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Research Article

Modelling and Managing Airport Passenger Flow: A Case of Hasan Polatkan Airport in Turkey

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Abstract

The airport passenger flow process is an integrated system in which passengers interact with multiple components of the system, and a failure in one component can cause greater disruption in others because of time-related constraints. Airport operators analyse and decide the results by using decision support systems under the airport management strategies by determining the potential congestion and related problems such as capacity limitations or equipment malfunctions. In this study, airport systems handle the passenger flow that covers all activities between the airport entrance and boarding. Discrete event simulation was used to assess the passenger flow and performing the activities in the related processes. The model comprises security screening, check-in, passport control and boarding processes. Within the proposed model, points with potential bottlenecks in Hasan Polatkan Airport have estimated according to International Air Transport Association (IATA) performance values.

Keywords

Airport Management
Decision Support Systems
Simulation
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Airport terminal analysis

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1. Introduction

Airports are one of the important components of the air transport industry. Airports are highly complex system comprising interconnected subsystems and places where planning becomes important. Airports are an integrated system comprising departure and incoming passenger flow processes. Depending on the size of the airport, passengers' needs for eating, drinking and shopping may fulfilled as requested. Any failure in the system may affect another system, causing system-wide failures. Decision analysis and planning prevents the problems may occur in airport operations [1].

The airport management weighs the decisions in order to meet the demands of the airline operators within the service and the security criteria determined by the aviation authorities and to implement the suggestions to improve the operational processes. Although the processes at airports are basically similar, services offered at airports may vary depending on the number of passengers and the size of the airport [2]. Because of the annual increase in the number of passengers and flights in airports under normal conditions, the airport's performance may decrease to a certain extent from year to year. The airport management should analyse the reason of the performance decreases and make the improvements at reasonable costs [3].

In parallel with the developments in the airline industry, the airport operator will offer the best service quality with the lowest cost of service. Also, airport operator should keep passenger satisfaction to desired levels by using dynamic facility planning, operational quality, and performance analysis. While passengers can catch their flights on time, they will still have enough time for shopping a little more and other fun activities at the airport, while contributing to the increase in airport operating income. It can change the overall experience

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of a traveler at an airport to challenging and time-consuming. Delays occur during parking, check-in, security screening and boarding. Also, the less time the passengers spend in the system, the higher the customer satisfaction [4]. As passengers are the largest source of income for airports, that passengers leave from airports satisfactorily and processes should plan to spend a minimum of time at potential bottleneck points between their entrance to the airport and access to the aircraft [5].

According to a study by Takakuwa and Oyama [6] in the international departure terminal of Kansai International Airport, passengers spend 25% of their total time spent in the terminal building by waiting in queues to complete their flight transactions, and 4% by having their transactions done at check-in counters. The increase in the waiting times of passengers in the terminal building negatively affects passenger satisfaction [7]. Also, it reduces the time during which passengers will wander and shop in duty-free stores and benefit from waiting lounges and other facilities within the terminal building. However, that the passengers travel freely and engage in activities such as shopping or eating and drinking contributes positively to the commercial revenues of the airport. Retail sales revenues, such as shopping from stores, food and beverage revenues, have an important place among the commercial revenues of airports [8]. Takakuwa and Oyama [6] study revealed that passengers spend only 23% of their time in the terminal building to generate commercial income. However, under the influence of psychological factors, the perception of time spent waiting by passengers may be higher than the perception of travel time. Because the perception of "time spent" is higher regarding the periods that have spent without being engaged in anything when it will end is uncertain or not disclosed [9]. Considering all this information, the strategic importance of reducing passengers' waiting times in queues is obvious to airports in terms of both improving service quality perception by positively affecting passenger satisfaction level and creating an opportunity to increase commercial revenues.

In air transport, it is possible to meet the expected future growth rates either by building new airports, by expanding existing airports or by using existing airports more effectively. For this purpose, the system should test continuously, and airport managers should analyse the decisions planned to correct the detected bottlenecks. Analysing each of the implemented improvements by trial and error is not appropriate because of its cost and potential disruption to the workflow. A simulation model should assess and test the system. This study proposes a discrete event simulation as a model that deals with passenger operations in an airport.

2. Literature Review

The performance evaluation of airports has been the subject of comprehensive studies in airport modelling and process optimization. As a result, there are many studies in the literature on the mathematical model and simulation method integrated with decision support systems. Airport managements use these models and tools in the planning, design and operation of land and air side operations for improving the operations such as aircraft, passenger, baggage, and cargo. Zografos et al. [10] have developed an integrated decision support system for airport performance analysis and used various analytical models and simulation tools. Bruno et al. [11] proposed a decision support system for improving airport performance services in order to make more practical and precise planning decisions, by proposing a mathematical model capable of performing check-in decisions by also integrating staff planning considerations. Herrero et al. [12] developed a decision support system that automatically provides the best routes and sequences for aircraft movement on the ground, depending on the operations requested for airport ground controls at Madrid Barajas International Airport. Stamatopoulos et al. [13] developed an integrated decision support system for strategic level airport planning that considers the operations between different parts of the airfield and the dynamic characteristics of the airfield capacity. Hayashi et al. [14] proposed a pushback decision support tool for the airport ramp tower controller for flow management under the current restrictions at the airport. The proposed systems provided the reduction of taxi time by one minute for each flight and helped minimized total consumption of departure flight fuel by 10-12% without limiting runway throughout. Fayez et al. [14] provided a simulation-based decision support system to test airport operations and compare the results of the decisions made.

There are many studies in the literature on the current problems of airport operations and operational performance covering the planning challenges. Beck [16] demonstrated the passenger flow at the new terminal at Heathrow Airport with simulation before the terminal opens. Yamada et al. [17] evaluated the performance of security checkpoints in domestic flights using a simulation model. Kierzkowski and Kisiel [18] investigated the effects of passenger behaviour characteristics of passengers and operators on airport security screening reliability. Dorton and Liu [19] analysed baggage amounts and alarm rates that affect operational efficiency within the queueing network and intermittent event simulation. Manataki and Ografos demonstrated the complexity and stochastic structure of processes in the airport terminal with a simulation model [20]. Sultan considering the stochastic aspects in the simulation, examined the effects of different parameters such as the number of passengers on the plane, counter opening and closing times, and used it with a linear program to reduce the number of counters in the check-in area [21]. Araujo and Repolho [22] proposed a method combining an optimization-based linear programming and simulation to minimize operational costs and found an optimum and opening counter tariff under a given service level. Mota and Zuniga [23] presented a hybrid method that uses an evolutionary algorithm based on passenger behavior to simulate check-in problems. Joustra and Van [24] studied the practical simulation approach to assess check-in at airports. Yan et al. [25] presented a simulation model to assist airport managers/operators to test the effects of random flight delays on static gate assignments, and random buffer times and real-time gate assignment rules. The proposed simulation model created in the experimental study using the data of Chiang Kai-Shek Airport in Taiwan. Dorndorf et al. [26] examined the studies on the gate assignment problem.

3. Research Aims and Methodology

3.1. Aims

The primary purpose of this research is to assess the effectiveness of airport management strategies at points where passenger flow occurs in an international airport, within the framework of the passenger satisfaction criteria determined by IATA. The proposed model that can accurately detect potential bottlenecks in passenger processes with a simulation approach and increase operational efficiency.

Airports are facilities that meet the needs of passengers and airlines. Airport managements dynamically change and apply the current and updated regulations at points in passenger service processes to sustain the best service quality. It is necessary to examine the contribution of decisions made and changed in practice to the potential bottleneck points at the airport and the system performance holistically, thus preventing unforeseen negative cases.

Decision-making is not the settlement of discrete disputes, but in a complex setting, continuous management of the state of affairs [27]. The decision support system is an information system that establishes and/or solves the models involved in a decision process, enabling the decision maker to assess the methods, models and algorithms of management science and operations research together with decision and utility theory, and designed to contribute to the quality of the decision [28].

A decision support system comprises user interface, model management, model solver and databases. Figure 1 shows the flowchart of a decision support system proposed within this study. The database contains information such as personnel working schedule, airport flight schedule, number of arrival and departure passengers, resources (such as X-ray, and check-in desk). Model management takes certain information from the database and runs a model according to the decision-maker's preference and presents the model results to the decision-maker with a user interface. The decision makers assess the results from solvers such as ARENA and runs different models until they satisfy with the results. When the airport manager decides that the results are appropriate, it takes a detailed report from the decision support system and applies the model's solutions. Before deciding about the changes in the system, the decision-maker should reveal holistic effects and relationships about the decisions and contribute the system in line with the specified goals and expectations.

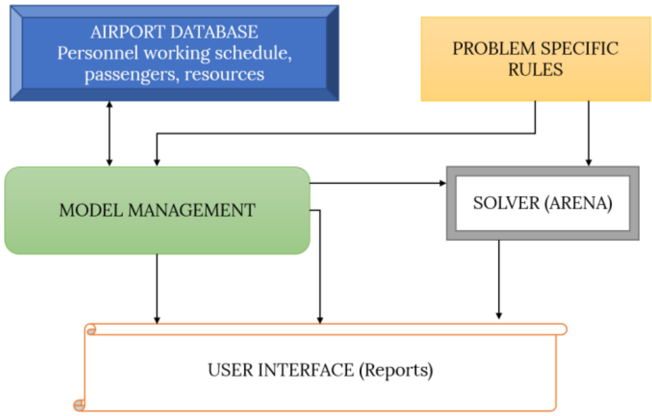

Fig. 1. Flowchart of the decision support system

3.2. Methodology

The follow-up and flexibility of the plans created for airport operations are also important. The decision-makers should analyse the plans created for airport operations for different conditions that may occur to keep the highest service quality. They also should assess different conditions and considered alternative action plans by the question "what if analysis". Performing all analyses by trial and error is not appropriate because of many reasons, especially cost. Therefore, the modelling model through the imitations of the system should use for analysing the system.

Using the simulation method, it is possible to analyse a complex system without disturbing the operation of the actual system and to compare it with its alternatives. Considering the complex system structure of the airports, simulation models come to the fore as suitable tools for the analysis of such a system.

Although the proposed model within this study is general, it only covers the departing passenger processes. The decision-maker can assess the performance analyses and the waiting times by adding/removing personnel to the system, adding/removing X-rays in the model, and use the resources more efficiently. Decision support system ensures the assessment of the effectiveness and results of the decision taken by the criteria for passenger satisfaction and airport operating strategies. The simulation results provide some performance metrics such as bottleneck points, average waiting time, the average queue length. A discrete event simulation and the first come first served (FIFO) principle applied for the modelling of this study.

The most appropriate method in modelling complex processes combined with a limited capacity infrastructure is simulation. One process whose stochastic structure best suits this is the flow of airport passenger traffic. As in some studies used to characterize the complex processes at the airport, the simulation analyses performed by Rockwell Arena in this study [24, 27, 28, 29].

Table 1. Level of service [30]

Level of Service (LOS)	Level	Average Waiting Time (minute)
A	Excellent comfort	< 1
B	Hight comfort	1-17
C	Good comfort	17-34
D	Adequate comfort	34-58
E	Inadequate comfort	> 58

IATA has defined Level of Service (LOS) for monitoring operational service performance at airports and planning new facilities. A grading system from A (excellent comfort) to E (inadequate comfort) is used to determine the level of service. Table 1 shows the level of service according to flow, delay and comfort [30].

System administrators and designers should specify the desired or required LOS. The recommended minimum level of service is the level of C. During the confusion times, the acceptable level of service is the level of D [31].

3.3. Model Architecture

After passengers pass the security checkpoint at the airport, they go to the check-in counter or kiosks for ticket approval and baggage delivery. After the passport control stage for international flights, passengers pass through a second security check for the passage to the secure area for boarding and pass to the boarding or gate area.

The departure and arrival passenger flow procedures of the airport are different. The process passengers go through at the airport before their flight is more important, as it has a greater impact on the entire operation of the terminal and on other aspects of the airport.

The classification of departure passengers in the terminal building is as follows [32]: Terminal entrance security check, ticket control, interfaces (eating, drinking, shopping), passport control, waiting room, gate control, boarding the aircraft.

Terminal entrance security check

Entering the terminal building, the passenger proceeds towards the security point. This unit is a processing unit. Each passenger passes from the security check one by one. The terminal entrance security control is the stage where security procedures such as checking all the luggage of each person entering the airport on the x-ray device, passenger security control, turning on and off devices such as computers.

Checking Counter

Checking counter is a unit of processing. The number of counters required for ticket control depends on the duration of a passenger's ticket control and the distribution of passengers to the ticket control point. Passengers deliver their luggage and receive their boarding pass at check-in counter [33]. Every passenger should have completed the check-in process before passport control. At some airports, the passenger does check-in using kiosks, independent of the airport personnel. There is not a kiosk at Hasan Polatkan Airport.

Interfaces

Interfaces are places such as eating, drinking, and shopping areas. These venues cover small areas in small airports. These units are also waiting units. Passengers can spend time in these units or pass without stopping at the units. There is a food and beverage area in the international flights section of Hasan Polatkan Airport that passengers can use. Although passengers can benefit from interfaces before passport control at small airports, they can use them both before and after passport control at large airports.

Passport Control

Passport control unit is a processing unit, like ticket control unit. Unlike the ticket control unit, the passport control unit is not available at the domestic terminal. The queue and passenger movements proceed according to the sequence formed by the passengers in the processing units. There are two passport control points in the international flights department of Hasan Polatkan Airport.

Waiting room

Passengers passing through the gate control go to the waiting room and wait in this area until the airlines/airport personnel let them to go to aircraft. Since this space is a waiting area, the level of service for the area is measured by the number of people per square meter.

Gate control

It is one of the flight gate control point processing units. The feature that distinguishes this unit from other control points is that the number of control points is unique. Therefore, the waiting time at the checkpoint is longer. Passing through the flight gate control, the passenger reaches the last waiting room before boarding the plane.

Boarding

It is the point where passengers directly go to the plane with the official's announcement and permission by walking or by bus according to aircraft location at the airport. The average processing time varies with each airport.

3.4. Hasan Polatkan Airport

Hasan Polatkan Airport was first opened to air traffic on March 29, 1989 under the name of "Anadolu Airport" and is an international airport operated by the Faculty of Aviation and Space Sciences on behalf of Eskisehir Technical University Rectorate. International Civil Aviation Organization (ICAO) and IATA code of airport is LTBY and AOE, respectively. The airport primarily aimed to meet the national and international air transport demand that may occur in Eskisehir and surrounding provinces with the educational activities of the Faculty of Aviation and Space Sciences. Hasan Polatkan Airport started international flights in May 2005. Eskisehir Technical University pilot flight training, VIP/CIP flights, air taxi and ambulance flights, training flights of private flight schools, scheduled/non-scheduled domestic passenger transportation flights, scheduled/non-scheduled international passenger transportation flights carry out at airport.

Hasan Polatkan Airport terminal used for international and domestic traffic is 4000 m² in total and comprises two floors. There are two passport control cabins at the transition from the departure passenger section to the sterile lounge.

Figure 2 and Table 2 show the number of commercial passengers and commercial aircraft traffic between 2015 and 2019 for Hasan Polatkan Airport, respectively [34].

Table 2. The number of commercial passengers at Hasan Polatkan Airport between 2015 and 2019 [34]

Year	Domestic	International	Total
2015	2,389	49,536	51,925
2016	1,057	55,397	56,454
2017	1,808	78,240	80,048
2018	787	98,544	99,331
2019	657	88,365	89,022

3.5. Parameters and Assumptions of the Model

Simulation is one of the most useful tools for predicting the relationship and interaction between processes at the airport. Passengers behave differently because their personal and physical characteristics are independent from each other. Simulation is an important tool in modelling passenger behaviour, determining the number of personnel and technical equipment used, analysing the changes depending on the week and passenger density [27].

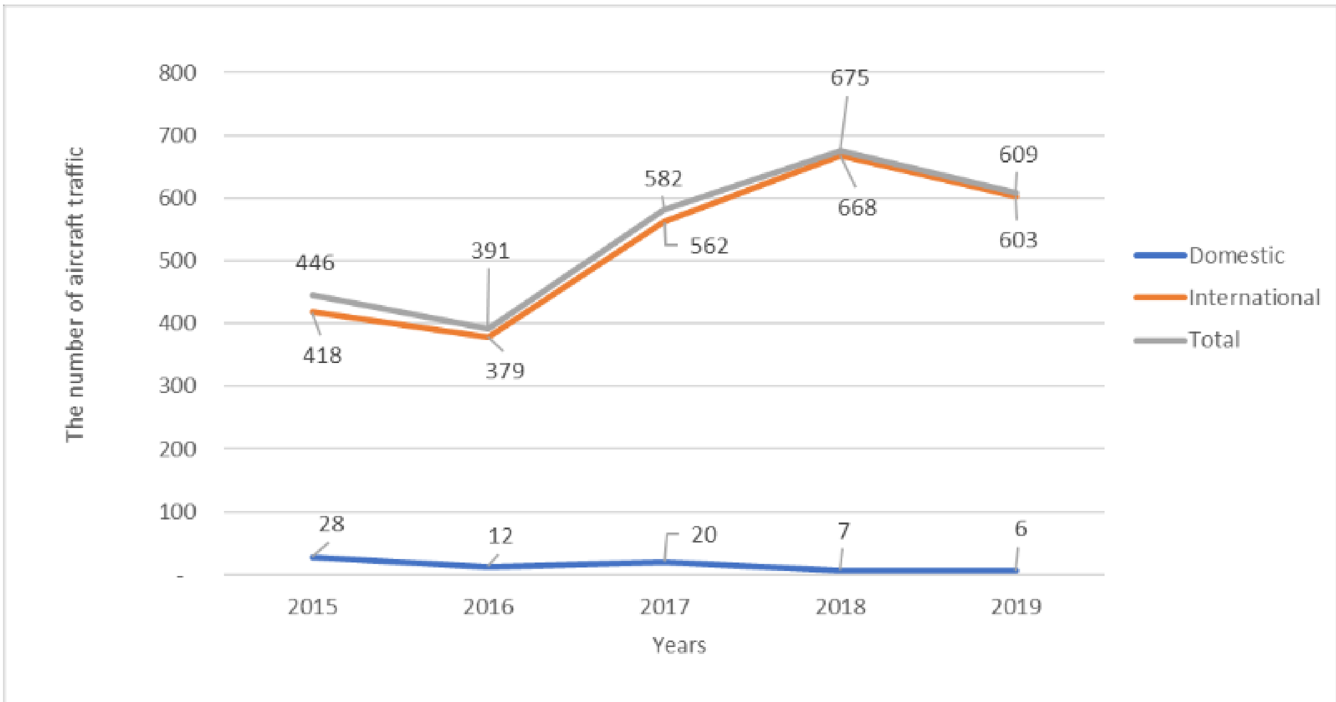

Fig. 2. The number of commercial aircraft traffic at Hasan Polatkan Airport between 2015 and 2019 [34]

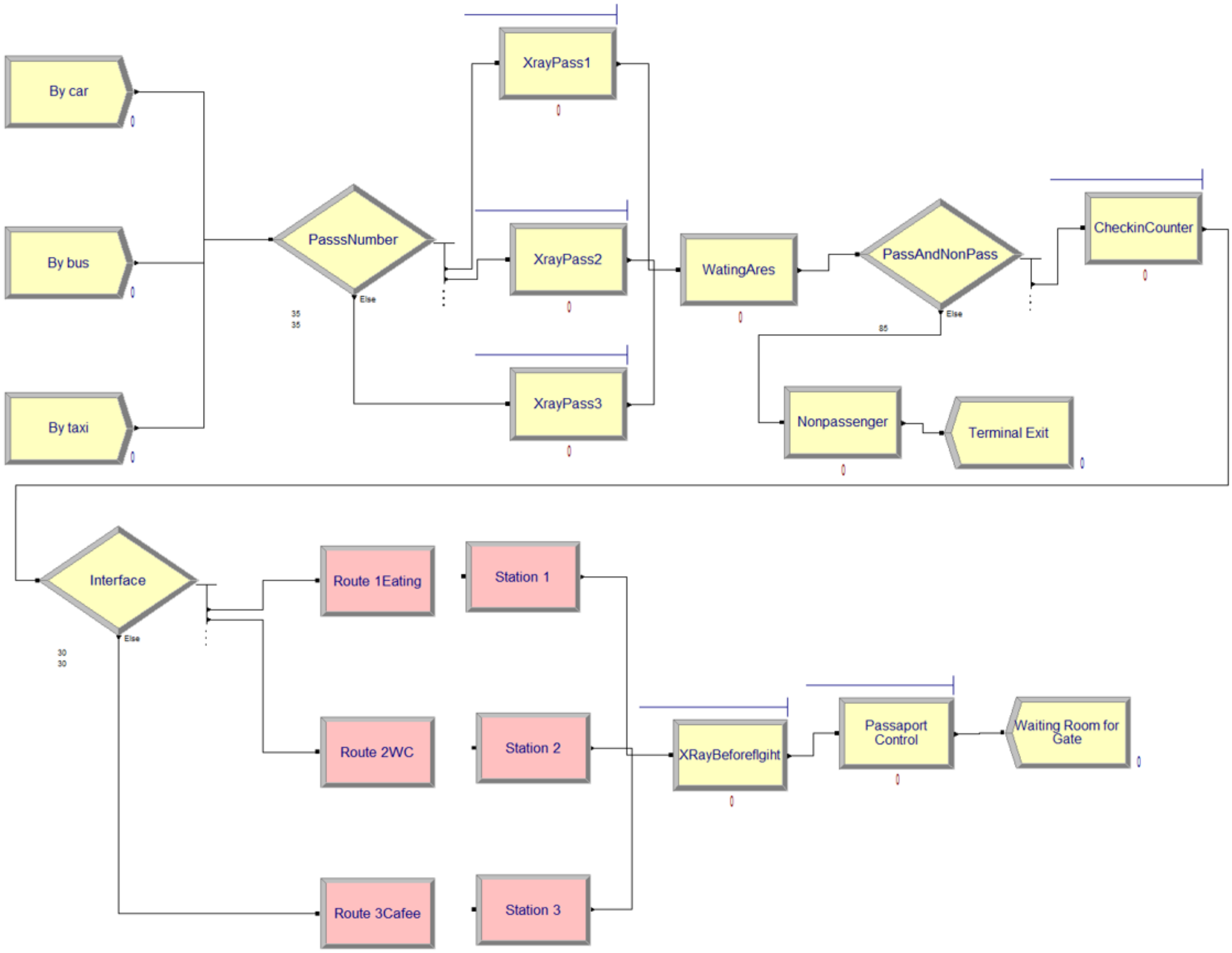

Fig. 3. The simulation model

The following assumptions considered in this study.

- Charter flights are available at the airport. All passengers travel in economy class.
- Passengers arrive at the airport by using their own private vehicles, buses and taxis, with rates of 36%, 24% and 40% respectively [35].
- Passengers arrived by their own vehicles or left by their relatives to the airport have EXPO (2) minutes between arrivals 3 hours before the flight starts, and the passengers arrive with a probability of 20%, 40%, 20% and 20% respectively 1, 2, 3 and 4.
  - Passengers coming by bus arrived at the airport 180 to 210 minutes before the flight and have a uniform distribution. The number of people coming by bus was 45 people on average with Poisson distribution.
  - The taxi arrived between 2 and 2.5 hours before the flight, with 40% and 60% probability. They were also 1 and 2 persons respectively and EXPO (2) minutes between arrivals.
- Since there is no kiosk at the airport, all passengers use check-in counters for ticket and baggage procedures.
- Passengers' baggage count is between 1 and 3. The processing time at the terminal entrance security check is 30 seconds for each baggage.
- 10% of the people entering the airport are the departure passenger's relatives.

Check-in counter and pre-flight final X-ray security control processing times are given in Table 3 [28].

Table 3. Observed Service Times for Passenger Processing Facilities at Airports [36]

Component Type	Service Rate per Passenger (second)	Standard Deviation
Ticketing and baggage		
Manual with baggage	180–240	60
Manual without baggage	100–200	30
Baggage only	30–50	10
Security		
Hand-check baggage	30–60	15
Automated	30–40	10

Figure 3 shows the simulation model established according to assumptions. In the simulation model, incoming passengers have different check-in service times according to the number of passengers and their baggage. The simulation has considered the walking distance from the check-in point to the cafe and waiting area.

4. Case study

The simulation model applied to Hasan Polatkan International Airport, considering the observations made at the airport and the parameters in the literature. Passengers entering the airport after the X-ray security checks go to the airport lounge or airport retail spaces. Passengers who complete their ticket and baggage procedures proceed to the passport processing stage. After completing the second X-ray security checks for hand luggage before the flight, they pass to the waiting room where they will wait until boarding the plane.

The airport provides services to an airline company that performs charter flights. Passengers arrive at the airport 3.5-4 hours before the flight on international flights. Passengers reach the airport in a certain period by using different means of transportation.

At the x-ray security point, which is the first entry point of the passengers to the airport, 2 devices serve and 4 officers work on each device. It is the number of luggage that mainly affects passengers' transit times. Passengers went through security checks with a minimum waiting time of 6.20 minutes, maximum 27.74 minutes and an average of 15.57 minutes and an average of 9 passengers waiting in the queue. When the airport served with a single X-ray device at the entrance, the average number of people waiting in line increased to 43.69 people and the waiting time increases to 68.88 minutes. According to these results, the simultaneous service of both x-ray devices at the airport entrance reveals its importance to prevent an important bottleneck point. The simulation study showed that when 2 x-ray devices served at the x-ray security point, the IATA service level was at the "high comfort" level.

The operation phase with the longest queue length and the longest waiting time is the check-in counter. The check-in counter is the stage where passengers arrive a certain time before the departure time, show their boarding cards or reservation codes (PNR code) to the staff at the counter, complete the acceptance procedures, and the airline employee at the counter prints the boarding card required for boarding. At the counter, passengers can make seat changes, baggage delivery, special service requests, and check-in. Therefore, it is the stage where passengers spend the most time. If four check-in counters served according to the accepted parameters, the average waiting time in the system is 38.78 minutes, ranging from 28.99 to 48.61 minutes. The average number of people waiting in line was 26, with a minimum and maximum number of 22 to 32 people. If five check-in counters served instead of four, the waiting time decreased by 76.32% to 9.18 minutes. However, if four check-in counters serve instead of four, the waiting time increased by 92.70% to 74.73 minutes. According to the data within the study and the results of the simulation, five counter desks should serve in order to increase the service level from "adequate comfort" to "high comfort" in the check-in counter phase.

The average waiting time during the last security check phase before boarding to aircraft and passport control processes performed before the transition to the clean area is less than one minute. These two stages are at the "excellent comfort" level in terms of performance evaluation of IATA. Passengers wait in the queue at the check-in stage. The short processing time in the next process stages contributes to the completion of the subsequent processes without queuing and waiting time.

5. Conclusions

Airport managers consider the capacity and conditions of the airport in the decision processes of operations. Since passengers who want to make the best use of the day at airports prefer flights that take place, especially in the morning and evening hours, there is a certain density in these time periods. Airport managements often make plans to overcome the density, using their experience. It is important for decision-makers to assess their decisions. The improvement or solution proposal for one point can cause a bottleneck at another point. However, it is possible to minimize the potential problems and analyse the decision taken by simulating the operations at the airport.

The proposed simulation model allows the decision maker to analyse all processes and potential bottleneck points in international passenger operations of an airport. It also allows the decision-maker to assess the waiting time and queue lengths in the system and enables the best usage of airport resources.

Simulation is one of the most useful tools for predicting the relationship and interaction between processes at the airport. Passengers behave differently because their personal and physical characteristics are independent from each other. In modelling passenger behaviour, simulation is an important tool to analyse the changes of personnel and technical equipment used in the process depending on the week and passenger density.

There is a need for simulation-based decision support systems that assess the results and effects of decisions taken to manage operations at airports. Considering the increase in airline traffic expected nowadays and, in the future, the integrated systems will ensure that total performance, quality and passenger satisfaction at a high level and the potential bottleneck points prevent.

CRediT Author Statement

Ilkay Orhan: Conceptualization, Data curation, Methodology, Software, Visualization, Investigation, Validation, Writing-Original draft preparation, Writing-Reviewing and Editing. **Gamze Orhan**: Conceptualization, Data curation, Writing-Original draft preparation, Investigation, Validation, Writing-Reviewing and Editing.

References

[1] Mota, M. M. (2015). Check-in allocation improvements through the use of a simulation–optimization approach. Transportation Research Part A: Policy and Practice, 77, 320-335.

[2] Alodhaibi, S., R.L. Burdet.t, and P.K.D.V. Yarlagadda, (2017). Framework for Airport Outbound Passenger Flow Modelling. Procedia Engineering, 174, 1100-1109.

[3] Gatersleben, M. R., & Van der Weij, S. W. (1999). Analysis and simulation of passenger flow in an airport terminal. In Proceedings of the 31st conference on Winter simulation: Simulation---a bridge to the future, 2, 1226-1231.

[4] Guizzi, G., Murino, T., & Romano, E. (2009). A discrete event simulation to model passenger flow in the airport terminal. Mathematical methods and applied computing, 2, 427-434.

[5] Martel, N. and Seneviratne, P.N. (1990) Analysis of Factors Influencing Quality of Service in Passenger Terminal Building, *Transportation Research Record*, No. 1273, 1-10.

[6] Takakuwa, S., Oyama, T. (2003). Simulation analysis of international departure passenger flows in an airport terminal. Proceedings of the 2003 Winfer Simulation Conference, 1627-1634.

[7] Appelt, S., Batta, R., Lin, L., & Drury, C. (2007). Simulation of passenger check-in at a medium-sized US airport. In 2007 Winter Simulation Conference, 1252-1260. IEEE.

[8] Graham, A. (2009). How important are commercial revenues to today's airports?. Journal of Air Transport Management, 15 (3), 106-111.

[9] Katz, K. L., Larson, B. M. ve Larson, R. C. (1991). Prescription for the waiting-in-line blues: Entertain, enlighten, and engage. Sloan Management Review, 32(2), 44-53

[10] Zografos, K. G., & Madas, M. A. (2006). Development and demonstration of an integrated decision support system for airport performance analysis. *Transportation Research Part C: Emerging Technologies*, 14(1), 1-17.

[11] Bruno, G., Diglio, A., Genovese, A., & Piccolo, C. (2019). A decision support system to improve performances of airport check-in services. *Soft Computing*, *23*(9), 2877-2886.

[12] Herrero, J. G., Berlanga, A., Molina, J. M., & Casar, J. R. (2005). Methods for operations planning in airport decision support systems. Applied Intelligence, 22(3), 183-206.

[13] Stamatopoulos, M. A., Zografos, K. G., & Odoni, A. R. (2004). A decision support system for airport strategic planning. Transportation Research Part C: Emerging Technologies, 12(2), 91-117.

[14] Hayashi, M., Hoang, T., Jung, Y. C., Malik, W., Lee, H., & Dulchinos, V. L. (2015). Evaluation of pushback decision-support tool concept for Charlotte Douglas International Airport ramp operations.

[15] Fayez, M. S., Kaylani, A., Cope, D., Rychlik, N., & Mollaghasemi, M. (2008). Managing airport operations using simulation. *Journal of Simulation*, *2*(1), 41-52.

[16] Beck, A. (2011). Case study: modelling passenger flows in Heathrow Terminal 5. Journal of Simulation, 5(2), 69-76.

[17] Yamada, H., Ohori, K., Iwao, T., Kira, A., Kamiyama, N., Yoshida, H., & Anai, H. (2017). Modeling and managing airport passenger flow under uncertainty: a case of Fukuoka Airport in Japan. In International Conference on Social Informatics (pp. 419-430). Springer, Cham.

[18] Kierzkowski, A. and T. Kisiel. (2014) An impact of the operators and passenger's behavior on the airport's security screening reliability. in Safety and Reliability: Methodology and Applications - Proceedings of the European Safety and Reliability Conference, ESREL

[19] Dorton, S. and D. Liu, (2015). Effects of Baggage Volume and Alarm Rate on Airport Security Screening Checkpoint Efficiency using Queuing Networks and Discrete Event Simulation. Human Factors and Ergonomics in Manufacturing & Service Industries.

[20] Manataki, I. E., Zografos, K. G. (2009). A generic system dynamics-based tool for airport terminal performance analysis. Transportation Research Part C: Emerging Technologies, 17(4), 428-443.

[21] Al-Sultan, A. T. (2016). Optimization of airport check-in scheduling at passenger terminal. International Journal of Applied Business and Economic Research, 14(5), 3233-3245.

[22] Araujo, G. E., Repolho, H. M. (2015). Optimizing the airport check-in counter allocation problem. Journal of Transport Literature, 9(4), 15-19.

[23] Mota, M. M., Alcaraz, C. Z. (2015). Allocation of airport check-in counters using a simulation-optimization approach. In Applied Simulation and Optimization (pp. 203-229). Springer, Cham.

[24] Joustra, P., and Van Dijk, N., (2001). Simulation of Check-in at Airports. Proceedings of the 2001 Winter Simulation Conference, 1023.

[24] Yan S., Shieh C., Chen M. (2002) A simulation framework for evaluating airport gate assignments. Transportation Research Part A, 36, pp 885-898.

[26] Dorndorf U., Drexl A., Nikulin Y., Pesch E. (2005) Flight gate scheduling: State-of-the-art and recent developments. Omega, 35, pp 26 – 334.

[27] Rasmussen, J. (1993). Deciding and doing: decision making in natural context. In Decision Making in Action: Models and Methods. G. A. Klein (Ed.). Ablex Publishing.

[28] Kapanoglu, M. (2016). Karar Destek Sistemleri: Temel Kavramlar (Decision Support Systems: Basic Concepts). In Karar Destek Sistemleri (Decision Support Systems), Kapanoglu, M. (Ed.), T.C. Anadolu Üniversitesi Yayını No: 3458, Eskisehir, Turkey.

[27] Verbraeck, A., and Valentin, E., (2002). Simulation Building Blocks for Airport Terminal Modeling, Proceedings of the 2002 Winter Simulation Conference, 1199-1200.

[28] Appelt S., Batta R., Lin Li, Drury C., (2007). Simulation of passenger check-in at a medium sized airport. Proceedings of the 2007 Winter Simulation Conference, 1252-1260.

[29] Chun Wai Hon, Wai Tak Mak R. (1999.), Intelligent Resource Simulation for an Airport Check-In Counter Allocation System. IEEE Transaction on Systems, Man, and Cybernetics – part C: applications and reviews, vol. 29, no.3.

[30] IATA., (1981). Guidelines for Airpot Capacity/Demand Management. Geneva, Switzerland.

[31] Brunetta, L., L. Righi and G. Anderetta. (1999). An Operations Research Model for The Evaluation Of An Airport Terminal: SLAM (Simple Landside Aggregate Model) Journal of Air Traffic Management 5, 161-175

[32] Federal Aviation Administration, (1980). AC 150/5360-9, Planning and Design of Airport Terminal Building Facilities at Non-hub Locations, Washington, DC

[33] Guizzi, G., Murino, T., & Romano, E. (2009). A discrete event simulation to model passenger flow in the airport terminal. In Proceedings of the 11th WSEAS International Conference on Mathematical Methods and Computational Techniques in Electrical Engineering (MMACTEE'09), 427-434.

[34] GDSAA (2020), General Directorate of State Airports Authority, “Airports Comparative Statistics”, available at: https://www.dhmi.gov.tr/sayfalar/istatistik.aspx.

[35] Savas, S. A. (2020). Analysis of Airport Ground Access Services By Sp/Rp Model Within The Scope of Hasan Polatkan Airport Master Plan. Journal of Management Marketing and Logistics, 7(3), 143-153.

[36] Horonjeff, R., McKelvey, F. X., Sproule, W., & Young, S. (2010). Planning and design of airports (Fifth Edition). New York: McGraw-Hill.