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Research Article

Evaluation of Passenger Behavior in the Baggage Claim Area of the Airport Passenger Terminal

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The importance of the baggage claim area as the gateway to the city is extremely high. Therefore, the initial impression of the quality of services provided at the destination airport is based on this area. In this research, an agent-based and discrete event approach using five parameters (speed and traffic of passengers, speed and arrangement of carousels, and air traffic) was applied in order to simulate passenger flow in the baggage claim area of Imam Khomeini International Airport, Tehran, Iran. In this regard, forty-eight scenarios were identified and simulated using AnyLogic software, and the waiting time and level of service for each scenario were obtained. Finally, it was revealed that changing the arrangement of the carousels from *T*-shaped to oval-shaped and expansion of the circumference by 10% had the greatest effect. Also, changing the speed of the carousels had the least influence on increasing the level of service and reducing waiting time.

1. Introduction

Today, the high growth of air travelers plays a pivotal role in transportation. Improving the efficiency of airport facilities and optimizing passenger flow for maximum use of terminals have been considered a reasonable solution to the growth [1]. On the other hand, the intensifying competition in the transportation industry has led airports to examine optimization designs and determine the development capacity of infrastructures. For example, the baggage claim area is highly important because of the role of the entrance gate of the city [2]. Moreover, passenger behavior and its characteristics can affect delays, processing time, and queue length. The number of required carousels depends on the number as well as the type of aircraft arriving during peak hours, the time distribution of these arrivals, passenger traffic, the amount of bags, and the mechanism used to transport bags from the aircraft to the baggage claim facilities [3]. Generally, airports manage two types of passenger traffic (arrival passenger flow and departure passenger flow). Departure procedure includes airport access facilities, check-in security screening, immigration, custom, and boarding. Also, arrival flows include the procedure of disembarkation, immigration, baggage claim, customs, quarantine, and airport leaving [4]. Simulation models have been widely used around the world to predict and understand the impact of various policies on pedestrian flow in and around airport terminal buildings, allowing policymakers to make informed decisions [5]. Therefore, in recent years, simulation models have been developed by the use of different approaches such as dynamic system, discrete event, and agent-based methods. Agent-based modeling is newer compared to those two methods, and it is considered due to (1) the need for complete mastery of system behavior, (2) the development of computer science-based modeling techniques, and (3) the rapid growth in power of the CPU processing power and computer memory. In addition, agent-based models require more processing speed and memory than the other two traditional methods [6].

In general, the main purpose of agent-based simulators is to determine the behavior of individuals and their interactions [7]. Many studies have used simulation and modeling to better understand passenger flow inside airport terminal buildings. In this regard, Yoon and Jeong first predicted the passenger demands in the real case of Incheon International Airport by the SARIMA model for the years to come and then estimated the passenger delays using a discrete event model to extend the carousels of baggage claim. Finally, they presented a pattern to expand the capacity of the carousels aiming at the maximization of the cost-benefit ratio [8]. Alodhaibi created a discrete event simulation framework using the ExtendSim software to develop passenger flow at the Brisbane airport. They showed that flight schedule has a significant effect on passenger flows. The model was used to assist airport operational management in determining system bottlenecks in relation to flight schedule planning issues. The simulation also provided precise data on the effects of infrastructure and operational changes [4]. Instead of conventional methods for modeling passenger flow at the airport terminal, Yarlagadda and Ma used an agent-based method introducing a bottom-up approach for observing passenger flow routing at a microscopic level. They looked into service facilities at 15 major airports around the world, including three in Europe (London Heathrow, Amsterdam Schiphol, and Frankfurt), three in the United States (Atlanta, Chicago O'Hare, and Los Angeles), three in Asia (Singapore Changi, Hong Kong, and Tokyo Haneda), two in Australia (Melbourne and Brisbane), one in the Middle East (Dubai), and a few limited examples elsewhere. By making this choice, they ensured that any cultural/regional variation can be represented. They demonstrated that by incorporating discretionary activities into the whole passenger flow processes, passengers would spend roughly double the time in the check-in hall rather than proceeding directly to security inspection counters, which appears intuitive in terms of real-world airport scenarios [1]. I-Casas simulated the movement of entities using a simple reflexive agent to obtain the accurate time and delay characteristics due to the behavior of entities [9]. Cheng investigated the effect of group dynamics on facilities and density in the check-in area using agent-based simulation with three scenarios, including (1) individual passengers, (2) group travelers, and (3) group travelers with fellow travelers. They showed that group dynamics could potentially lead to greater congestion and more delays in the check-in area. Also, the model was made by the AnyLogic software which provided a suitable method to evaluate the efficiency of space design and terminal service allocation [10]. In another research, Verma developed an agent-based model to improve the air transport system using the AnyLogic software. They examined the sensitivity of the model to the variables affecting the likelihood of participating in voluntary activities. They studied the impact of six policy scenarios on the system's throughput at Bangalore Airport to determine the effectiveness of the suggested policies. The results showed a significant impact of the proposed policies on system performance [5]. In order to establish the new ideal airport level-of-service (LOS), Kim and Wu suggested an agent-based simulation-based methodology. This technique would help terminal designers create more affordable facilities while still offering passengers a suitable LOS. By shutting off LOS values during peak and off-peak hours, it seeks to give at least 50% of passengers, access to the new and ideal LOS range [11].

Janssen et al. presented AbSRiM, a novel agent-based modeling and simulation approach for airport security risk management that employs formal sociotechnical models with temporal and spatial dimensions. Their study included a threat scenario in which an adversary used an improvised explosive device to attack an airport terminal. The method offered a promising way to incorporate important elements, such as human aspects and spatiotemporal aspects, into risk assessment. The approach is demonstrated by using a case study involving an IED at an airport terminal. It was demonstrated that opening an additional security lane and hiring a behavior detection employee can be advantageous, depending on the maximum risk the airport is willing to accept and the maximum costs it is willing to pay [12].

Pisinger and Scatamacchia presented a B & P scheme for optimal flight assignment to baggage belts in the baggage claim area. The approach addresses several business and fairness concerns while avoiding congestion and maintaining a good passenger flow. The solutions' robustness is achieved by aligning the delivery time with the expected arrival time of passengers and by adding buffer time between two flights on the same belt. Computational experiments, using data from Copenhagen airport and randomly generated instances, show that the proposed algorithm is effective at delivering high-quality solutions in short computational times, allowing the solution approach to be used in daily operations at medium- and large-sized airports [13]. Kalakou and Moura used a multinomial logit model to understand passengers' decisions to engage in discretionary activities at the Lisbon Portela airport. By modeling passengers' activity choices, they contributed to a better understanding of the passenger behavior and experience in the airport terminal [14].

Due to the fact that Iran has an excellent geographical position in the Middle East for air transit, therefore, the prosperity of the country's airports plays an important role in employment and economic development. Consequently, measurements such as building a new airport, increasing the capacity of high-demand airports, improving the air infrastructure, and identifying performance policies and management guidelines are essential in order to make better use of existing capacity. In this regard, an important approach is the simulation of passenger flows in the design and management of airports and can be a great help in studying and analyzing passenger behavior and the performance of the system. So, in this study, passenger behavior in the baggage claim area of the passenger terminal of Imam Khomeini International Airport, Tehran, Iran, was investigated.

2. Methodology

In this study, the contributing elements of supply and demand were studied, and various scenarios were obtained to achieve the closest answer to the real and optimal state in the baggage claim area of Imam Khomeini International Airport as a case study. At first, five factors affecting the performance of baggage claim were considered, including the design and circumference of the carousels, carousels' speed, arrival passenger traffic, passengers' speed, and the number of passengers' bags. Two factors of design and speed of carousels were regarded as elements of supply scenarios and traffic and speed of passengers and the number of passengers' bags as elements of demand scenarios. Figure 1 shows the process of this research.

2.1. Supply and Demand Scenarios. The main users of the airport are passengers who have varied characteristics. This variety in characteristics can be observed in the age of passengers, number and size of bags, number of companions and trips, passenger familiarity with the aviation process and airport, place of residence, culture, etc. All of these can affect determining the space occupied by passengers, the time spent in the baggage claim area, and the passenger's satisfaction with the baggage claim service. Thus, the demand scenarios were divided into three categories, including passenger arrival traffic, passenger speed based on the speed range set by Fruin, and the number of passengers' bags [15]. Due to the reason that supply policies, in addition to affecting passengers, are an important parameter for the airline and are directly dependent on demands and policies of the airline and airports, therefore, as supply elements, three states for carousel setting and two different speeds of conveyor belt were considered. For the variable of passengers' speed, two triangular values with distributions (0.6, 0.8, and 1.4 m/s) and (1, 1.7, and 1.9 m/s) were considered, for passenger arrival traffic, a peak day and a typical day, for the percentage of passengers with bags, two forms (50% of passengers without any bags and 50% with one bag) and (10% of passengers without any bags and 90% with one bag), for the speed of conveyor belts two values of 1 m/s and 0.5 m/s were considered. Also, for the carousel design, the settings were considered, including *T*-shaped without expanding the carousel circumference based on the carousel design and circumference of Imam Khomeini International Airport, the oval-shaped carousels with a 10% expansion of carousels' circumference, and the third setting was 20% expansion in the circumference of carousels. Figure 2 indicates the supply and demand scenarios.

Therefore, by combining supply and demand scenarios, 48 different scenarios (see Table S1 in the supplementary file) were obtained, and simulations of the models were performed separately for each scenario.

2.2. Queueing Simulation. The queuing system is determined by its calling population, the nature of arrivals, the service mechanism, and the queueing discipline. A single-channel queueing system is represented in Figure 3.

In this system, the calling population is assumed to be unlimited; that is, if a person leaves the calling population and joins the waiting queue or goes to the place of service, there will be no change in the arrival rate of the population in need of service. In addition, in this system, the entries occur once at a time, and they are random, and if the arrivals join the queue, they will be eventually serviced. Service times are also random and determined in the form of probabilistic distributions that remain unchanged over time. The capacity of the system is also unlimited. Arrivals receive service (often known as first-in-first-out (FIFO) or first-come, first-served (FCFS)) by a simple servicer or multiple parallel servers. In general, two events can change the state of the system. These two events are the arrival event (the service beginning event) and the departure event (the completion event). The unit finds the server either empty or idle; hence, either the unit begins service immediately, or it enters the queue. The flow diagram for departure and arrival events is presented in Figures 4(a) and 4(b), respectively. The unit takes actions shown in Table 1 [16].

Simulation results such as average waiting time, the probability that a customer has to wait in the queue, the probability that the server is idle, average service time, average time between arrivals, average waiting time of those who wait, and average times customers spend in the system computed as the following equations:

$$\text{Average waiting time (minutes)} = \frac{\text{Total time customers wait in the queue (minutes)}}{\text{Total number of customers}}, \tag{1}$$

$$\text{Probability (wait)} = \frac{\text{Numbers of customers who wait}}{\text{Total number of customers}}, \tag{2}$$

$$\text{Probability of idle server} = \frac{\text{Total idle time of server (minutes)}}{\text{Total run time of the simulation (minutes)}}, \tag{3}$$

$$\text{Average service time (minutes)} = \frac{\text{Total service time (minutes)}}{\text{Total number of customers}}, \tag{4}$$

$$\begin{array}{l}\text{Average time}\\ \text{between arrivals (minutes)}\end{array} = \frac{\text{Sum of all times between arrivals (minutes)}}{\text{Number of arrivals} - 1}, \tag{5}$$

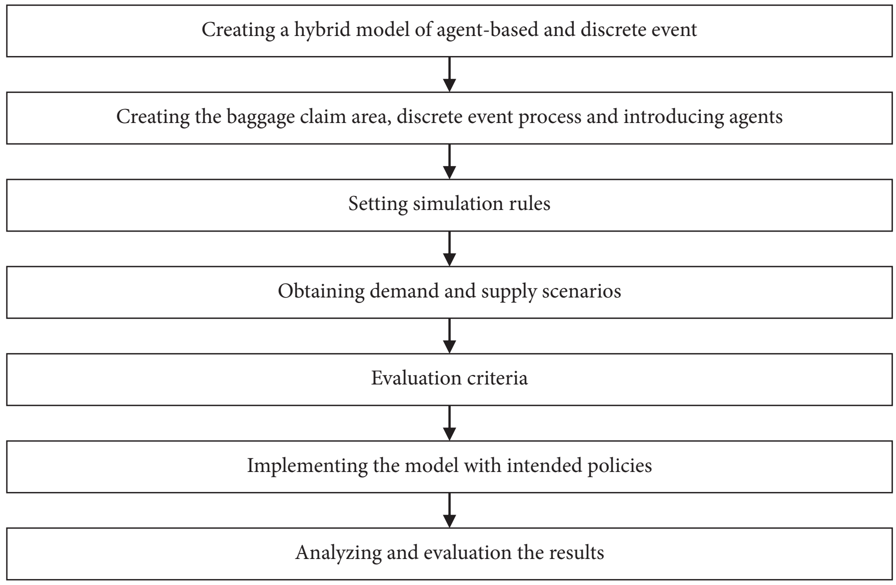


Figure 1: The steps of the research process.

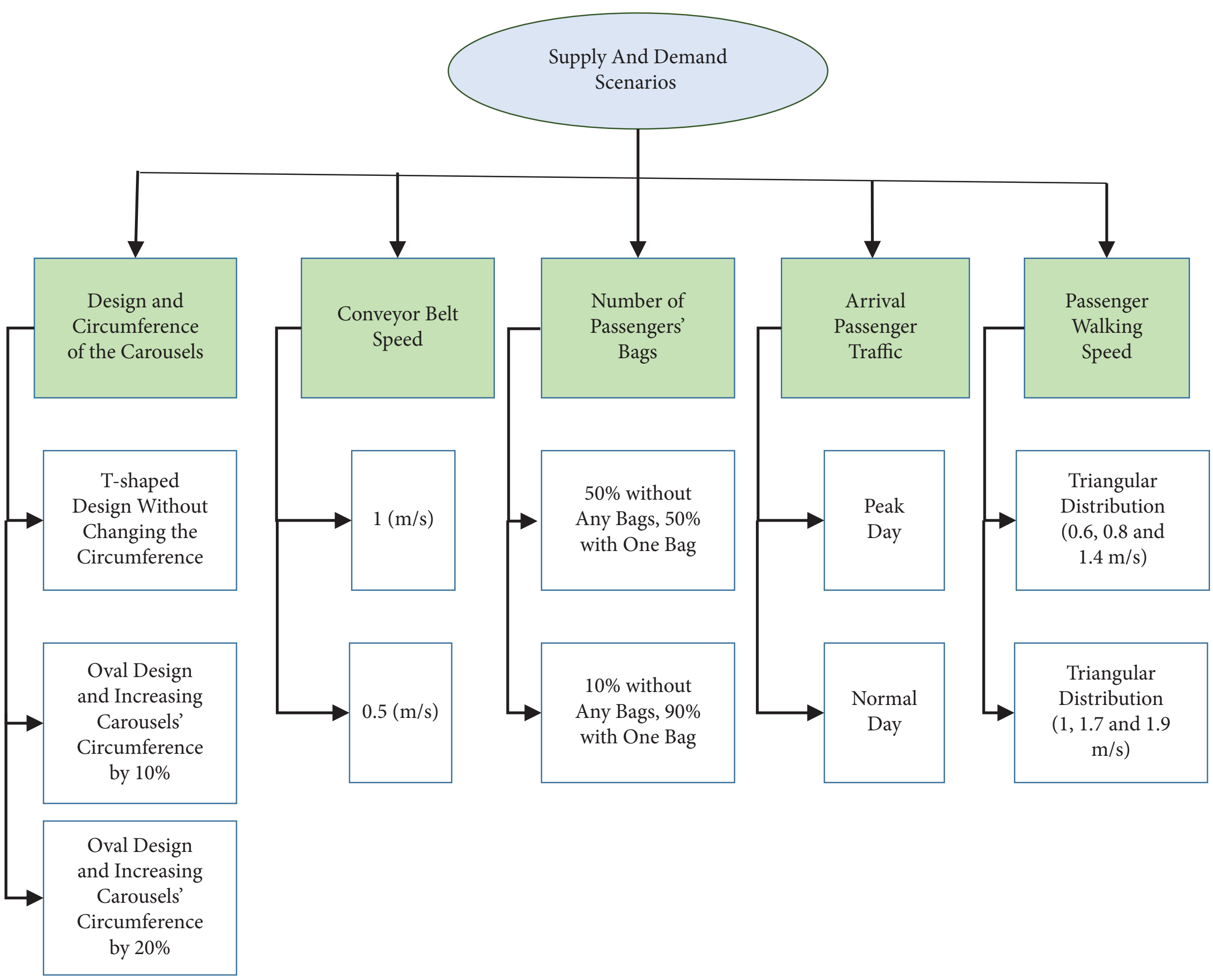


Figure 2: The supply and demand scenarios used in this research.

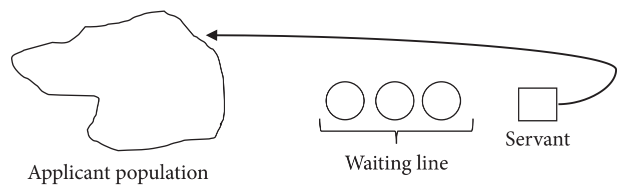


Figure 3: A single-channel queueing system.

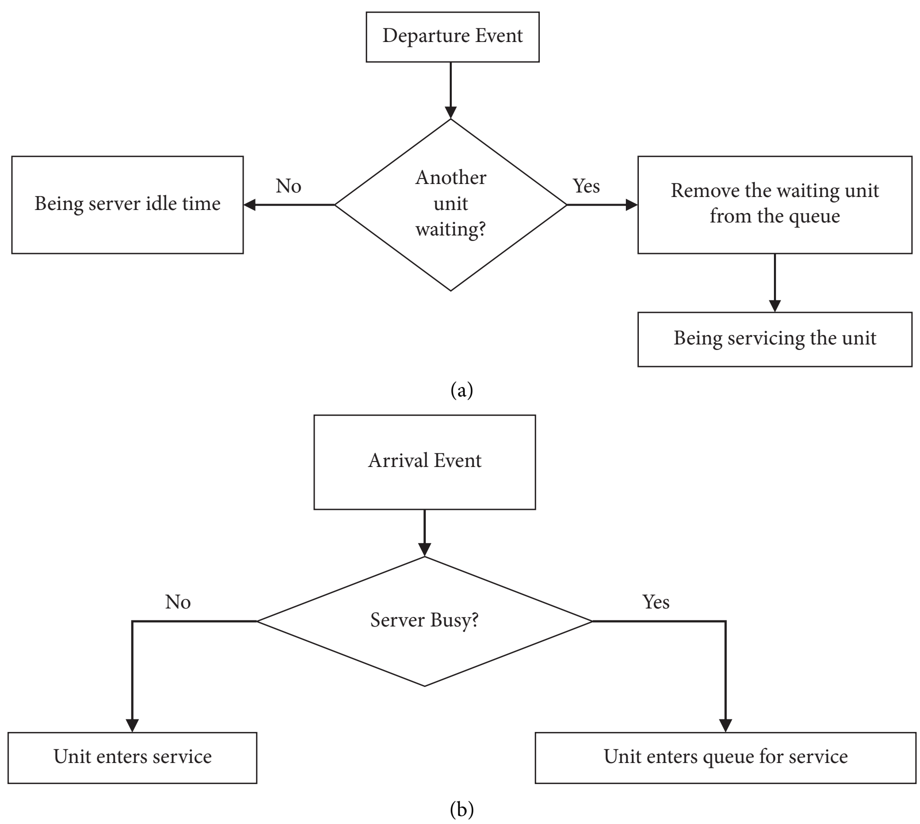


Figure 4: (a) Departure event flow diagram. (b) Arrival event flow diagram.

$$\begin{matrix}\text{Average waiting time of}\\ \text{those who wait (minutes)}\end{matrix} = \frac{\text{Total time customers wait in queue}}{\text{Total number of customers who wait}}, \tag{6}$$

$$\begin{matrix}\text{Average time customer}\\ \text{spends in the system (minutes)}\end{matrix} = \frac{\text{Total time customers spend in the system (minutes)}}{\text{Total number of customers}}, \tag{7}$$

$$\left\{\begin{matrix}\text{Average time customer spends}\\ \text{in the system (minutes)}\end{matrix} = \begin{matrix}\text{Average time customer spends}\\ \text{waiting in the queue (minutes)}\end{matrix} + \begin{matrix}\text{Average time customer}\\ \text{spends in service (minutes)}\end{matrix}\right\}, \tag{8}$$

2.3. Data Collection. The data regarding the day and time of the arrival passengers' flights of Imam Khomeini International Airport, Tehran, Iran, within two years (2017–2019) were obtained from the airport database. The model was then performed on a peak day and a normal day in the middle of the week without any official holidays during the week in these two years.

2.4. Simulation Using AnyLogic Software. In this research, AnyLogic software was used to simulate the models. AnyLogic is a unique simulation software that supports three methods of system dynamics, discrete event, and agent-based models and allows the creation of a multimethod model. By the use of this software, various environments can be modeled in both two-dimensional and three-dimensional

Table 1: The potential unit actions upon arrival.

		Queue status	
		Nonempty	Empty
Server status	Busy	Enter queue	Enter queue
	Idle	Impossible	Enter service

environments with different routes and means of traffic, and the results can be viewed and analyzed graphically and animated.

2.4.1. Creating the Baggage Claim Area. First, the baggage claim area of Imam Khomeini International Airport was modeled in AnyLogic software. The baggage claim area of the airport consists of two independent areas, each of which has three similar carousels. Figures 5(a)–5(c) show the simulated terminal space for the three T-shaped designs without increasing the circumference of carousels, the oval design and increasing the carousels' circumference by 20%, and the oval design and increasing the carousels' circumference by 10%.

2.4.2. Creating a Two-Method Model of Agent-Based and Discrete Event. The modeling process was performed by a discrete event model implemented by the agents. Pedestrians, flight schedules, and bags were considered agents and built in a simulation environment with their own characteristics. 48 models were implemented and analyzed according to the scenarios mentioned in Table 1. In fact, a two-method model was created using AnyLogic software. Figure 6 shows the discrete event process that was performed in the presence of agents. The simulation was performed in a way that (1) each agent has its own exclusive bag and has to wait until its bag arrives, (2) the flight load is assigned to the carousel randomly between the vacant carousels, and (3) the passengers and the bags of each flight arrive simultaneously at the baggage claim area.

2.5. Analysis Method. Initially, specified scenarios were implemented using AnyLogic software, and the results were obtained in terms of the percentage of passengers who experienced each Table 2 time interval during each scenario, and the average time spent in minutes in the baggage claim area. Due to the reason that the service level criterion is used to determine the efficiency of the airport terminal, here, the criteria provided by Correia and Wirasinghe were used to determine the level of service based on the time that passengers spent in this area [17]. Table 3 shows the recommended levels of service of Correia and Wirasinghe in terms of processing time. By the use of Table 3, 4% of levels of service were obtained for the models. Then, in order to facilitate the analysis of the results, the levels of service (LOSs) were normalized. For this purpose, the impact factor for each LOS was calculated according to equation (9). The impact factor for LOS A, B, C, D, and E was considered 1, 0.96, 0.46, 0.23, and 0, respectively. Finally, each LOS was multiplied by the obtained impact factor, and their sum was obtained as the percentage of the total normalized LOS of that scenario [17].

$$Z = \frac{\max(x) - x}{\max(x) - \min(x)}, \tag{9}$$

where max (x) is the highest number in the whole set, min (x) is the lowest number in the whole set, and x is the lowest number in each subset.

3. Results

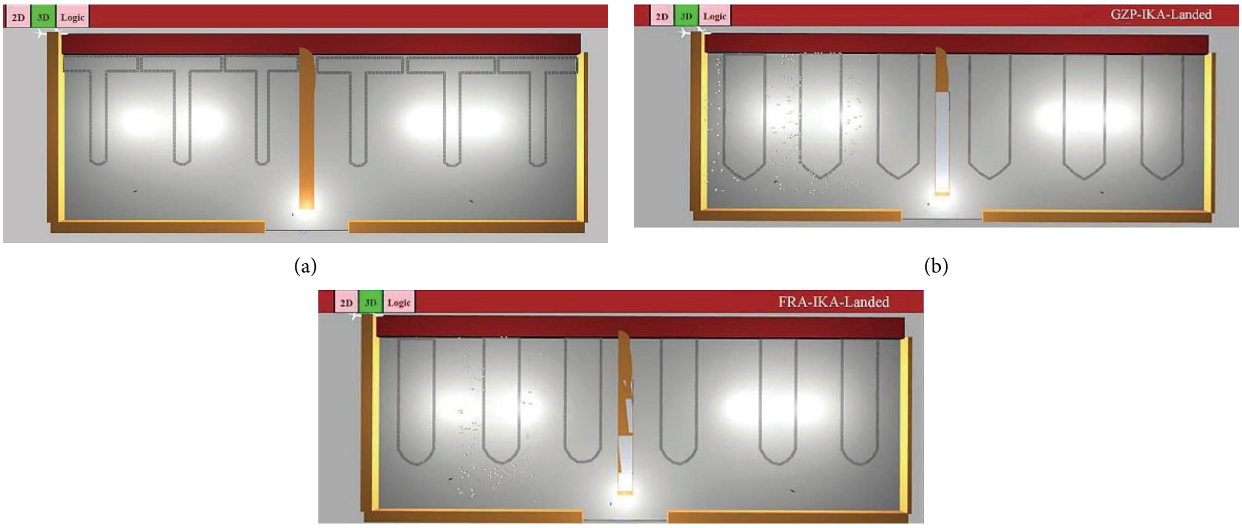
3.1. Normalization of LOSs. Figure 7 shows the results of the normalized LOSs in the baggage claim area for 48 scenarios. As shown in the figure, scenario 29, with a normalized LOS of 71.48%, had the highest percentage for normalized LOS. Therefore, passengers in scenario 29 are in the best position, and this scenario can be considered the best model. Also, scenario 4, with 32.83% of normalized LOS, had the lowest percentage; hence, passengers in scenario 4 are in the worst situation, and this scenario can be regarded as the worst state for passengers.

3.2. Average Time Spent. Waiting time and time spent are among the factors that affect passengers' perception of the LOS. The shorter the waiting time, the higher the LOS, and the more desirable for passengers. Figure 8 shows the results of the average time spent by passengers in the baggage claim area for all 48 scenarios. It can be seen that scenario 29 with 10 : 34 minutes had the lowest average time spent and scenario 4 with 21 : 19 minutes had the highest time spent. Therefore, according to these results, scenario 29 was selected as the best scenario, and scenario 4 as the worst. In addition, it is observed that the average time spent in scenario 4 was almost twice the average time spent in scenario 29.

3.3. Effect of Traffic. In order to observe the effect of traffic on the normalized LOSs and the average time spent by passengers, the scenarios were divided into two parts of peak day and normal day. Figure9 shows the normalized LOSs for both normal and peak days. Figure 10 shows that the LOSs in all scenarios were higher on a normal day than on a peak day, which is due to the fact that the traffic reaches its maximum on the peak day and the baggage claim area gets crowded; therefore, passengers are not in good condition on the peak day. Figure 10 shows the effect of passenger traffic on the normalized LOSs in the baggage claim area.

By comparing each scenario on a peak day with its similar scenario on a normal day, the maximum impact of traffic on LOS can be seen in scenarios 8 and 24, and by changing the total LOS by 18.77%, the lowest impact of traffic was observed in scenarios 34 and 42 with 1.49% change in LOS. On average, the traffic change altered the total LOS by 7.49%. The differences in LOS values resulting from the impact of passenger traffic can be seen in Figure S1 in the supplementary file.

The results have shown that the average time spent on a normal day was less than that on the peak day, and passengers were in a more desirable state on a normal day since the average



(a) (b) (c)

Figure 5: (a) Simulated baggage claim area with *T*-shaped carousels. (b) Simulated baggage claim area with oval-shaped carousels and 10% expansion of carousels' circumference. (c) Simulated baggage claim area with oval-shaped carousels and 10% expansion of carousels' circumference.

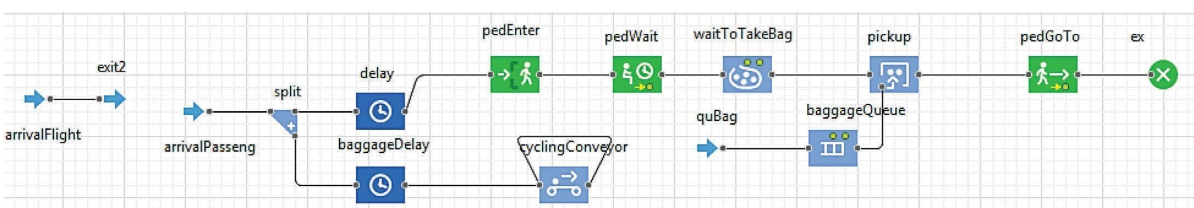


Figure 6: Discrete event process in the presence of agents.

Table 2: Proposed levels of service according to processing time [17].

LOS	Processing time (min)
A	<1
B	1–14
C	14–20
D	20–26
E	>26

time spent was inextricably linked with the LOS. Figure 11 illustrates the average time spent in the baggage claim area.

According to the results, the highest impact of traffic on the average time spent can be seen in scenarios 13 and 29, accounting for 4 minutes and 12 seconds change, and the lowest influence of traffic is in two scenarios 36 and 44 with a change of 7 seconds. On average, the traffic alteration changed the total LOS by 7.49%, and the average time spent changed by 1 minute and 58 seconds. Figure S2 in the supplementary file has shown the difference between the average time spent in the baggage claim area in scenarios on a peak day with similar scenarios on a normal day.

3.4. Effect of Passenger Walking Speed. In order to investigate the effect of passenger walking speed on the convenience of passengers in the baggage claim area, scenarios with two speeds of 1, 1.7, and 1.9 m/s as well as 0.6, 0.8, and 1.4 m/s were considered. It is observed that scenarios with the walking speed of 1, 1.7, and 1.9 m/s had a higher normalized LOS than scenarios with the walking speeds of 0.6, 0.8, and 1.4 m/s. Therefore, pedestrians with walking speeds of 1, 1.7, and 1.9 m/s are in a better state in this area. Figure 12 shows the normalized LOSs of 48 scenarios at two different walking speeds.

According to the results, it can be stated that under the same conditions, the highest effect of walking speed was seen in two scenarios 7 and 8 with a difference of 12.19%, and the least effect of walking speed in scenarios 38 and 37 with a difference of 0.43%. On average, a change of 5.72% in the total normalized LOSs was observed by increasing the walking speed. The differences in normalized LOS values have been provided in the supplementary file (see Figure S3).

Figure 9 compares the results of average time at two speeds 1, 1.7, and 1.9 m/s as well as 0.6, 0.8, and 1.4 m/s. It is illustrated that the scenarios with speeds of 1, 1.7, and 1.9 m/s have less average time spent. The results showed that scenarios 3 and 4 with a time difference of 3 minutes and 21 seconds and scenarios 14 and 13 with a time difference of 23 seconds had the highest and lowest differences, respectively. Therefore, changing the walking speed had the greatest impact on scenarios 3 and 4 and the least impact on

Table 3: Maximum, minimum, and average values for the effect of each item.

Item	Maximum	Minimum	Average
Normalized LOS	71.48%	32.83%	56.9%
Average time spent	00 : 21 : 19	00 : 10 : 34	00 : 15 : 12
Effect of traffic in LOS	18.77%	1.49%	7.49%
Effect of traffic in average time spent	00 : 04 : 12	00 : 00 : 44	00 : 01 : 58
Effect of passengers walking speed in LOS	12.19%	0.43%	5.27%
Effect of passengers walking speed in average time spent	00 : 03 : 21	00 : 00 : 23	00 : 01 : 44
Effect of passengers' bags in LOS	6.95%	0.2%	2.35%
Effect of passengers' bags in average time spent	00 : 02 : 00	00 : 00 : 08	00 : 00 : 59
Effect of carousels design in LOS	27.72%	0.37%	15.01%
Effect of carousels designs in average time spent	00 : 06 : 24	00 : 00 : 02	00 : 02 : 59
Effect of conveyor belt speed in LOS	3.58%	0.02%	0.96%
Effect of conveyor belt speed in average time spent	00 : 01 : 17	00 : 00 : 01	00 : 00 : 19

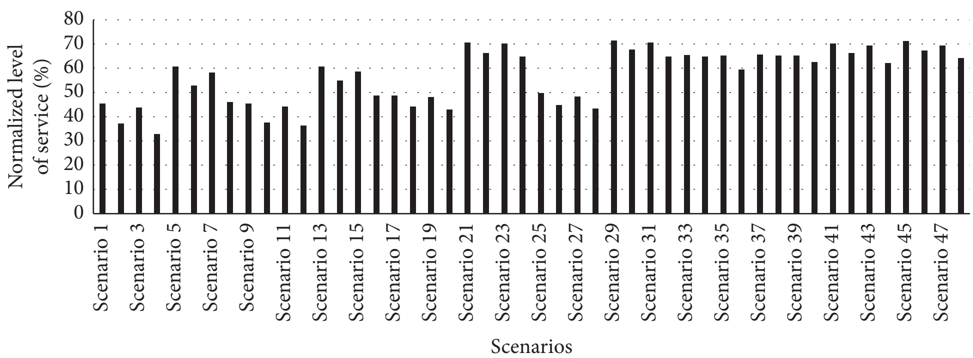


Figure 7: Normalized LOSs for each scenario.

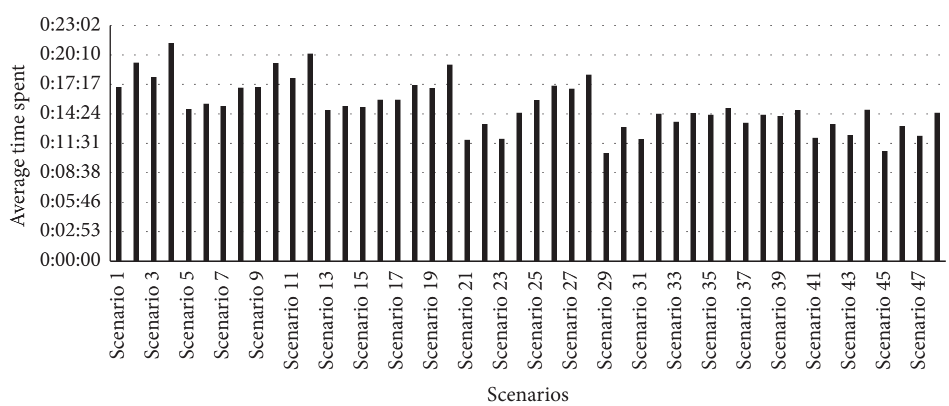


Figure 8: Average time spent for each scenario.

scenarios 14 and 13. On average, a change of 1 minute and 44 seconds was observed in the average time spent by changing the passenger's walking speed.

It is observed that the average time spent was higher for scenarios with walking speed distribution of 0.6, 0.8, and 1.4 m/s. The results of differences in the average time spent on scenarios with two different distributions for walking speeds have been shown in Figure S4 in the supplementary file.

3.5. Effect of the Number of Passenger Bags. In order to investigate the effect of the number of bags on the normalized LOS and the average time spent in the baggage claim area, scenarios were divided into two categories of passengers (50% without the bag, 50% one bag, and 10% without the bag, 90% one bag). Each scenario was compared with a similar scenario except for the number of bags. As results revealed, the amounts for the normalized LOS were higher for passengers with 50% no bag and 50% one bag. The reason for this can be attributed to the low amount of passengers' bags. Figure 13 shows the results obtained from the normalized LOS for the two groups of passengers' bags.

According to the results, changing the number of passenger bags had the greatest impact on two scenarios 6 and 8 with a change of LOS of 6.95% and the least impact on two

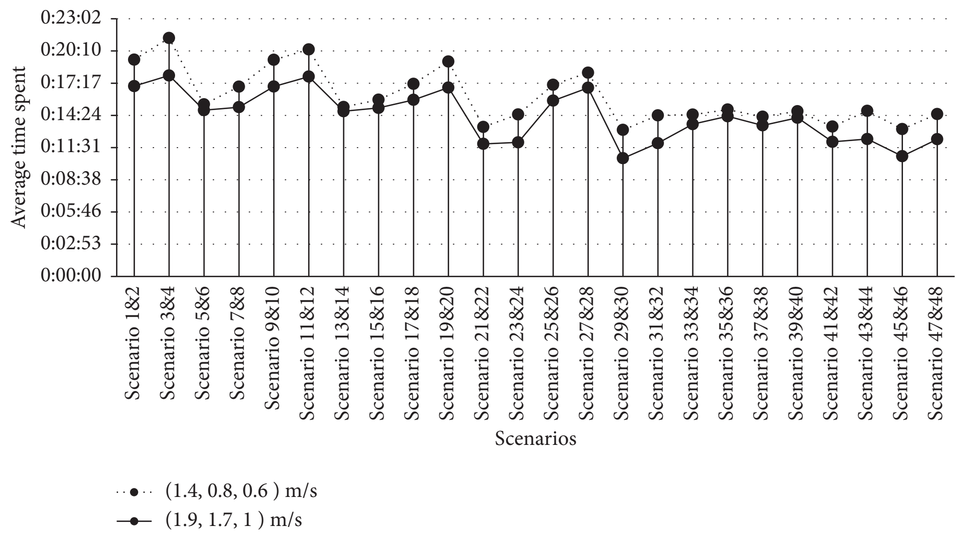


Figure 9: Average time spent for passengers with two different walking speeds.

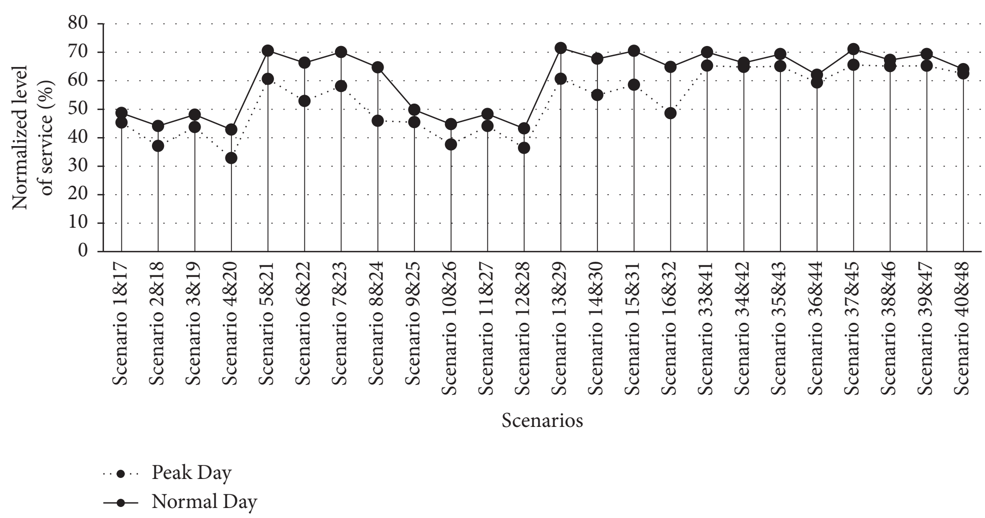


Figure 10: Normalized LOSs on a peak day and normal day.

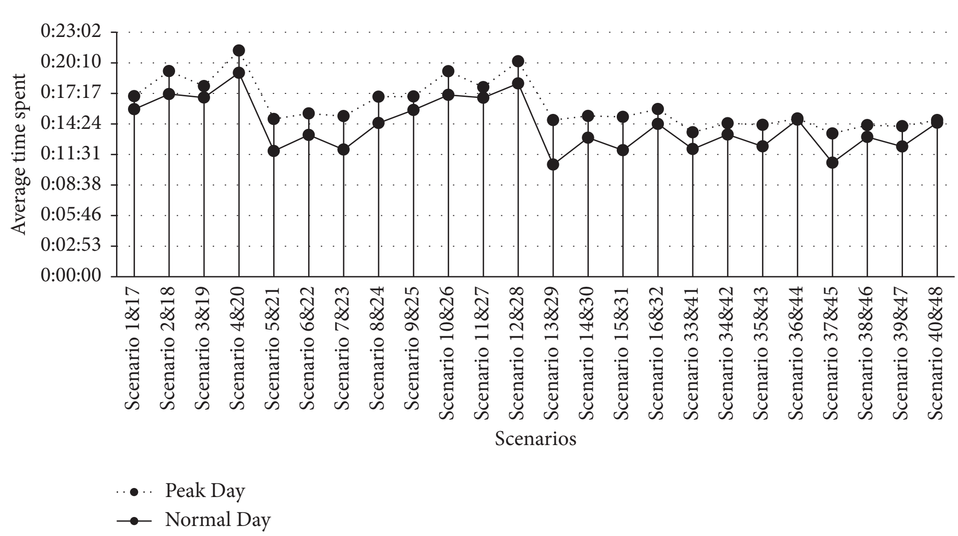


Figure 11: Average time spent on a peak day and normal day.

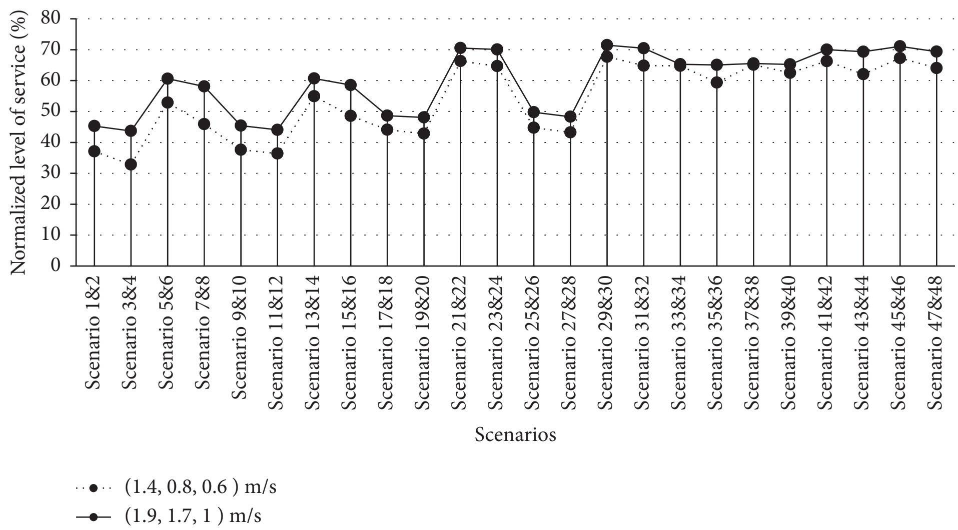


Figure 12: Normalized LOS values of scenarios with two di8erent passengers' walking speeds.

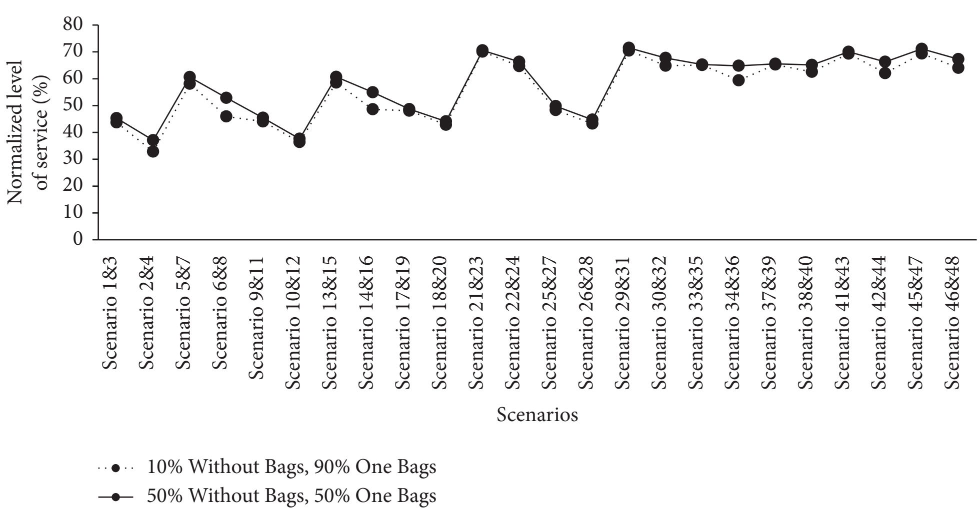


Figure 13: Normalized LOS for two groups of passengers in terms of the number of bags.

scenarios 35 and 33 with a difference of LOS of 0.2%. In addition, due to the negligible difference in the normalized LOSs, it can be said that the number of passenger bags had a slight effect on changing the normalized LOSs compared to the two previously mentioned factors, namely increasing the traffic of passengers and passenger walking speed. By changing the number of passenger bags, in general, the normalized LOS was changed by 2.35%. Effect of the amount of passengers' bags and the differences that it makes has been shown in the supplementary file (Figure S5).

Furthermore, Figure 14 shows that the passengers 50% without any bags and 50% with one bag spend less time in the baggage claim, and it can also be resulted that passengers with fewer bags had better LOSs in this mentioned area.

Scenarios 20 and 18 had the highest time difference of 2 minutes, and scenarios 23 and 21 had the lowest time difference of 8 seconds. By alteration of the number of passenger bags, a total of 59 seconds in the average time spent was changed.

The results of the average time spent for the two groups of passengers with different numbers of bags claimed that in general, for the first group (10% with no bags, 90% one bag), the average amounts of the time spent in the baggage claim area were higher.

Differences in average time spent with changing the number of passengers' bags are provided in the supplementary file (Figure S6).

3.6. Effect of Carousels' Design. In order to investigate the effect of the carousels' design on LOS and the average time spent in the baggage claim area, three different designs of the carousels are considered, including *T*-shaped without increasing the circumference, oval carousels with a 10% increase in circumference, and oval carousels with a 20% expansion. According to the results, it can be seen that the oval-shaped carousels with a 10% increase in the environment had the highest normalized LOSs, and the *T*-shaped

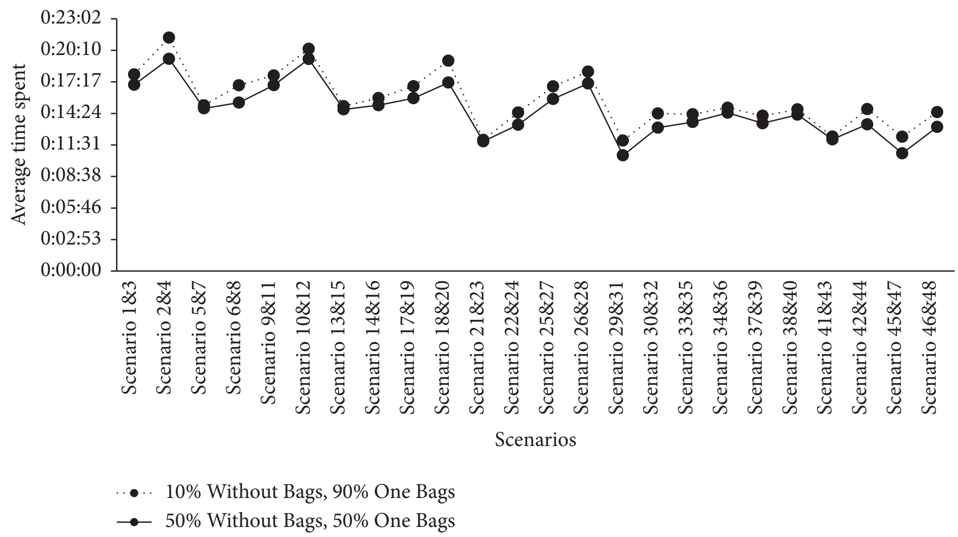


Figure 14: Average time spent by two groups of passengers with different numbers of bags.

carousels had the lowest ones. By comparing these scenarios, Figure 15 shows that by changing the design of the carousels from *T* to oval and increasing the circumference by 10%, the greatest impact on the overall LOSs was observed in scenarios 2 and 34 by a change of up to 27.72%. Also, on average, by changing the design of the *T*-shaped carousels to oval-shaped and expanding by 10%, the total normalized LOS was increased by 22.52%. Moreover, by changing the design of *T*-shaped carousels to oval-shaped and expanding the circumference by 20%, the greatest impact on the overall LOSs was observed in scenarios 26 and 30 and for a change of up to 22.97%. On average, the design of the T-shaped carousels to oval and the expansion of the circumference by 20% enhanced the overall normalized LOS to 18.36%. Figure 15 shows the normalized LOSs for these three carousels' arrangements.

Results have shown that *T*-shaped carousels with no increase in circumference and oval carousels with a 10% expansion in circumference had the highest and lowest average time spent, respectively. Also, by changing the *T*-shaped design to oval-shaped and expanding by 10%, the greatest change was observed in scenarios 4 and 36 and with a change of 6 minutes and 24 seconds. On average, by changing the design of the *T*-shaped carousels to oval and expansion of the circumference by 10%, the average time spend decreased by 4 minutes and 4 seconds. In addition, changing the design of the carousels from *T* to oval and increasing the circumference by 20% had the greatest effect on the average time spent in scenarios 25 and 29, with a change of 5 minutes and 9 seconds. On average, changing the design of the *T*-shaped carousels to oval-shaped carousels and increasing the circumference by 20% changed the average time spent by 3 minutes and 54 seconds.

The results of time spent on different types of carousel designs have shown that *T*-shaped carousels without increasing the circumference and oval-shaped with 10% increasing the circumference had the highest and the lowest average time spent in the baggage claim area, respectively. Figure 16 compares the average time spent on the three designs of the carousel design.

3.7. The Effect of Conveyor Belt Speed. The effect of the speed of the conveyor belt on LOS and the average time spent in the baggage claim area for passengers with two speed values of 0.5 m/s and 1 m/s was performed. Figure 17 showed that changing the speed of the conveyor belts did not have a significant effect on the normalized LOS. However, it can be said that, in part, scenarios with a speed of 1 m/s had higher and better LOSs than scenarios with a conveyor belt speed of 0.5 m/s.

The results revealed that changing the speed of the conveyor belt had the greatest impact on the normalized LOSs in scenarios 4 and 12 by 3.58%. The lowest effect of speed change was observed in two scenarios 47 and 43, with a change of 0.02%. On average, changing the speed of the conveyor belt changed the overall level of service by 0.96%. The results of the difference in the normalized LOSs between two groups of carousels with different speeds have been provided in Figure S7 in the supplementary file.

Considering the results of the average time spent for the two different speeds of the conveyor belt, this can be stated that passengers who were serviced by conveyor belts with the speed of 0.5 m/s spent more time in the baggage claim area, and this time difference was not very significant. Figure 18 shows the average results of time spent on scenarios with carousel speeds of 0.5 m/s and 1 m/s.

According to the results, the average time spent at a speed of 0.5 m/s was more, but the difference was not significant. The two scenarios 21 and 29 with 1 minute and 17 seconds difference had the highest difference. It can also be seen that by changing the speed of the conveyor belt in some of the scenarios, the change in the average time spent was about 1 second. On average, changing the conveyor belt

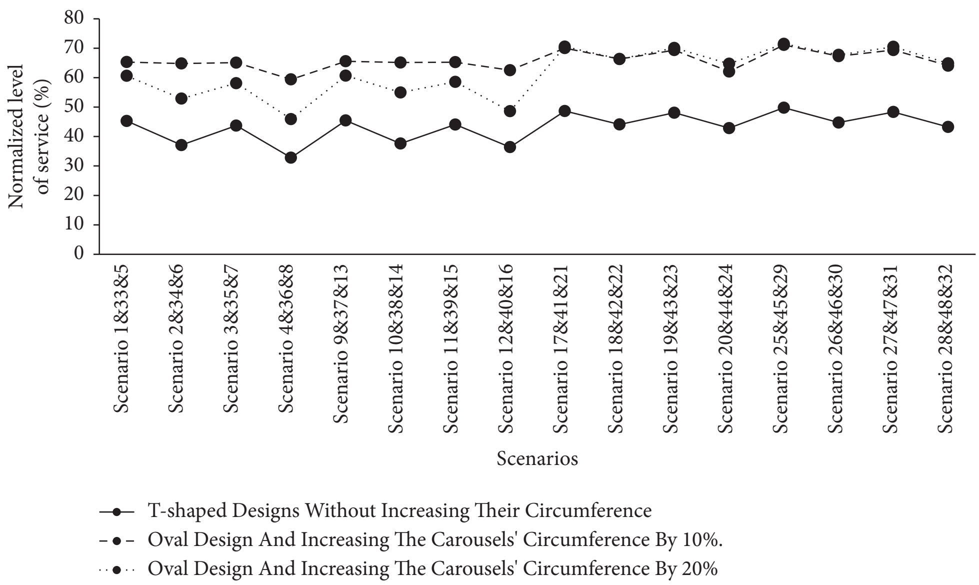


Figure 15: Normalized LOSs for three different carousels' arrangements.

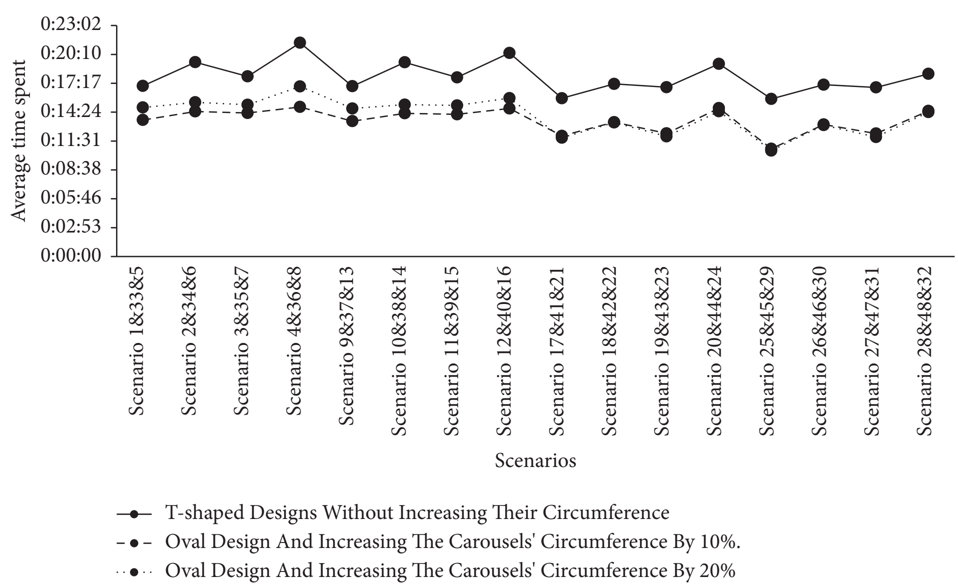


Figure 16: Average time spent according to three different carousels' arrangements.

speed changed the overall time spent by 19 seconds. Figure S8 in the supplementary file shows the difference between the average time spent by the passengers with two carousel speeds of 0.5 and 1 m/s.

In order to determine the effects of each parameter, each scenario was compared with its similar scenarios with the difference in that specific parameter. The results showed that changing the design of the carousels from T-shaped to oval-shaped and increasing the circumference by 10% had the greatest effect on reducing LOS. Also, increasing the speed of the conveyor belt had little effect on reducing the time spent and LOS. 20% increase in carousels' circumference, passenger traffic, passenger walking speed, and the number of passengers' bags had the greatest impact on LOS and average time spent, respectively. Table 3 shows the minimum, maximum, and average values in case of changing any considered characteristic.

This finding is consistent with previous studies, which found that the proposed policies had a significant influence on system throughput. This can aid in the development of various policies to improve the efficiency of terminal operations.

With changing policies and new technologies in airport terminals, handling passenger flows has faced a major challenge. So far, many studies have been conducted on departure passengers, but despite the high importance of arrival flows and facilities, less attention has been paid to it.

In the past, Yoon and Jeong conducted an extensive analysis to estimate passenger delay using a discrete event simulation model, and they developed a plan to expand

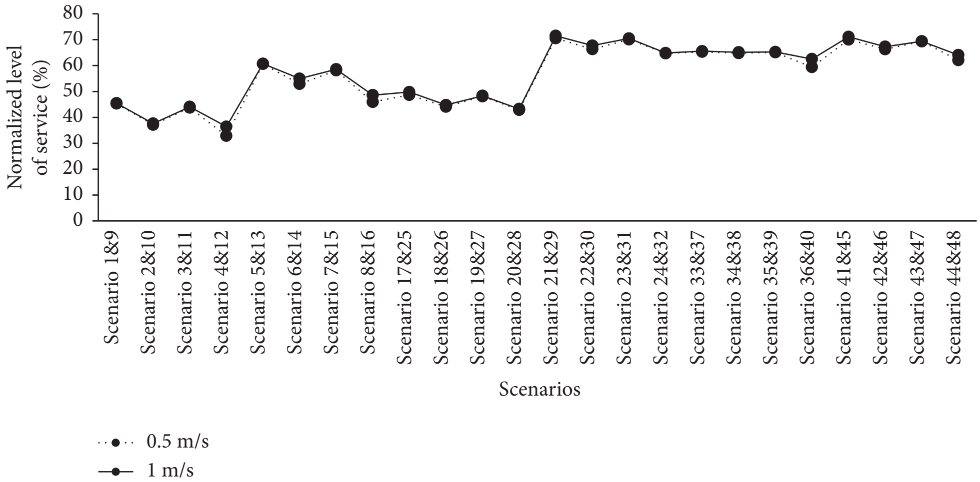


Figure 17: Normalized LOSs of scenarios with two different conveyor belt speeds.

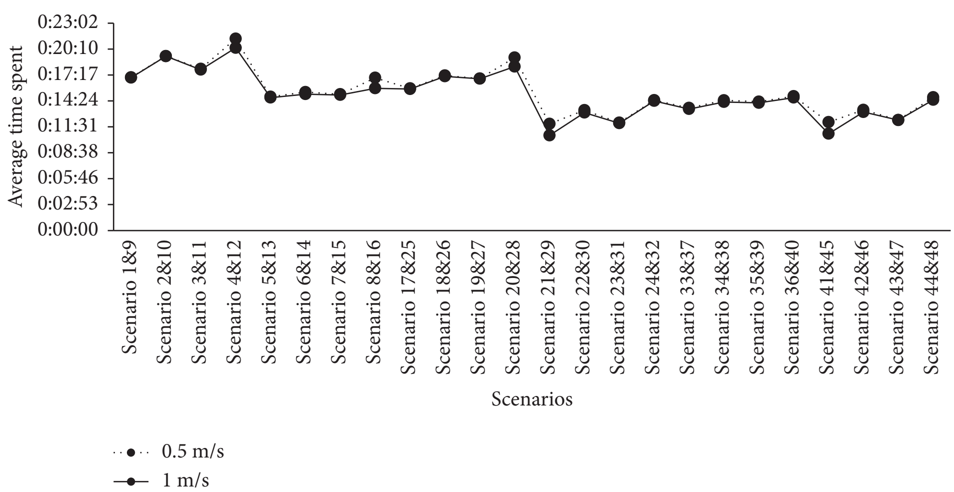


Figure 18: Average time spent for scenarios with two different conveyor belt speeds.

baggage carousel capacity at Incheon International Airport that accounts for expansion costs and passenger benefits. Construction and conveyor costs were applied to expansion costs and increased capacity benefits for passengers by reducing waiting time [8]. Yan and Shi investigated the issue of the airport terminal's passenger baggage turntable. They demonstrated the feasibility of the simulated annealing algorithm distribution method by improving the assignment model, designing simulated annealing algorithm steps to solve the objective function, and analyzing the original distribution method with examples. The comparison of the obtained results to the results of the first-come, first-served distribution method demonstrates that the simulated annealing algorithm outperforms the first-come, first-served distribution method and meets the target requirements. It provided a solution to the airport baggage claim carousel allocation problem as well as a feasible method of utilizing efficiency [18]. Stimac et al. demonstrated that using the described new model, the Airport Management Strategy Software (AMSS) application provides airport management with more accurate data and reports regarding airport infrastructure capacity and operations when negotiating with airlines than their own negotiation team can provide based solely on simplified analyses and experiences. The application was validated at Zagreb Airport, which saw 3.4 million passengers pass through in 2019. The goal of this approach was to precisely determine the potential free capacity of an airport's infrastructure and operations, as well as the aircraft that can be added to increase and maximize the airport's efficiency by maintaining an adequate level of service and conducting airport business without causing any delays [19]. However, recent studies have shown that agent-based models can be used as a proactive alternative in airport planning, operations, and commercialization strategies. By introducing some scenarios, Verma et al. proposed and developed an agent-based simulation model for departure flow at Kempegowda International Airport in Bangalore to understand and predict the impact of various proposed policies aimed at improving the airport system's throughput [5]. The investigation of the characteristics affecting baggage claim areas using the agent-based approach is the research's innovation. This research sought to distinguish both passenger and baggage claim characteristics that influence the level of service those passengers perceive in the baggage claim area. We contribute to a better understanding of passenger behavior and experience in the baggage claim area of the airport terminal by modeling passengers' activities using an agent-based approach, which was not previously addressed in this manner.

4. Conclusion

Today, the high growth of air travelers plays a significant role in transportation. In this research, 48 models were created using AnyLogic software. Then, the time spent, and the percentage of LOSs was obtained according to Correia's research [17]. Finally, by analyzing the results and comparing them with each other, the following results were obtained:

(i) By changing the design of the carousels to oval and increasing its circumference by up to 10%, the time spent in the baggage claim area will be reduced by an average of 4 minutes and 4 seconds, and the level of service will increase by 22.52%

(ii) Among the considered parameters, the speed of the conveyor belt had the least impact on the results among other parameters by an average of 0.96% in terms of normalized LOS and 19 seconds in terms of the average time spent. Also, a 20% increase in the conveyor belt environment, arrival traffic, passenger walking speed, and passenger bags had the greatest impact on the level of service with an average of 18.36%, 7.49%, 5.27%, and 2.36%, respectively.

(iii) Except for the 20% increase in the conveyor belt environment, which reduced the average time spent in the baggage claim area by 3 minutes and 54 seconds, the rest of the characteristics changed this time by less than 2 minutes.

In general, according to the study and the results obtained, it is suggested that for future studies, the level of service in terms of occupied space and delivery counter per person, as well as other parameters such as percentage of passengers in groups, dimensions, and weight of bags, other designs with different environments for carousels, etc., can also be considered.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Supplementary Materials

The characteristics of each scenario and the differences in the normalized level of service values and the average time spent in the scenarios in case of changing each characteristic are provided in the supplementary file. (*Supplementary Materials*)

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