemer, 1992). However, comfortable walking for the movement of pedestrians is already a necessity in modern transportation systems (Cepolina et al., 2018). Although large spaces may be needed for an unobstructed pedestrian flow, the fact that there are spaces that are larger than necessary causes the resources not to be used effectively. The concept of LOS, introduced by Transport Canada in the 1970s due to the inadequacy of the widely used definition of capacity, was developed by planners and designers to provide a degree of precision in the design and capacity analysis for transport facilities (Ashford, 1988; IATA, 2014). While the concept of capacity is always related to the level of service provided, an airport system can operate with varying degrees of intensity and delays. For example, a particular system can handle 1000 passengers per hour at the optimal service level or 1500 passengers per hour at an inadequate LOS (e.g. in case of overcrowding) (IATA, 2014). However, it is difficult to establish a precise quantitative relationship between available space, time and LOS. Many factors such as passenger behavior patterns, psychological needs and passenger comfort can affect the required space depending on the waiting time (IATA, 1995). Passenger characteristics vary according to the region they come from, travel purposes and flight destinations. For example, a businessman/woman may travel with a small number of bags and arrive at the airport later than those traveling for holiday purposes.

There are studies in the literature that take into account the waiting and processing times, the space requirement, and different users (e.g. transit and arriving passengers) related to the LOS (Correia & Wirasinghe, 2007; de Barros et al., 2007; Ronzani Borille & Correia, 2013). There are studies that aim to produce forecast models that will allow calculating the daily and hourly density of passengers in the terminal (Kim et al., 2004; Liu et al., 2018). In addition, passenger flow simulations are produced for different usage scenarios over real and hypothetical spaces (Fonseca i Casas et al., 2014; Jim & Chang, 1998; Li et al., 2019; Roanes-Lozano et al., 2004). There are also studies in the literature examining behaviors and processes of passengers at the terminal (Kalakou & Moura, 2021; Stolletz, 2011). There is also a study using questionnaires to determine LOS (Park, 1999) and a study on the compliance of IATA LOS standards with pandemic conditions (di Mascio et al., 2020). There are also studies that examine the time spent in check-in and baggage claim areas with fuzzy logic over both the time perceived by the passengers and the number of people and luggage (Kıyıldı & Karaşahin, 2008; Yen et al., 2001). Within the scope of this paper, unlike other studies that proceed through fuzzy logic, the LOS standards of the check-in departments, both time and space, and only space needs are emphasized.

As mentioned above, there are different LOS definitions in different editions of ADRM. According to Table 1, level C is recommended in order to obtain a good level of service with affordable cost and to use resources effectively. There is no upper limit for level A. In the eighth edition of ADRM, published in 1995, there are LOS standards for five different areas in terminal buildings (IATA, 1995) (Table 2).

Table 1. Definitions of level of services (IATA, 1995).

Level of Service	Definition
A	An Excellent level of service. Conditions of free flow, no delays.
B	High level of service. Conditions of stable flow, very few delays.
C	Good level of service. Conditions of stable flow, acceptable delays.
D	Adequate level of service. Conditions of unstable flow, acceptable delays for short periods of time.
E	Inadequate level of service. Conditions of unstable flow, unacceptable delays.
F	Unacceptable level of service. Conditions of cross-flows, system breakdowns and unacceptable delays.

Table 2. IATA LOS standards (sq. meter/occupant) (IATA, 1995).

	A	B	C	D	E	F
Wait / Circulate	2.7	2.3	1.9	1.5	1.0	
Bag Claim Area (excl. claim device)	2.0	1.8	1.6	1.4	1.2	
Check-in Queue Area	1.8	1.6	1.4	1.2	1.0	System Breakdown
Hold Room	1.4	1.2	1.0	0.8	0.6	
GIS	1.4	1.2	1.0	0.8	0.6	

In the ninth edition of ADRM, check-in LOS standards have become more detailed with four different possibilities, according to row widths and the number of luggage and trolleys owned by passengers (Table 3).

Table 3. IATA LOS standards for the check-in queue (in a single line) (sq. meter/occupant) (IATA, 2004).

	A	B	C	D	E
Few carts and few passengers with check-in luggage (row width 1.2 m).	1.7	1.4	1.2	1.1	0.9
Few carts and 1 or 2 pieces of luggage per passenger (row width 1.2 m).	1.8	1.5	1.3	1.2	1.1
High percentage of passengers using carts (row width 1.4 m).	2.3	1.9	1.7	1.6	1.5
'Heavy' flights with 2 or more items per passenger and a high percentage of passengers using carts (row width 1.4 m).	2.6	2.3	2.0	1.9	1.8
Average of four different LOS	2.1	1.8	1.6	1.5	1.3

When the check-in LOS values in Tables 2 and 3 are compared, it can be seen that the values in Table 2 are close to the values of row 2 in Table 3 (few carts and 1 or 2 pieces of luggage per passenger). In addition, since the possible scenarios in Table 3 are situations that a terminal may be constantly exposed to, the values in each column have been averaged in order to provide an optimum approach within the scope of the evaluation. The LOS concept has been updated in the tenth edition of ADRM to reflect the dynamic nature of terminal operation more strongly. Unlike previous ADRM editions, the new concept, which defines time as a LOS indicator has three levels as indicated in Table 4 (IATA, 2014).

Table 4. IATA LOS standards (IATA, 2014).

Level of Service	Space	Time
Overdesign	Excessive or empty space.	Overprovision of resources.
Optimum	Sufficient space to accommodate the necessary functions in a comfortable environment.	Acceptable processing and waiting times.
Suboptimum	Crowded and uncomfortable.	Unacceptable processing and waiting times.

While planning/designing the waiting areas of the facilities, two important variables determine LOS together, viz; Queue area and waiting time. In Table 5, the space axis defines the amount of area per passenger, while the time axis indicates the maximum waiting time for passengers waiting in line. Both axes are required to define the LOS (IATA, 2014).

Table 5. IATA LOS space/time standards (IATA, 2014).

		Space		
		Overdesign (>Y m^2)	Optimum (X to Y m^2)	Suboptimum (<X m^2)
Time	Overdesign (<A mins)	Overdesign	Optimum	Consider improvements
	Optimum (A mins to B mins)	Optimum	Optimum	Consider improvements
	Suboptimum (>B mins)	Consider improvements	Consider improvements	Underprovided, reconfigure

If both space and time axes indicate optimum/suboptimum level, the facility offers an acceptable/unacceptable LOS. When one of the axes indicates an optimum and the other suboptimum, it may be necessary to make improvements in the facility. Operational improvements such as increasing the quality of personnel and processing speeds, or physical improvements such as removing circulation from a queue, rearranging queues to increase free space, or adding processing units can be made. Any facility that falls into "suboptimum" requires major improvements and immediate action to be taken (IATA, 2014). LOS standards for check-in departments, both in terms of space and time, are defined in the tenth edition of ADRM (Table 6).

Table 6. IATA Check-in LOS standards (IATA, 2014).

	Space standards for waiting areas (sq. meter/occupant)			Waiting time standards for processing facilities (economy class – mins)		
ADRM 9th Ed.	A B	C	D E	A B	C	D E
ADRM 10th Ed.	Overdesign	Optimum	Suboptimum	Overdesign	Optimum	Suboptimum
Self-Service Boarding Pass / Tagging	>1.8	1.3 - 1.8	<1.3	0	0-2	>2
Bag Drop Desk (queue width 1.4-1.6 m)	>1.8	1.3 - 1.8	<1.3	0	0-5	>5
Check-in Desk (queue width 1.4-1.6 m)	>1.8	1.3 - 1.8	<1.3	<10	10-20	>20

In the eighth, ninth and tenth editions of ADRMs, it is seen that the most detailed approach regarding the check-in level of service in terms of space was carried out in the ninth edition where possible situations were taken into account and 6 graded evaluation charts such as A, B, C, D, E and F (not shown except in table 2) were used. In the tenth edition, the sub-functions of the check-in areas were examined. However, it can be seen that the square meter values are repeated, and it is passed from the 6-grade evaluation chart to a 4-grade evaluation chart such as overdesign, optimum, consider improvements and underprovided (not shown except in table 5). This situation prevents the intermediate and/or limit values to be seen, apart from being good/moderate/bad/unacceptable. Apart from these standards, eleventh and twelfth editions of ADRM have also been published (IATA, 2019; IATA 2022). However, it is not added to the fuzzification model. Since it is seen that they are not open sources currently. Also, the main aim of this research is to constitute the mathematical evaluation models for the LOS standards. Thus, the database can be extended effortlessly in the future.

3. Fuzzy Approach to the Concept of Level of Service

Fuzzy approach or fuzzy logic, introduced by L. Askerzadeh, is a system of thought that allows the definition of propositions that cannot be expressed precisely and contain uncertainty through mathematics (Zadeh, 1965). It requires fuzzy set logic to be able to use the values that we cannot distinguish precisely and cannot judge clearly by machines such as computers. Thanks to this important expansion that fuzzy logic brought to literature and practice, many points where Aristotle's dual logic missing within the framework of Ancient Greek philosophy were revealed (Ross, 2010). In the context of architectural design, fuzzy logic is used to make precise and efficient decisions and evaluations (Diker & Erkan, 2021). Besides, there are studies integrated with the analytical hierarchy process and conducted with the spherical fuzzy set theory (Bostancioglu, 2020; Singer & Özşahin, 2021).

The reasons for choosing the fuzzy approach in modeling levels of service are that it allows for taking into account the differences between standards that change over time, for preventing of gradual decreases in LOS, and for analyzing the intense changes in unexpected situations quickly and efficiently (Ballis et al., 2002; Klir & Yuan, 1995). Although the standards that change over time may seem close to each other, at some points the changes can reach values such as 30% (the difference between the standards in different editions of ADRM for defining the E level of service). For this purpose, the aforementioned LOS standards in different editions of ADRM are gathered on a single graphic (Figure 1).

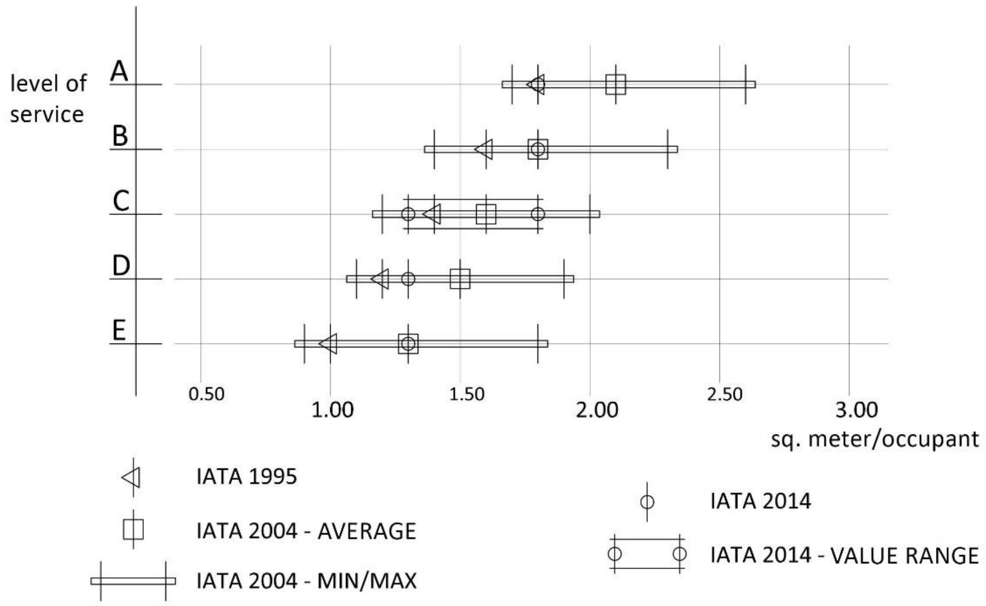

Fig. 1. Check-in LOS space standards in different editions of ADRM.

In the ninth edition of ADRM, LOS standards have been introduced for four different situations that may occur in check-in areas. In Figure 1, the minimum and maximum values of these standards defined in the ninth edition are shown with an empty long rectangle and the average of the 4 values defined for each case is shown with a hollow square. A similar situation exists in the tenth edition of ADRM. Here only the 1.3-1.8 sq. meter/pax range (circle and double horizontal line) for LOS C is shown, but the average (1.55) is not shown.

4. Fuzzy Approach Models of Check-in LOS Standards

Within the scope of the study, four mathematical models were created with the fuzzy extension of matlab program in order to evaluate the LOS of the check-in section. One of the four models is univariate and focuses on space, while the other three are bivariate and focus on space and processing times. While there are space values in all four models developed, a 6-level evaluation chart was used in Model 1 (univariate). However, since the output variables are 4 degrees in other models, a 4-grade evaluation chart was used for space values. Otherwise, the model will be insensitive to extra input variables.

The fuzzification of check-in space LOS standards common to all four models was made using the values given in Figure 1. To create mathematical models within the framework of fuzzy logic, the LOS values in the examined standards are defined as membership functions (Figure 2). In order to define the membership functions of Model 1, the arithmetic average of the values existing in all three regulations was taken. While the arithmetic average of the regulations was taken, each regulation was evaluated with an equal coefficient. For the averaged values in Figure 1, the values are shown with an empty triangle, square and circle, and in Figure 2, they are expressed with a solid rectangle. The value of 1.55, which is the average of the range of 1.3-1.8 for the 2014 IATA standard, which is defined only for the level C, is included in the weighted average. The averaged A, B, C, D and E levels are defined as the points where the fuzzy logic membership functions have a value of 1.00. The point where the LOS A membership function is 1 is 1.90 sq. meter/pax, while for B, C, D and E it is 1.73, 1.52, 1.33 and 1.20 sq. meter/pax, respectively. The part where the LOS F membership function is defined as 1 is the lowest value in the ADRM (ninth edition) standard, which is 0.9 sq. meter/pax and below. The point where the LOS A is defined as the maximum in the regulations is 2.60 sq. meter/pax. Values above this LOS are defined as A+ level. Each membership function is given the name of the point or range where the membership degree is 1.00. The points where each membership function takes the value 0.00 are defined where the neighboring upper and lower LOS membership functions take the value 1.00. For values above 1.90 sq. meter/pax and below for A+ and above 1.20 sq. meter/pax for F, both membership functions take the value 0.00.

For Models 2, 3 and 4, each membership function of the 4-level evaluation chart defined for the space in the tenth edition of ADRM is derived from the membership functions of Model 1. Overdesign, optimum, consider improvements and underprovided levels are defined as fields where fuzzy logic membership functions have a value of 1.00. The point where the overdesign LOS membership function is 1.00 is 1.90 sq. meter/pax and above, while for the others it is 1.52, 1.20 and 0.90 sq. meter/pax and below respectively. Therefore, the values corresponding to the B and D levels in the membership functions of Model 1 correspond to the intermediate values in the space membership functions of Models 2, 3 and 4 (Figure 2).

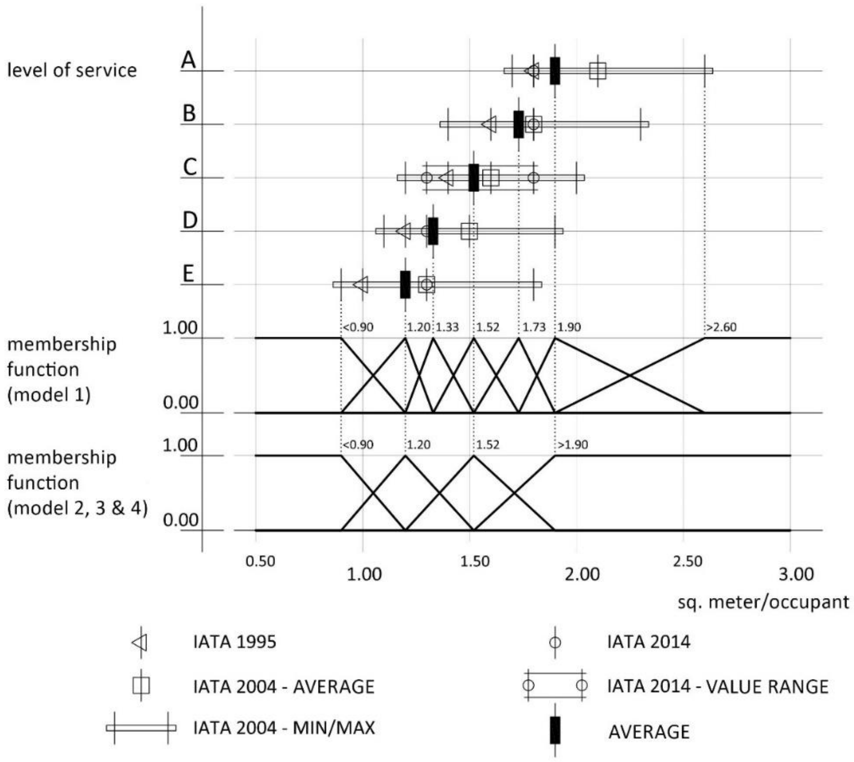

Fig. 2. Fuzzification of check-in LOS space standards.

In Figure 2, LOS standards and fuzzy membership functions are aligned with vertical dotted lines. The name of each function is written in the upper right part of the peaks where the membership functions are 1.00. The value ranges of the membership functions of the models are defined between [0.5-3.00]. However, smaller or larger values can be included in the membership functions < 0.90 or > 2.60, respectively.

The fuzzification of the check-in processing time standards defined in the tenth edition of ADRM was made using the values given in Table 6 (Figure 3). The midpoints of the optimum service levels defined in Table 6 are defined as the points where the membership functions are 1.00. The points where the optimum service levels were defined as 0.00 were calculated by adding half of the optimum time interval to the maximum value of the optimum time and subtracting half of the optimum time interval from the minimum value of the optimum time. If overdesign LOS is defined as 0 (zero) minute, that point is also the point where the optimum LOS is defined as 0. The points where optimum LOS are defined as 0.00 are also points where other membership functions are 1.00.

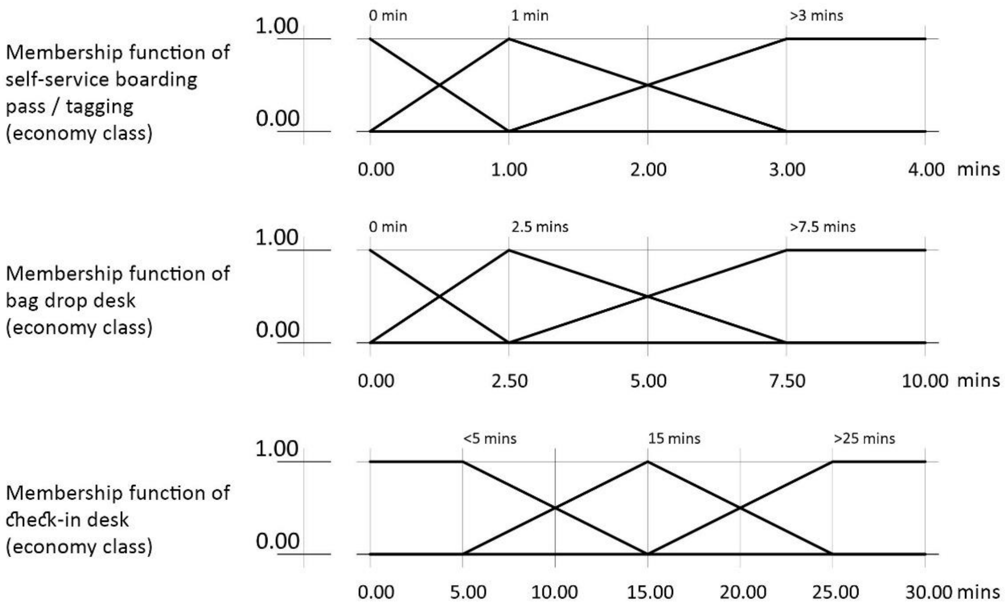

Fig. 3. Fuzzification of check-in LOS processing time standards.

In this section, in order to model the LOS standards of the check-in areas with a fuzzy approach, the data obtained from the standards were defined as membership functions and thus, the fuzzification process was carried out. To define the membership functions, the averages and min-max values of the data obtained from the regulations were used. The rule base and defuzzification of the four models is explained in the sub-headings.

Within the scope of the study, Sugeno Fuzzy Inference System (FIS) was preferred. The weighted average method was used for the defuzzification process. The reason why Mamdani method is not preferred is that the output functions to be defined for A+ and F in Model 1 and for overdesign and underprovided in Model 2, 3 & 4 will be in trapezoidal form, so the appropriate results from the geometric center of the area under these functions are not given. However, since the Sugeno method separates each LOS in the output function in terms of category, appropriate results can be obtained.

4.1. Model 1 – LOS of check-in areas

In Model 1, a mathematical model of the check-in sections was created only in the context of architectural design. After the membership functions (Figure 2) have been created, the rules that can be expressed as "IF sq. meter/pax is … THEN level of service is …" are written. While creating the rule base, the membership function indicating each LOS is matched with the corresponding level:

1. IF (m2/occupant is <0.9) THEN (level_of_service is F) (1)
2. IF (m2/occupant is 1.2) THEN (level_of_service is E) (1)
3. IF (m2/occupant is 1.33) THEN (level_of_service is D) (1)
4. IF (m2/occupant is 1.52) THEN (level_of_service is C) (1)
5. IF (m2/occupant is 1.73) THEN (level_of_service is B) (1)

6. IF (m2/occupant is 1.90) THEN (level_of_service is A) (1)
7. IF (m2/occupant is >2.6) THEN (level_of_service is A+) (1)

Since each input variable was matched with a different output variable, a total of 7 rules were written. The expression (1) at the end of the rules indicates the coefficient at which each rule affects the result. Within the scope of this study, the coefficients of all rules were included in the system to be equal. As a result of defining 7 LOS for the defuzzification process, values between 0 to 6 were assigned to the output function and the LOS was defined for each unit, 0, 1, 2, 3, 4, 5, 6, as F, E, D, C, B, A and A+ respectively. For example, when 1.58 sq. meter/pax value is entered in Model 1, the system gives the value 3.29. In this case, since the value of 3.29 is between 4.00 (B) and 3.00 (C), it represents the level B by 29% and the level C by 71% membership grade.

4.2. Model 2 – LOS of self-service boarding pass/tagging area and processing time

In Model 2, a mathematical model of the check-in self-service boarding pass/tagging section was created in terms of both area and processing time. After the membership functions (Figures 2, 3) have been created, rules that can be expressed in the form of "IF processing time is … AND sq. meter/pax is … THEN level of service is …" are written. Table 5 was used while creating the rule base:

1. IF (self-service_boarding_pass is 0min) AND (m2/occupant is >1.9m2) THEN (level_of_service is overdesign) (1)
2. IF (self-service_boarding_pass is 1min) AND (m2/occupant is >1.9m2) THEN (level_of_service is optimum) (1)
3. IF (self-service_boarding_pass is 3mins) AND (m2/occupant is >1.9m2) THEN (level_of_service is consider_improvements) (1)
4. IF (self-service_boarding_pass is 0min) AND (m2/occupant is 1.52m2) THEN (level_of_service is optimum) (1)
5. IF (self-service_boarding_pass is 1min) AND (m2/occupant is 1.52m2) THEN (level_of_service is optimum) (1)
6. IF (self-service_boarding_pass is 3mins) AND (m2/occupant is 1.52m2) THEN (level_of_service is consider_improvements) (1)
7. IF (self-service_boarding_pass is 0min) AND (m2/occupant is 1.2m2) THEN (level_of_service is consider_improvements) (1)
8. IF (self-service_boarding_pass is 1min) AND (m2/occupant is 1.2m2) THEN (level_of_service is consider_improvements) (1)
9. IF (self-service_boarding_pass is 3mins) AND (m2/occupant is 1.2m2) THEN (level_of_service is underprovided) (1)
10. IF (self-service_boarding_pass is 0min) AND (m2/occupant is <0.9m2) THEN (level_of_service is underprovided) (1)
11. IF (self-service_boarding_pass is 1min) AND (m2/occupant is <0.9m2) THEN (level_of_service is underprovided) (1)
12. IF (self-service_boarding_pass is 3mins) AND (m2/occupant is <0.9m2) THEN (level_of_service is underprovided) (1)

Since there are 3 input variables for the processing time and 4 input variables for the sq. meter/pax, a total of 12 (3×4) rules were written. The expression (1) at the end of the rules indicates the coefficient at which each rule affects the result. Within the scope of this study, the coefficients of all rules were included in the system to be equal. As a result of the definition of 4 LOS for the defuzzification process, values between 0 to 3 were assigned to the output function and the LOS was defined for each unit, 0, 1, 2, 3 as underprovided, consider improvements, optimum and, overdesign respectively.

For example, when 1.5 minutes (90 seconds) processing time and 1.35 sq. meter/pax value are entered into the Model 2, the system gives the value 1.22. In this case, since the value of 1.22 is between 1.00 (consider improvements) and 2.00 (optimum), it represents the "consider improvements" level by 78% and the "optimum" level by 22%.

4.3. Model 3 – LOS of bag drop desk area and processing time

The mathematical model of the bag drop desk section in Model 3 which is created in terms of both area and processing time is almost the same as the work done for Model 2. The difference is the use of the other membership function in Figure 3 related to the processing time. Therefore, the rule base is the updated version of the rule base used in Model 2.

For example, when 3.5 minutes (210 sec) processing time and 1.10 sq. meter/pax value are entered in Model 3, the system gives the value 0.53. In this case, as the value of 0.53 lies between 0.00 (underprovided) and 1.00 (consider improvements), the "underprovided" level represents 47% and the "consider improvements" level by 53%.

4.4. Model 4 – LOS of check-in desk area and processing time

The mathematical model of the check-in desk section in Model 4 which is created in terms of both area and processing time is also very similar to that of Model 2, as in Model 3. The difference is the use of the other membership function in Figure 3 related to the processing time. Therefore, the rule base is the updated version of the rule base used in Model 2.

For example, when 10 minutes (600 sec) processing time and 1.70 sq. meter/pax value are entered in Model 4, the system gives the value 2.26. In this case, since the value of 2.26 is between 2.00 (optimum) and 3.00 (overdesign), it represents the "optimum" level by 74% and the "overdesign" level by 26%.

5. Results and Discussions

Within the scope of the study, the LOS standards determined by IATA for the check-in areas were modelled and made flexible by means of fuzzy logic. The LOS standards in different editions of ADRM are fuzzificated and modeled. Thanks to the mathematical models built on the fuzzy approach, the uncertainty of the level of service (LOS) standards in the context of different regulations and the sharpness of the gradual level decreases were eliminated. In the models, output data were obtained for each input data and LOS could be determined by interpreting these outputs degree of representation.

The four mathematical models using fuzzy approach have the potential to be used both as an architectural design decision support model for airport check-in departments and to measure the instant performance of the check-in departments thanks to the integration of the models with sensor technologies, on one hand, and to provide quick measures and solutions for business and operation, on the other. In humanoid technologies, more accurate designs and operations can be realized by using the decision-making models created in this study. It seems possible that this study, which is carried out on the check-in sections, can also be applied to the other aspects of the airport.

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