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Internet of Things Supported Airport Boarding System and Evaluation with Fuzzy

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Abstract: The existing systems sustained with the investments made require more automation and digital transformation with the continuous advancement of technology. The aviation industry is a sector that is open to more automation and digital transformation, mainly because of the intense competition and the analysis of a large variety of data. The long duration of operations in current airline processes and some process flows cause customer dissatisfaction and cost increase. In this study, the boarding process, which is one of the operational processes of airline transportation and is open to improvement, was discussed. The classical boarding process has been redesigned using Internet of Things technology a model called Boarding 4.0 was created. With Boarding 4.0, it is aimed to design a process where passengers can take their time before boarding more efficiently. In the study, the sub-processes of the Boarding 4.0 model, other processes that the sub-processes interact with, their activities, and data exchange passenger movements during the activities are explained in detail. Compared to the classical boarding process and Boarding 4.0 with the fuzzy ahp technique, it has been shown that boarding 4.0 is more advantageous and passenger movement times can be reduced during boarding. As a result of the evaluation made with the fuzzy ahp, it was determined that boarding 4.0 is more advantageous than the classical boarding process. In addition, when the total time of the sub-activities in the boarding process is calculated, boarding activities for a passenger take 50 min with the classic boarding process and 20 min with Boarding 4.0. Thus, when Boarding 4.0 is used, the passenger gains 30 min. Furthermore, when the calculation is made concerning the airport's current capacity, two passengers are hosted with the classical boarding process, while five passengers are hosted with Boarding 4.0. This acquisition is significant for airports in terms of efficient use of resources.

Keywords: Intelligent airport; internet of things; boarding system; process management model; fuzzy ahp

1 Introduction

The aviation sector, which is one of the sectors where competition is intense, has developed itself with the advancement of technology. As a result, both airline and airport operators and other process stakeholders have to develop technologies by improving their processes to better meet customer needs by triggering competition.

The timely and effective operation of the processes is of great importance in aviation the delays experienced cause the costs to increase. The boarding process is fundamental in terms of ensuring that delays can be managed more effectively. At the same time, the boarding speed was nine passengers per minute in the late 1970 s, with 20 passengers per minute in the 2000 s [1]. Many studies can be done in the direction of process improvement in the aviation sector. For example, resource planning at airports with limited capacity, considering the number of landing times and passengers, simulation to reduce passenger waiting times [2], analysis of the effects of human factors onboarding [3], seat assignments [4] or hand luggage placements [5].

Shortening the boarding time is beneficial for both airline and airport companies and passengers. Since it is a sector where intense data flow is experienced, Industry 4.0 technologies, a new understanding that will analyze these data that machines can communicate with each other wirelessly, has more security produces fast solutions, can be used. In this study, the boarding process was redesigned and the "Boarding 4.0" model was created using IoT, one of the Industry 4.0 technologies. The model aims to allow airline companies to keep pace with developing technology, meet passenger needs more quickly increase operational efficiency. With Boarding 4.0, the boarding process will be accelerated the passenger will be able to evaluate their time during this process more effectively.

In the second part of the article, the IoT technology used in the application and its usage areas is explained. In the third part, the classical boarding process has been examined the airline company's problems, airport operators other stakeholders are explained. The Boarding 4.0 model developed is given in detail differences between the classical boarding process and Boarding 4.0 and how problems experienced in the classical boarding process with boarding 4.0 are eliminated. In the discussion section, boarding operations manager evaluations are included. On business process management employees, while working for an airline company in Turkey with experience of experts, expert support is taken from the place of operations and information technology specialists.

2 Related Works

Internet of things (IoT) is a technology that enables data exchange and control of processes by connecting smart devices via the internet. It offers real-time connectivity and interaction between networked devices [6]. Electronic and software embedded sensors, actuators, etc. It is based on establishing a network with systems, physical devices, vehicles, buildings other objects to exchange data within the network by connecting them with information technologies [7–9]. IoT, sensors, readers, etc. The detection layer, in which the integrity/confidentiality of the information transfer is preserved [10], the network layer that includes network technologies such as the cloud and the data exchange is provided [11], the service layer where the transactions are carried out, the end-user of the system and presented to the user It consists of the interface layer where the applications are [12,13].

There is no problem with the data obtained with IoT, an essential significant data source, to have characteristics such as heterogeneity, diversity, redundancy and lack of structure [14]. Therefore, it can be used very quickly in many areas. Researchers argue that IoT plays a significant role in gaining a competitive advantage by improving business processes and operations [6].

In IoT applications, the manufacturer and user may face system operation, maintenance security challenges. Embedded systems are supported to eliminate them [15]. One of the indispensable components of the IoT is security. For the system to operate reliably and smoothly, the security component must be designed completely. The properties of the security component in the IoT can be listed as follows [16]: * Integrity (the data entered into the system is correct), * Availability (data can be used by systems, devices and when requested), * Identification and Authentication (identification and verification of persons, devices and terms for access to data), * Privacy (that only permitted persons to have access to permitted information). For design examples related to ensuring security in IoT technology, [17–21] can be examined.

With the development of the IoT technology, processes can be managed more efficiently cost reduction can be achieved. As a result, IoT technology has been used in process-related studies in many sectors, with fewer resources and the need to make processes more efficient. Examples of these sectors can be given as aviation [22–27], agriculture [28–30], public [31–34], waste management [35], transport [36], health [37–42], education [43], military [44], energy [45], financial [46], examples of intelligent systems [47–52].

3 Implementation

3.1 Classic Boarding Process

The airline company's processes provide services to passengers are the main operational processes. The primary operational process consists of the processes in which the customer is in contact with the airline company. The preflight process is the process the passenger makes his reservation while planning his flight. After the reservation process is completed, it indicates that he will go to the flight by checking in. The process between the check-in process at the airport and the boarding process is called the "boarding process." The inflight process is another process in which the customer is in contact with the airline company. Finally, the primary operational process is completed with the landing-baggage purchase.

In this study, an IoT application will be made for the boarding process, one of the lower-level processes of the primary operational process. The boarding process consists of: * Manage customer departures, * manage check-in, * manage security processing, * manage pre-departure gate process, * manage passenger boarding process [53].

The boarding process is the process the passenger goes through at the airport after completing the check-in process it is completed when the passenger gets on the plane. The process map of the boarding process is shown in Fig. 1 The boarding process can be examined in three sub-processes:

- Security sub-process: It is a sub-process in which the passenger's physical and systemic safety is controlled. It consists of three activities: Identity/Passport control, ticket-ID matching security check. Most of these processes are carried out manually with computer support today.
- Waiting time sub-process: The passengers passing between the end of the security phase and boarding the plane can do shopping, eating drinking. It is a sub-process that includes activities that meet personal needs. It consists of meeting personal needs (shopping, eating, drinking, etc.) and going to the door. Depending on the customer's personal preferences, the operation of this sub-process can be varied. Effective management of time is essential in this sub-process. The customer must meet his personal needs within a certain period. Since there is a specific time limitation in this sub-process and the activities performed differ depending on personal preferences, Industry 4.0 technologies can be used while managing time.

Ticket control and boarding sub-process: When it is time to board the plane, the ticket control and boarding sub-process begins. It is the last sub-process spent at the airport. It is the process until the customer's ticket is checked and allowed to board the plane until the seats are seated the door of the plane is closed. Ticket ID matching includes the reading of the ticket and taking on the plane.

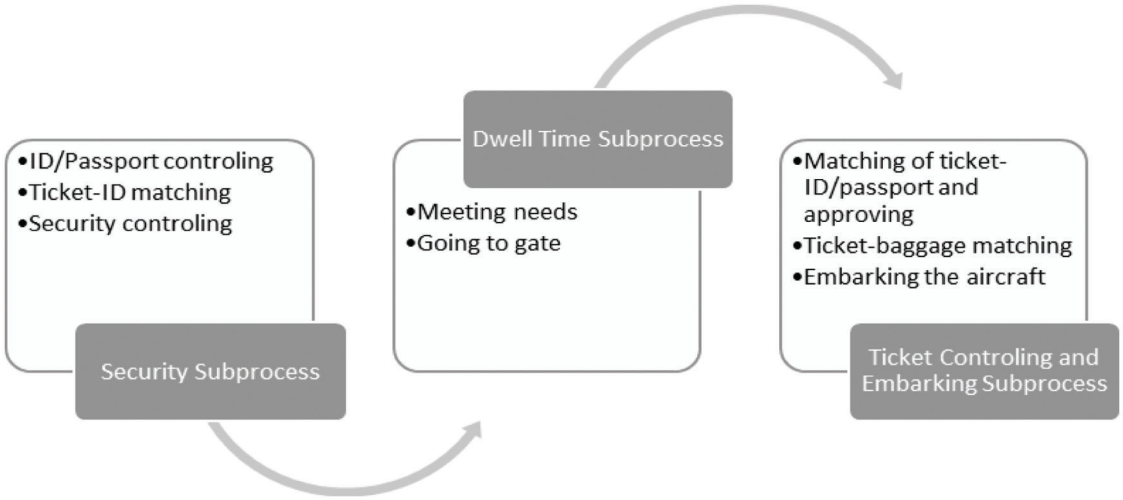

Figure 1: Boarding process map

In the Classic Airline Boarding Process, three basic systems are used: * National Safety System, * Airport System * Airline System. The Airport Safety System is used within the airport as a subsystem of the National Safety System.

The Airport Safety System is the system that enables the information of the customer to be questioned in the system by the personnel in charge. Through the system, confirmation is received from the National Safety System to check whether the customer is a safe passenger. The system used by the airport operator is the Airport System. The system used by airlines is the Airline System. Aircraft departure, arrival, flight number etc. The Airline System, which has information, transfers this data to the Airport System. The Airport System also helps the customer in providing service by matching the data about the gate.

It is possible to find studies that identify problems and offer improvement suggestions by analyzing the boarding process. It is analyzed the boarding process by examining the movements of passengers and the confusion that could hinder the movement of passengers on the platforms and identified factors that reduce boarding efficiency [54]. It is conducted a study on improving the processes in boarding facilities for disabled passengers [55]. It is identified the incompatible behaviors of the passengers by observing the landing-boarding characteristics of the passengers [56]. They showed that these maladaptive behaviors led to more extended landing and boarding times for passengers. On the other hand, managed to shorten the boarding time in their studies by assigning an apron bus (the vehicle that provides the transfer of passengers from the airport terminal to the plane or other directional transfer) according to the number of seats on the plane in order to shorten this [57].

The turnaround time (when the plane lands at the airport until the departure time when a new flight will occur) is significant in the aviation industry (when the plane lands at the airport until the departure time when a new flight will occur). Digital solutions can be integrated into existing systems to overcome the problem of not managing time and resources effectively. With this integration, the more the turnaround time can be reduced within the rules' framework, the more the costs will be reduced. Effectively managing the boarding process and making result-oriented improvements are effective in reducing costs and increasing customer satisfaction. While IoT uses various technologies and software integrated to collect, process, analyze and store information, at the same time supporting improvements in the processes where this information is used, both customer satisfaction and cost reduction can be achieved for the boarding process and a suitable platform can be created for the sustainability of these gains.

3.2 Internet of Things Based Boarding Process (Boarding 4.0)

This study aims to redesign the classical boarding process with IoT technology to produce more value-added outputs resulting from improvements in sub-processes and make the boarding process more effective and efficient. Thus, it is aimed to better respond to the changing needs and expectations of the passengers. The structure of the model named Boarding 4.0 is shown in Fig. 2.

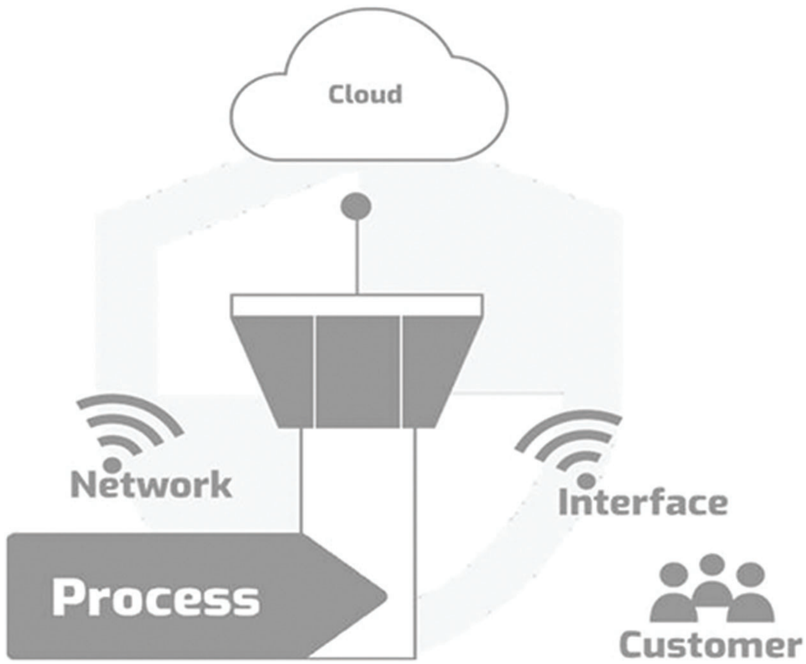

Figure 2: Internet of things supported boarding process management model (Boarding 4.0)

Boarding 4.0 consists of five components: Process, Network, Cloud, Interface Customer.

Process: The process, the first component of Boarding 4.0, refers to the passenger who has participated in activities. First, all stakeholders of Boarding 4.0, the systems used by the stakeholders the other sub-processes they interact with should be determined. Tab. 1 shows the identification card for the process component, including the stakeholders, the systems used other sub-processes in the interaction.

Table 1: Process identification card

	Subprocess stakeholders	Systems used by subprocesses	Interacting with other subprocesses
Security subprocess	-Passenger (The person who started the process) -Security staff (The person who controls systems)	-Airport safety system (Passenger will upload ID information to this system) -National safety system (The system that checks passenger ID information)	Dwell time subprocess (The process in which people whose security control has been approved continue)

(Continued)

Table 1 (continued)

	Subprocess stakeholders	Systems used by subprocesses	Interacting with other subprocesses
Dwell time subprocess	-Passenger (Person who handles the process) -Airport staff (Persons providing service in the process)	-Airport system (Door number, system providing airport internal map information) -Airline system (The system that provides aircraft, passenger information)	Ticket controlling and embarking subprocess (The process in which passengers go through on flight time)
Ticket controlling and embarking subprocess	-Passenger (Person who handles the process) -Airport Staff (Person control in the process)	-Airport system (The system that provides door number and aircraft occupancy information) -Airline system (The system that receives aircraft occupancy information)	Dwell time subprocess (The process of passengers waiting for the flight time)

Network: Inter-system connections with this component will be marked. With the effect of the Industry 4.0 philosophy, local networks and global networks will be provided within this component. The systems and data flow used on the model are shown in Tab. 2.

Table 2: System/data table

Receiver system / Transmitter system	Airline system	Airport system	National safety system	Airport safety system
Airline system	-	- Passenger ID information - Passenger flight information	-	Passenger ID information
Airport system	- Aircraft gate information - Airport map information	-	-	-
National safety system	-	-	-	Passenger flight confirmation/rejection
Airport safety system	-	-	- Passenger ID information - Passenger flight query	-

Cloud: Within the scope of the cloud component, all data can be stored on the internet, processed accessed at any time. Systems will be authorized to access the cloud. Within the systems, users will also be given access permission. Thus, it will be determined who can access the stored data. Tab. 3 shows the data authorization table of the Cloud component of the Internet of Things-based boarding process.

Table 3: Data authorization table

Data	Systems	Users
Passenger ID	Airline system	Airline staff (boarding officer)
Passenger safety situation	Airport safety system	Safety staff (airport safety control officer)
Passenger flight ınformation	Airline system, Airport system	Airline staff (boarding officer), Airport staff (Station boarding officer)
Passenger shopping ınformation	Airline system, Airport system	Airline staff (marketing officer), Airport staff (Station marketing officer)

Interface: It is the component with which the passenger manages the system and interacts with the system. The Boarding 4.0 Model will reach passengers thanks to the applications developed under this component.

As part of the Boarding 4.0 Model, the "Boarding 4.0 Mobile Assistant" application was designed. On the first screen of the mobile assistant, the input of Boarding 4.0 Mobile Assistant is shown. Passengers are offered the option to log in by scanning a fingerprint, face scan, or ticket code. The flight information of the passenger is displayed on the second screen in line with personal information. The time until the door is closed and the door information is displayed live at the top of Boarding 4.0 Mobile Assistant and continues to be displayed in real-time at the top of the screen until passengers exit the application. Passengers can choose the activity they want from the second screen and choose their food and beverage, shopping, or personal needs. The third screen shows options for food and beverage. On the fourth screen, the "fastest" option is calculated, considering the person's location and food preparation time. Finally, the obtained options are shown on the screen for selection. For passengers who do not choose the "fastest" option, "fast food" options are shown on the fifth screen. The sixth screen displays the menu selection and online payment option for the selected fast food restaurant. After the payment is made, a QR code is generated to be read in the restaurant (seventh screen). Boarding 4.0 Mobile Assistant notifies passengers in real-time when flight-related changes such as aircraft door changes (eighth screen). Boarding 4.0 Mobile Assistant includes an indoor map feature. With this feature, navigation service is provided to the door, restaurants, shops other desired points (ninth screen).

Customer: This component covers the passenger's movements, needs expectations. The sub-process in Boarding 4.0 shows how the passenger moves are in Tab. 4.

Table 4: Subprocess-customer movements table

Subprocesses	Customer movements
Security	ID/Passport controlling Ticket-ID matching Security controlling
Dwell time	Meeting needs Going to gate
Ticket controlling and embarking	Matching of ticket-ID/passport and approving Ticket-baggage matching Embarking the aircraft

Security: Data transfer occurs between different software and devices at the network layer due to the scope of IoT projects. Verification and authorization are essential in the communication of all IoT interfaces with each other. Within this project's scope, the passengers' data are sent to internal (airport, airline systems) and external systems (National systems) from the beginning of the process. For this reason, confidentiality and integrity of data are essential during the communication of these systems. Tab. 5 shows the security scope among Boarding 4.0 components and which protocols are to be used to provide security.

Table 5: Security table

Component	Security scope	Protocols
Network	Data privacy and integrity	HTTPS, WEP, WPA, WPA2
Cloud	Identity and access management (IAM), Data protection and availability	OAuth 2.0, Database and backup solution
Interface	Passenger authentication	Single sign-on solutions

3.3 Architectural Building for Boarding 4.0

Architecture should be designed to manage the development stages of the system and to maintain its integrity. The architectural structure of the Boarding 4.0 model is as in Fig. 3 for Security, Dwell Time, Ticket Controlling Embarking Process sub-processes. The first phase of the boarding 4.0 system architecture for the "security sub-process" starts with the passenger coming to the security control machine after check-in. The passenger gives the security control machine fingerprint or faces scanning and ID or passport QR code data. Fingerprint/face-scanning data and identity/passport information are transmitted to the National Security System through the Boarding 4.0 model and are checked whether the current passenger has an obstacle to travel. The control result can be positive or negative. This step is completed by matching the identity or passport information and ticket information if it is positive. If it is negative, the passenger is not allowed to pass. The "waiting time sub-process" stage of the architecture includes the part until the passenger completes the security checks and the plane's door closes. The "Boarding 4.0 Mobile Assistant" application has been developed to enable the passenger to use the waiting time most effectively and assist their activities in the process. Boarding 4.0 Mobile Assistant will enable passengers to meet some of their needs digitally and digitally direct some of their needs. With Boarding 4.0 Mobile Assistant, all movements of the passengers in this process will be stored in "big data." The final stage of the architecture is the "ticket and boarding control sub-process." At this stage, the passenger has arrived at the door where he will board the plane. Passenger provides fingerprint/face scan/ticket information to the boarding control machine. With this information, the boarding control machine checks whether the passenger is a passenger on the plane at the current door. When the information is confirmed through the "Airline System," the approval goes for the luggage of the relevant passenger. Thus, passengers and their luggage, if any, are allowed to board the plane. If the information is not confirmed by the "Airline System," the boarding control machine directs the passenger to the right door of his plane.

The Boarding 4.0 model ends when the passenger gets on the plane the following process (inflight) in the primary operational process begins.

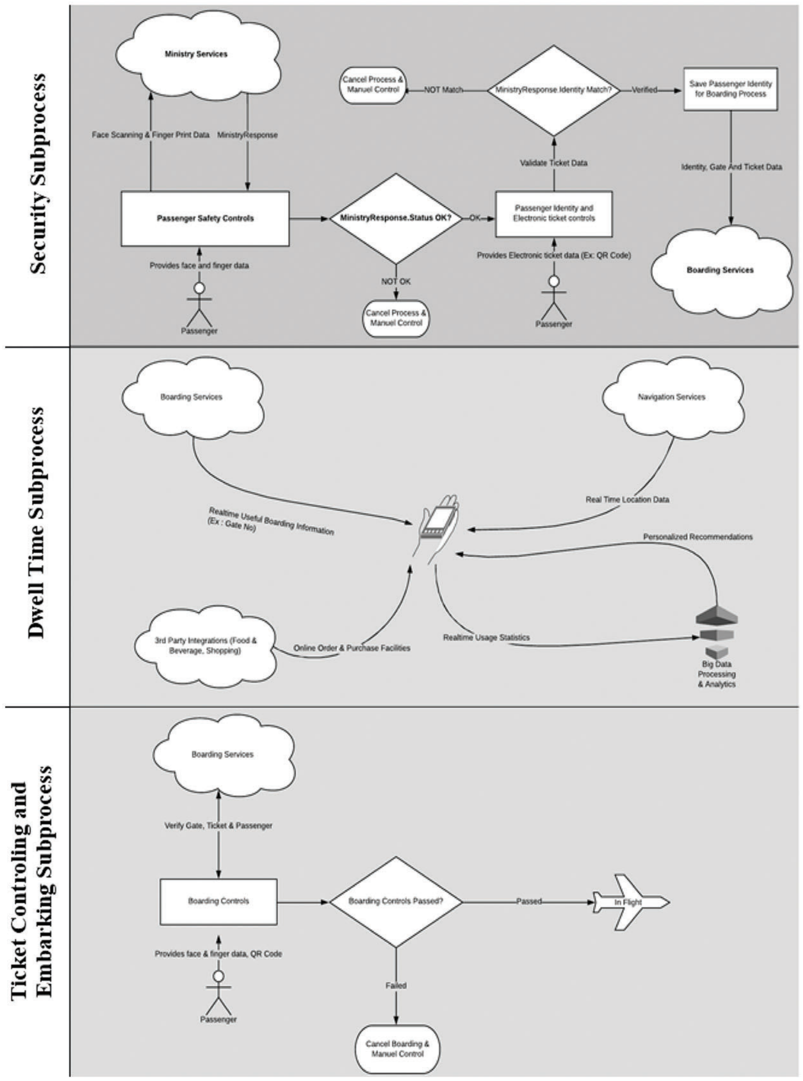

Figure 3: The system architecture of boarding 4.0

In the second and third phases of the Boarding 4.0 architecture, in addition to the "Boarding 4.0 Mobile Assistant", "Autonomous Electric Vehicle" is also offered to passengers who wish. The Autonomous Electric Vehicle is capable of carrying single passengers and hand luggage. Autonomous Electric Vehicle; a seat, a hand luggage basket, four wheels (two of which can rotate left and right), a DC motor, a servo motor, a battery, a distance sensor, a presence sensor, a tablet (containing the mobile app developed in it), an embedded software system It will contain hardware and software components such as. In line with the instructions from the tablet, the embedded system will operate the mechanical parts of the autonomous electric vehicle. The embedded system is written in C software.

The Boarding 4.0 Mobile Assistant developed will work on the tablet on the Autonomous Electric Vehicle. Service will be provided to both arriving and departing passengers. After the outgoing passenger passes the security process, the Autonomous Electric Vehicle will detect the passenger's position and go to the passenger himself. After the passenger logs in on the tablet in the Autonomous Electric Vehicle, the vehicle will enter the passenger service. The passenger will be able to move the vehicle to the desired location via the tablet. By using image processing technology through the tablet's camera, the safety of the passengers will be further increased the stores will be allowed to do personalized marketing. The vehicle is programmed to go to the door automatically for a specific time before the aircraft door is closed. However, this service can be disabled at the request of the passenger. For the arriving passenger, on-demand, depending on the landing time of the aircraft, the relevant passenger will be ready at the aircraft gate. Moreover, similar to the outbound passenger service, it will make use of the IoT technology to provide transportation and routing services to incoming passengers.

The workflow of the proposed methodology is shown in Fig. 4.

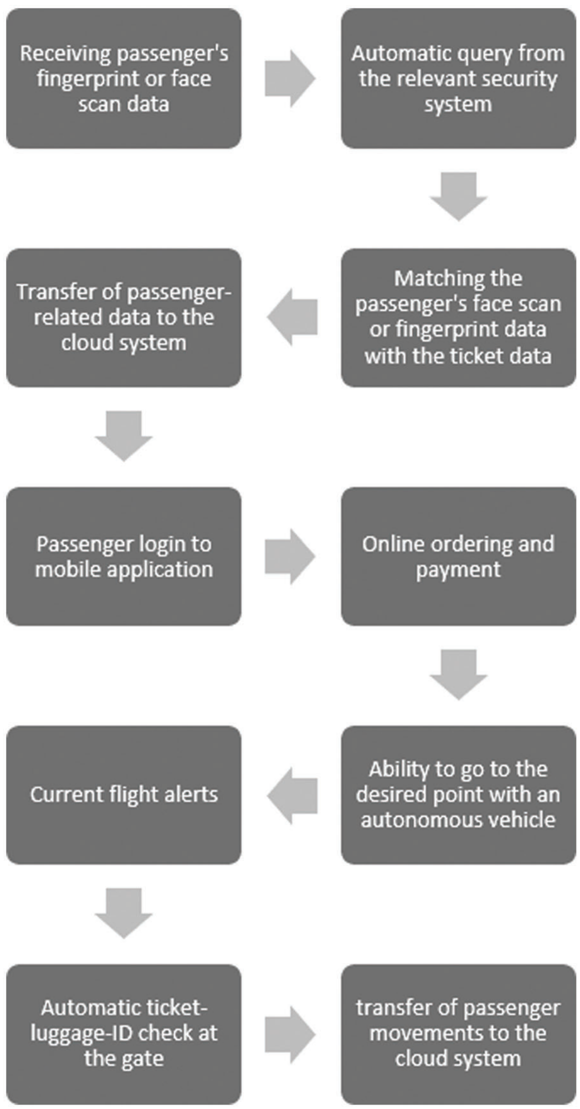

Figure 4: The workflow of the proposed methodology

The detailed version of the passenger movements in the classical boarding process and Boarding 4.0 model is given in Tab. 6.

Table 6: Passenger movements in boarding process

Passenger movement	Classic boarding	Boarding 4.0
ID/Passport controlling	The passenger gives their identity and passport to the passenger security staff. Security staff checks on the computer. Before this process, queues occur.	After the passenger check-in, the location information is sent to the security control machine and the control is provided through the system. Finally, it reaches the result by giving fingerprint and face scanning information to the passenger security machine. There will be no queues in this process.
Ticket-ID matching	The security staff checks the passenger's ID and ticket.	Identity matching will be checked by scanning the ticket to the security machine.
Security controlling	Security staff takes action for X-ray passage and overhead scanning.	Security staff takes action for X-ray passage and overhead scanning.
Meeting needs	The passenger meets their needs at the airport on foot he can wait in line to eat in restaurants, wait in line at shopping places, or meet his other needs.	Passengers will go anywhere they want without consuming energy with the developed mobile application-supported autonomous vehicle. It will make shopping and restaurant orders through the online application and go there when the product is ready. Thus, it will be able to meet other needs during the preparation period.
Going to gate	When the gate closes, the time approaches, and the passenger checks on the screens for current gate information and goes to the gate.	When the gate comes to a close, the autonomous vehicle will go to the current gate itself. The passenger will not wait in a queue.
Matching of ticket-ID/ passport and approving	At the gate, airline ground operations staff check the passenger's ticket and ID/ passport information. There are queues for this process.	The passenger reads the ticket to the boarding control machine and matches it with face recognition/fingerprint information.
Ticket-baggage matching	Passengers whose boarding is approved through the system are allowed to load their luggage.	Passengers whose boarding is approved through the system are allowed to load their luggage. In addition, he will be able to track the location of his baggage live on the mobile application.
Embarking the aircraft	The passenger gets into his/her seat on the plane.	The passenger gets into his/her seat on the plane.

4 Discussion

The Fuzzy AHP method was used to evaluate the results of the developed Boarding 4.0 model. The people who gave input for the fuzzy AHP model are Istanbul Airport Boarding Operations Chief, Le-gal Specialist, Technical Chief and Finance Specialist. Istanbul Airport Boarding Operations Chief has been involved in all boarding processes for about 10 years. He currently manages a large team. Legal Specialist has extensive experience in aviation. Laws and rules in aviation are crucial to the design of every process. The Technical Chief has more than 10 years of experience in technical processes. He has experience in hardware and software integrations. The Finance Specialist works in the unit where investment decisions are made. Boarding 4.0; the operational evaluation, economic evaluation, technical evaluation, legal requirement evaluation factors are considered. The operational evaluation assesses whether and how well the airport's boarding needs can be met. Economic evaluation, benefit/cost factor is evaluated. The technical assessment focuses on the technical resources available to the airport. It is evaluated whether the technical resources of the airport meet the capacity. The technical evaluation includes the evaluation of the hardware, software, and other technical requirements of the proposed system. Finally, it is investigated whether the legal assessment contradicts the legal requirements.

Classical boarding and boarding 4.0 were evaluated with fuzzy ahp. First, the degree of criticality of the factors was determined. Then, the scores of the two systems on these factors were calculated with the fuzzy ahp technique.

Evaluation of classical boarding and boarding 4.0 with fuzzy ahp is as in Fig. 5.

Legal	Classic Boarding			Boarding 4.0		
Classic Boarding	1,00	1,00	1,00	2,00	3,00	4,00
Boarding 4.0	0,25	0,33	0,50	1,00	1,00	1,00

Legal	Geometric Mean		
Classic Boarding	1,41	1,73	2,00
Boarding 4.0	0,50	0,58	0,71
Sum	1,91	2,31	2,71
Inverse	0,52	0,43	0,37
Increasing order	0,37	0,43	0,52

Legal	Fuzzy Weight			Mi	Normalized
Classic Boarding	0,52	0,75	1,04	0,77	0,74
Boarding 4.0	0,18	0,25	0,37	0,27	0,26
				1,04	1,00

Economic	Classic Boarding			Boarding 4.0		
Classic Boarding	1,00	1,00	1,00	0,17	0,20	0,25
Boarding 4.0	4,00	5,00	6,00	1,00	1,00	1,00

Economic	Geometric Mean		
Classic Boarding	0,41	0,45	0,50
Boarding 4.0	2,00	2,24	2,45
Sum	2,41	2,68	2,95
Inverse	0,42	0,37	0,34
Increasing order	0,34	0,37	0,42

Economic	Fuzzy Weight			Mi	Normalized
Classic Boarding	0,14	0,17	0,21	0,17	0,17
Boarding 4.0	0,68	0,83	1,02	0,84	0,83
				1,01	1,00

Technical	Classic Boarding			Boarding 4.0		
Classic Boarding	1,00	1,00	1,00	0,17	0,20	0,25
Boarding 4.0	4,00	5,00	6,00	1,00	1,00	1,00

Technical	Geometric Mean		
Classic Boarding	0,41	0,45	0,50
Boarding 4.0	2,00	2,24	2,45
Sum	2,41	2,68	2,95
Inverse	0,42	0,37	0,34
Increasing order	0,34	0,37	0,42

Technical	Fuzzy Weight			Mi	Normalized
Classic Boarding	0,14	0,17	0,21	0,17	0,17
Boarding 4.0	0,68	0,83	1,02	0,84	0,83
				1,01	1,00

Operational	Classic Boarding			Boarding 4.0		
Classic Boarding	1,00	1,00	1,00	0,13	0,14	0,17
Boarding 4.0	6,00	7,00	8,00	1,00	1,00	1,00

Operational	Geometric Mean		
Classic Boarding	0,35	0,38	0,41
Boarding 4.0	2,45	2,65	2,83
Sum	2,80	3,02	3,24
Inverse	0,36	0,33	0,31
Increasing order	0,31	0,33	0,36

Operational	Fuzzy Weight			Mi	Normalized
Classic Boarding	0,11	0,13	0,15	0,13	0,13
Boarding 4.0	0,76	0,88	1,01	0,88	0,87
				1,01	1,00

Figure 5: Evaluation of classical boarding and boarding 4.0 with fuzzy ahp

The evaluation result of classical boarding and boarding 4.0 with fuzzy ahp is as in Fig. 6.

	Weight	Classic Boarding	Boarding 4.0
Legal	0,543	0,742	0,258
Economic	0,245	0,169	0,831
Technical	0,147	0,169	0,831
Operational	0,065	0,126	0,874

	Classic Boarding	Boarding 4.0
Legal	0,403	0,140
Economic	0,041	0,203
Technical	0,025	0,122
Operationa	0,008	0,057
	0,478	0,522

Figure 6: Evaluation result of classical boarding and boarding 4.0 with fuzzy ahp

Experts, who evaluated the operational applicability of Boarding 4.0, stated that both the operation would be relaxed and customer satisfaction would increase. In the economic evaluation, experts stated that the initial investment cost in the IoT technology would make the model's applicability difficult. However, they drew attention to the awareness of the long-term benefit. Furthermore, they stated that qualified personnel is needed for the follow-up and maintenance of the system developed in the technical evaluation. Finally, in the evaluation made in terms of legal needs, they stated that there are strict rules of aviation necessary permissions should be obtained for every detail of the system to be added. In summary, experts stated that the Boarding 4.0 model developed can be applied at Istanbul Airport, the difficulties that may be encountered are at a level that can be overcome there may be positive returns in terms of both customer satisfaction and profitability in the medium and long term.

5 Conclusions

The process where passengers spend the most time at the airport is the boarding process. Therefore, the improvements to be made in this process will be directly reflected on the passenger. However, more efficient use of limited resources such as time, equipment people is significant in minimizing costs. In this study, the classical boarding process has been redesigned with the IoT technology, one of Industry 4.0. The architectural structure of the Boarding 4.0 Model developed has been created and sub-processes and activities are explained in detail. In addition, within the scope of Boarding 4.0, "Boarding 4.0 Mobile Assistant" and "Autonomous Electric Vehicle" were developed. The Boarding 4.0 model, which was developed by obtaining the necessary information from the experts in the aviation industry, demonstrated the benefits to both passengers and airport and airline companies. Passengers will fulfill all their needs quickly and reliably. Thus, by increasing the digitalization of processes, faster service delivery will be provided customer-oriented service understanding will be developed.

As a result of the evaluation made with fuzzy ahp, it was determined that boarding 4.0 is more advantageous than the classical boarding process. In addition, when the total time of the sub-activities in the boarding process is calculated, boarding activities for a passenger take 50 min with the classic boarding process and 20 min with Boarding 4.0. Thus, when Boarding 4.0 is used, the passenger gains 30 min. Furthermore, when the calculation is made concerning the airport's current capacity, two passengers are hosted with the classical boarding process, while five passengers are hosted with Boarding 4.0. This acquisition is significant for airports in terms of efficient use of resources.

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