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Original Article

THE DECISION SUPPORT FACILITATING THE CHECK-IN SERVICE AT THE CHOPIN AIRPORT WITH THE USE OF COMPUTATIONAL EXPERIMENTS IN *SIMIO*

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Highlights:
- several scenarios for improving the passenger service process were presented;
- models were built and implemented in a simulation program;
- simulation results showing the benefits of modifying passenger schedules were presented;
- a comparison was made with the level of passenger service defined by IATA;
- conclusions were presented that may be valuable in the modernization of the passenger and baggage handling process.

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Abstract. Airlines strive to minimize the waiting time for passenger service at the airport. Modification of the passenger service process at check-in stands can be carried out by modelling and then simulating various scenarios in order to obtain time benefits. The organization of service for departing passengers is the most complex system, which includes numerous maintenance activities aimed at preparing them and their luggage for transport by aircraft. Therefore, this article aims to present a few scenarios to improve the passenger service process. Based on the research, assumptions were made for each check-in scenario. Then, the models were implemented in the SIMIO simulation program. In the next step, the passenger distribution for individual desks was modified and a comparison was made with the level of passenger service defined by International Air Transport Association (IATA). The simulation results for individual scenarios are presented and the benefits to be achieved after introducing the proposed changes are indicated. The simulations carried out showed 2 important elements in the current and proposed layout of the ticket and luggage service stations and the introduction of changes to the baggage desks. Article presents the specification of the time spent in the system and waiting in the queue. The conducted analyses have shown that the proposed concept will allow for taking over 40% of passengers using the adjacent Fast Bag Drop (FBD) stands. Research has shown that adding more machines for use will fully cover the demand for FBD. The conclusions presented in the article are valuable when introducing modernization of the passenger and baggage handling process. For future researches, it would be beneficial to test other simulation tools and other scenarios to compare these results with those presented in this article.

Keywords: SIMIO, check-in service, self-service baggage drop-off machine, level of service at airports, modelling, simulation.

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Notations

BD – bag drop;
CR – crew;
EC – economy class;
FBD – fast BD;
FC – family check-in;
IATA – International Air Transport Association;
ID – identity document;
NS–NS – non-Schengen–non-Schengen;
NS–S – non-Schengen–Schengen;
PRM – passengers with reduced mobility;
SA – special assistance;
SBD – self-BD;
SC – self-check-in;
SSK – self-service kiosk;
ST – self-tagged BD;
S–NS – Schengen–non-Schengen;
S–S – Schengen–Schengen.

Introduction

The process of ground handling of aircraft and passengers has been analysed in many interesting scientific publications. The period of the pandemic caused a temporary collapse of the aviation market, but the forecasts of air traffic are optimistic. The issues of passenger service, airport efficiency and air transport safety are still important. Modern technologies are implemented in air transport, increasing the safety and efficiency of ground handling processes, taking into account, inter alia, use of UAVs (Hrúz *et al.* 2021). Such caveats may be used during the ground handling of aircraft. In airport terminals, to handle passengers, modern devices are also used to shorten the service at the check-in desk.

Check-in service is the first stage of passenger service, requiring necessary pre-flight activities to be completed within a specified time frame. Today, airlines are looking to reduce check-in processing times, as well as to minimize waiting times for service (Araujo, Repolho 2015; Bruno, Genovese 2010). This requires the introduction of new technologies, but also the proper management of the process and equipment to minimize the duration of the process (ACI 2001). The process of handling a departing passenger begins in the terminal at the check-in desk and check-in can be done in the traditional way, at a SSK or online. The process of service an arriving passenger depends on the infrastructure of the airport, as they can either head to the terminal on their own or be transported by bus. Travelers traveling from Schengen countries are not subject to document control. When they arrive at the terminal, they can go to the baggage claim hall. Passengers arriving from non-Schengen countries are directed to document control (Figure 1) (WCA 2021).

A transfer passenger begins a journey on one aircraft and continues it on another aircraft. In order to streamline the service, separate passageways are separated for Schengen and non-Schengen passengers (Figure 1). Due to the direction from which the transfer passenger arrived, we can distinguish the following types of transfer (WCA 2021):

- S–S;
- S–NS;
- NS–S;
- NS–NS.

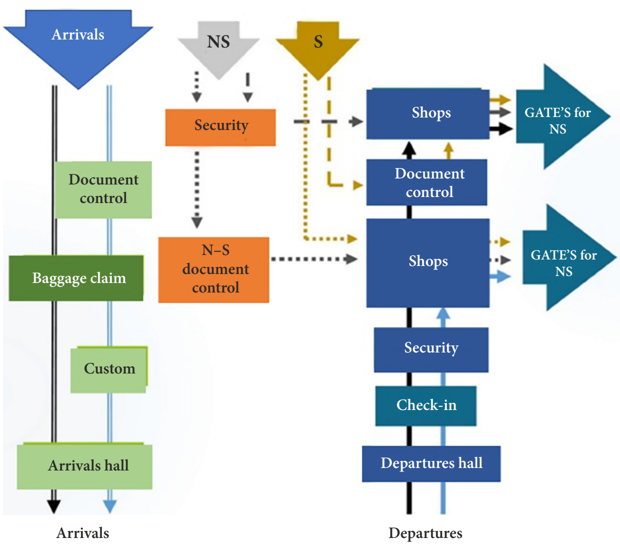

Figure 1. Arrival, transfer and departure passenger path

The above types of transfers take place at Schengen airports. The S–S transfer is, in terms of steps, the easiest passenger transition between planes, as the passenger only needs to check the information board and then proceed to the destination gate. The S–NS transfer differs from the S–S transfer in that after exiting the terminal, passengers must go to passport control and then head to the appropriate destination and flight number. NS–S transfer consists of 2 stages. After disembarking from the aircraft, passengers are taken by airport bus from a position away from the terminal or enter the terminal by a passenger gangway from the aircraft, then proceed to identity document control.

An important stage of passenger service is security control, which is compulsory for both travellers and employees heading to the restricted area of the airport (Skorupski, Uchroński 2019). The control of passengers and hand baggage is carried out by means of a metal detecting gate or manually (Skorupski, Uchroński 2018). When a passenger randomly actuates the gate, they are checked for the presence of gunpowder on himself and his personal belongings. Carry-on baggage is placed on a conveyor belt that passes through an X-ray inspection machine. If any kind of prohibited items are detected during the inspection, they are first taken away from the passenger, then the staff decides whether or not the passenger can continue to travel.

1. Check-in process analysis

The organization of departing passenger service is the most complex system. Departing passengers who enter the airport perimeter go through numerous handling activities to prepare themselves and their baggage for transport by aircraft (Bevilacqua, Ciarapica 2010). Passengers taking the flight head to the check-in desk. There are 2 types of passenger check-in:

- *common check-in*: it is a common check-in for all destinations of a given airline, the desks are open during the service hours of the carrier's flights and the passenger can check-in at any time,
- *destination check-in*: opened a certain number of hours before departure.

Depending on the size of the airline and the agreement with the airport operator, carriers have a set number of check-in desks available to travellers and these may be as follows:

- desks for EC;
- desks for business class or loyalty card holders;
- FC desks;
- desks for passengers requiring special care, known as PRM.

At the check-in desks, travellers' IDs, visas (if required) and e-ticket or booking confirmations are checked. Next, the passenger checks in their baggage, the handling agent hangs a tag on it, and then the baggage is sent to the sorting office, from where it is transported to the aircraft. In addition, a boarding pass will be issued to the passenger, entitling them to go to the restricted area of the airport and to use the duty-free stores. If the passenger is traveling with carry-on baggage only, they may bring it with them on the plane. Both those who travel with carry-on baggage only and those who leave their checked baggage at the check-in desk later can use the so-called online check-in. Using the carrier's mobile app or website, the passenger fills out a form with their booking number and name. Once the check-in is approved by the carrier, a link with the boarding pass for the flight arrives via email or text message (Kwasiborska 2016). It can be printed out or saved on the phone. If a person has checked baggage to be checked in, upon arrival at the terminal, they should go to the "Drop-off" desk to check in the baggage (Kierzkowski, Kisiel 2018; Kierzkowski *et al.* 2019). The automated check-in system sends a message to your cell phone or email address with an attachment containing your boarding pass. For status passengers and those travelling in the highest class, such check-in is active all the time, while passengers not belonging to any frequent flyer program should request such a check-in when booking a ticket. Passengers who are traveling with carry-on baggage have the option of using SC kiosks for their flight. Among SC, 2 types of desks can be distinguished:

- *dedicated*: the owner of such a kiosk is a specific airline and only persons using the services of that carrier may check-in at that desk;
- *common use self-services*: these are SSKs that check in passengers from different airlines, regardless of the Departure Control System used.

Those checked in at such a machine, provided they are traveling with carry-on baggage only, can go directly to security control. Using SSKs helps minimize queuing time, e.g., during the departure wave when many passengers want to drop-off their checked baggage. Figure 2 shows an example diagram mapping the layout of the various desks to which individuals from the passenger groups can report:

- FC: dedicated for passengers traveling with children under 12 years of age, as well as parents with children who will be traveling under the care of the carrier;
- SA: people with mobility problems requiring assistance (PRM), elderly, disabled, travellers with animals or guide dogs, and requiring emotional support;
- CR: flight crew members, airline employees, and those authorized to use employee tickets may report here;
- EC: any passenger traveling in EC without need of prior check-in;
- FBD: passengers who already have a boarding pass and wish to check in their checked baggage; in practice, however, any passenger with checked baggage can apply here);
- ST: checked-in passengers who have self-printed a hang tag at the SSK who want to drop-off their baggage go to this exact desk;
- SC: people traveling with carry-on baggage only, checking in or who are already checked in, self checking-in their baggage.

Passenger departure waves during the day (morning, midday, afternoon and evening) mean that queues can form in the check-in area. SC desks minimize these queues, but are usually dedicated to travellers with only carry-on baggage, as well as for travellers who want to check in their checked baggage on their own. Passengers should go through the following steps to check in their checked baggage on their own:

- *check-in at a SSK or online*: – the traveller has a boarding pass for the selected flight;
- *print a baggage tag at the SSK*: by scanning the boarding pass received online, or by continuing to check-in at the kiosk;
- *approach ST desks*: an employee scans the tag printed by the passenger, tags the bag, weighs it, and then sends the bag via conveyor belt to the sorting facility.

These stages show that checking in checked baggage requires the passenger to wait in at least one queue, which is the queue at the baggage drop-off desks. In addition, there is one employee dedicated to each of the desks, even though the idea is to check-in baggage on your own. In addition, it sometimes happens that a passenger accidentally prints out a baggage tag with no intention of checking the baggage in and the tag is abandoned or thrown in the trash, while still being entered into the system. At that point, the baggage and passenger correlation procedure is aborted. This procedure allows for providing indirect security related to, for example, baggage that will not fly without its owner.

Streamlining the desk described above would not only save the time passengers spend waiting in line, but also the number of staff that could sit at other desks. During the simulations performed in SIMIO (*https://www.simio.com*) software, the authors propose to introduce machines for SC of checked baggage: SBD machine instead of ST desks. It is used in many airports both in Europe and around the world, such as Amsterdam, Munich, or Frankfurt, Dublin and Tokyo. The change involving these desks would include eliminating the ST positions and replacing them with 2 SBD machines. The proposed desk distribution is shown in Figure 3.

The new stations can be placed in place of the ST desks making it easier for passengers to arrive directly after checking in at the SC. Changing the equipment of baggage check-in desks is economically beneficial for the airline (instead of a dedicated employee for each of the desks, one person can be designated to help with their operation), and such a solution is convenient for passengers by minimizing the time spent in the airport terminal.

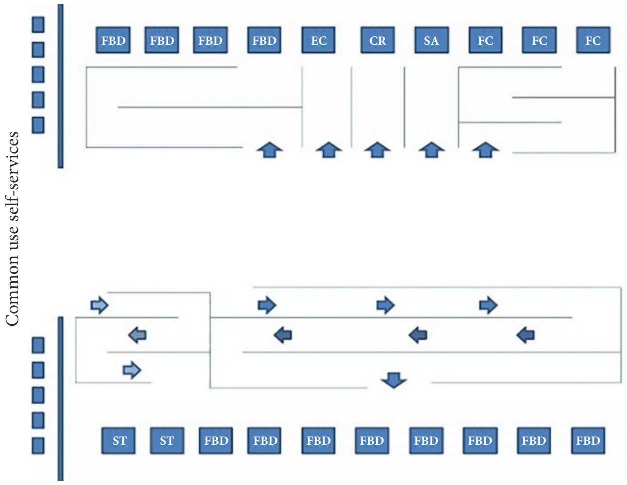

Figure 2. Example of check-in service desk layout (source: *own elaboration*)

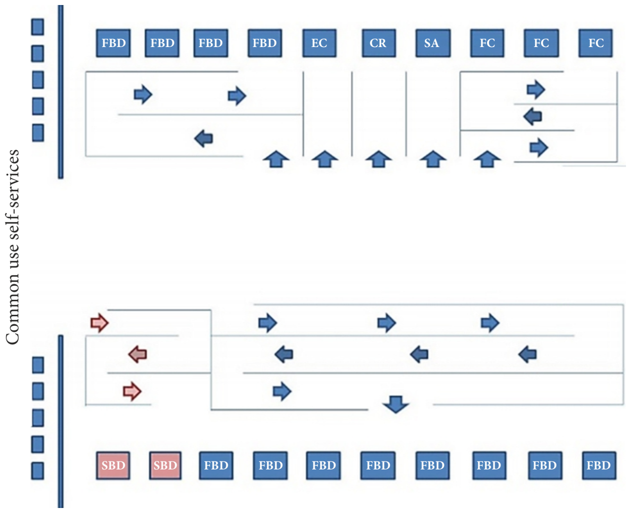

Figure 3. The concept of changing the stand-alone baggage check-in desks

2. Evaluation of the concept based on simulation studies conducted

The authors assumed 3 scenarios that were modelled in SIMIO and simulated (Kwasiborska, Postół 2021). Upgrading the desks and testing their usability considered the following assumptions:

- setting up check-in desks and SSKs;
- replacing ST desks with SBD machines;
- addition of 2 SBD machines.

The scenarios and the layout of each desk were mapped including: FC, SA, CR, and EC. During the tests and simulations performed, the stability of the system was verified and the time passengers would spend waiting for check-in service or using SSKs and modified machines was estimated. The research problem was to check the stability of the aforementioned service desks, as well as the distribution of traffic between them and the neighbouring desks – FBD off. The parameter that characterizes the stability of the system is the traffic intensity ϱ (Erlang's constant). Traffic intensity is the ratio of the average number of requests that come into the system per unit of time to the average number of requests that can be handled per unit of time (Gosavi 2021). When $\varrho < 1$, the system remains stable, when $\varrho = 1$, the system is at the stability limit, and with $\varrho > 1$, the system remains unstable. This was used to compare with the requirements placed on carriers and airport managers by IATA (2016).

2.1. Parameters for execution of check-in service scenarios

The characteristics of each desk type include service times – minimum, average and maximum. Table 1 shows the check-in service times for the different passenger check-in methods.

In addition to service times, it was necessary to determine the frequency of passengers reporting in. The study was done with the assumption of a departure wave beginning at 16:00. The first passengers showed up at the airport up to 3 h before the planes were scheduled to depart (e.g., long-haul flight participants), so a time slot of 13:00...18:00 was included. Passengers present at check-in around 13:00 may also be passengers on flights around 15:00. Therefore, a sample flight schedule was generated based on the current schedule along with the flight occupancy. The operation of 51 flights divided into Schengen – 25 flights, and non-Schengen – 13 flights, and domestic flights was accepted. Based on aircraft capacity (from 70-seat Bombardier Q400s, to 70-seat Embraer's (E70, E75, E90, E95), 170-seat Boeing 737-800s, to wide-body Boeing 787-8/9s accommodating up to 295 passengers), the number of passengers to be served at check-in was estimated at 5375. A 50% share of transfer passengers using the listed flights was assumed. As a result, there were 2687 people using check-in assumed. 10% of status passengers, i.e., those travelling in Business Class, Premium Class or holders of Star Alliance Gold Loyalty Cards, have been assumed. Additionally, based on observation, it was found that the peak check-in time occurs between 13:00 and 14:00. Slightly fewer people are checked in between 14:00 and 15:00. From 15:00 to 16:00, check-in is mainly used by people traveling around 17:00, so the departure wave in the check-in area calms down during this time. When the data on departing passengers was collected, the vast majority already had boarding passes (68%) i.e., that they use early check-in for their flight. The sample surveyed indicated that 45% of passengers have checked baggage, while 55% travel with carry-on baggage only. The percentage distribution of passengers using each check-in desk is an important element. Among the most popular was FBD, both among passengers traveling with checked and carry-on baggage. In addition, SSKs are popular, not only among travellers without baggage but also among those for whom quick and self-service check-in is a priority (using ST desks). Depending on the type of passengers (those traveling with children as well as those requiring special care), the interest in using dedicated desks decreases (Figure 4).

Assuming an aircraft fill rate of 80...90%, a schedule was generated supplemented with the assumed number of passengers.

Table 1. Passenger service times at individual check-in desks

Desk	Minimum time [s]	Average time [s]	Maximum time [s]
FBD	50	118	183
ST	7	16	128
SC	30	83	194
SBD	30	60	105
Staff	51	122	193
SA	60	142	224
EC	57	129	201
FC	58	132	198

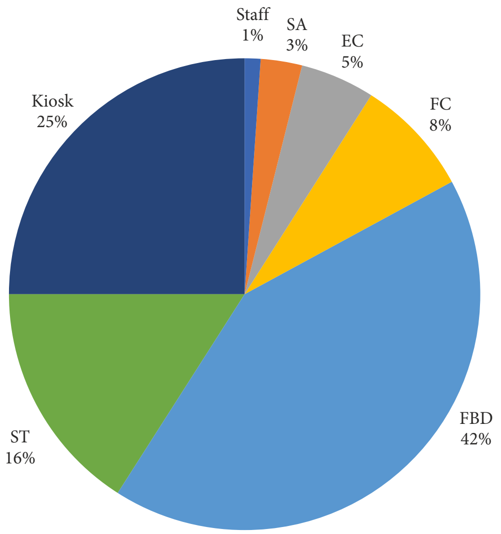

Figure 4. Percentage distribution of passengers using particular check-in desks

2.2. Implementation of the model in the SIMIO simulation software

3 scenarios for which the research was conducted were adopted. The Scenario 1 reflected the current setup of service desks. The Scenario 2 was to replace the ST positions with 2 SBD positions. The Scenario 3 was to set up 2 more SBD machines. System stability tests were carried-out, the time spent by passengers waiting for service was calculated. The time was compared with the requirements of IATA.

The data and assumed parameters allowed the execution of passenger handling scenarios in the SIMIO software. For the analysed airport, 3 scenario models were built, equipped with:

- traditional check-in desks;
- ST desks instead of SBD;
- 2 additional SBD machines.

2.2.1. Scenario 1

The Scenario 1 replicates the traditional airport check-in desk layout (Figure 5). The model built shows check-in desks, sample passenger movement routes, and the "source" and "outlet" of passengers generated by the program. Among the different types of passengers, there are several basic routes that passengers take:

- entrance – SSK – exit; passengers without boarding passes traveling with carry-on baggage only;
- entrance – exit; passengers already checked-in (e.g., via Internet) without checked baggage are also included;
- entrance – SSK – FBD – exit; people without boarding passes, checking in at the kiosk, then dropping off their luggage at the FBD desks;
- entrance – FBD – exit; those already holding a boarding pass with checked baggage to be dropped off at FBD desks;
- entrance – ST kiosk – exit; individuals printing their own baggage tag, proceeding to the fast checked BD desks;
- it was assumed that passengers using EC, SA, Staff and FC desks immediately after entering the terminal go directly to dedicated desks: entrance – EC/SA/Staff/FC desk – exit.

To implement the model, the following parameters were used: minimum, average and maximum passenger service times at each desk, approximate number of passengers, their percentage distribution along with the characteristics (having checked baggage or boarding pass). For the simulation of arriving passengers, their minimum, average, and maximum speed of moving through the terminal, the average number of units arriving at one time were determined. Simulations of the request processing from 13:00 to 18:00 were performed. Based on the reports generated in the software, a summary (Table 2) of the times of each desk type was created, along with the minimum, average, and maximum time spent in the system and waiting in the queue, and the system stability factor ϱ.

The simulation indicated that during the departure wave, 3 desks (EC, SA and Staff) are at the limit of stability, while the remaining desks are stable. The maximum time spent in the system does not exceed 5 min. When cumulating the times of using the self-service kiosk and ST, the maximum time slightly exceeds 5 min. Considering the average waiting times in the queue, the highest time is characterized by the EC desk, which is chosen by a large number of people, mainly due to the lack of awareness that service at this desk will definitely increase the waiting time in the service queue.

2.2.2. Scenario 2

The Scenario 2 replicates a station layout improved by replacing the ST with SBD machines (Figure 6).

The Scenario 2 differs with the times in operating the upgraded SBD desk. 2 of the passenger route were modified:

- *a route was added*: entrance – SBD – exit; SBD desk only requires a boarding pass;
- *route*: entrance – kiosk – (ST) SBD – exit, was changed due to machine replacement.

The departure wave simulation was carried out during the same hours as Scenario 1. An analogous table was created showing the results from the reports generated in the software (Table 3).

The summary shows that, as in Scenario 1, EC, SA, and Staff desks are at the limit of stability, while the remaining desks are within system stability limits. The maximum system dwell times again are approximately 5 min. It is

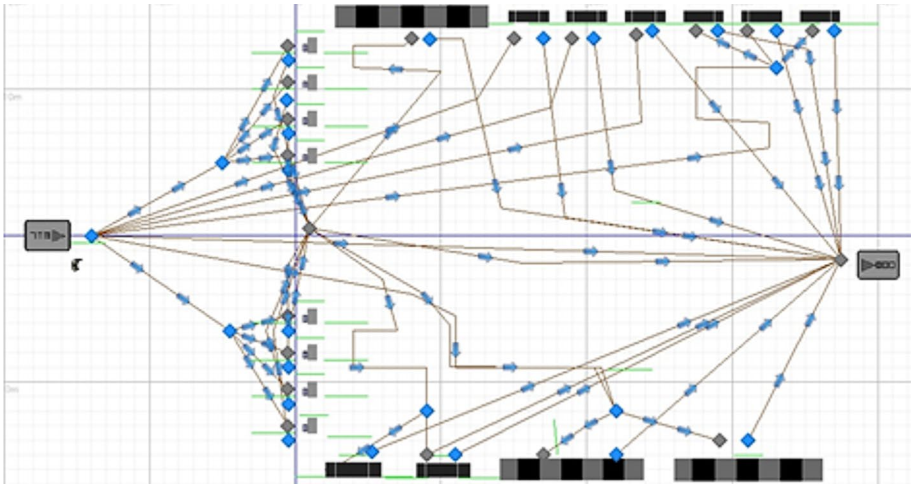

Figure 5. Traditional check-in desk layout in the SIMIO software

Table 2. Summary of time spent in the system and waiting in the queue

Desk	Minimal time in system [min:s]	Mean time in system [min:s]	Maximal time in system [min:s]	Minimal waiting in the queue [min:s]	Mean waiting time in queue [min:s]	Maximal waiting time in queue [min:s]
FBD	0:57	1:56	3:00	0:00	2:46	4:57
ST	0:37	1:06	1:46	0:00	0:11	1:34
SC	0:47	1:47	2:50	0:00	0:08	1:15
FC	1:15	2:11	3:07	0:00	2:06	8:34
EC	1:06	2:13	3:13	0:00	12:28	24:44
SA	1:01	2:19	3:40	0:00	4:41	10:31
Staff	0:54	2:03	2:55	0:00	0:38	3:16

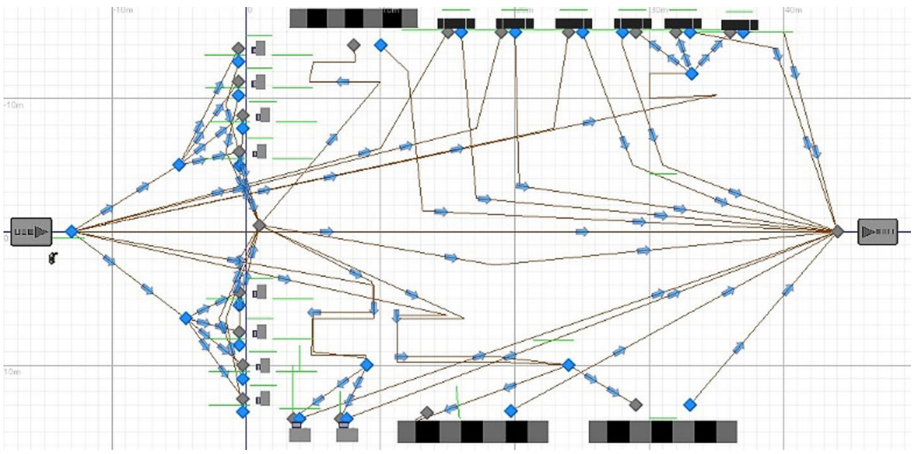

Figure 6. Layout of desks upgraded with SBD machines

Table 3. Summary of time spent in the system and waiting in the queue for Scenario 2

Desk	Minimal time in system [min:s]	Mean time in system [min:s]	Maximal time in system [min:s]	Minimal waiting in the queue [min:s]	Mean waiting time in queue [min:s]	Maximal waiting time in queue [min:s]
FBD	0:56	1:58	2:58	0:00	5:24	9:23
SBD	0:33	1:08	1:47	0:00	1:04	6:37
SC	0:45	1:39	2:41	0:00	1:04	2:42
FC	1:05	2:08	3:02	0:00	1:17	8:07
EC	1:07	2:10	3:14	0:00	10:26	22:16
SA	1:08	2:24	3:42	0:00	5:35	13:43
Staff	1:10	2:05	3:06	0:00	0:18	2:42

significant that for passengers with boarding passes who wish to drop their luggage off independently, the time is under 3 min. Average queue times for each desk average between 1 and 10 min for the EC desk. In addition, passengers using the SA need to be patient while waiting for service, as passenger service time at this desk is slightly longer than usual due to its specifics.

2.2.3. Scenario 3

In the Scenario 3, 2 SBD machines were added (Figure 7).

The parameters used in the simulation of this model are also identical to the previous Scenario 2. Table 4 contains data relevant to further analysis.

Table 4 indicates that the average times in the system are similar to those of Scenario 2, while among the average queuing times, a significant difference can be observed for the SBD machines. The average queuing time dropped to 11 s, where it was more than 1.5 min in the previous case. Stabilities of all desks are quite similar, being stable or borderline stable.

2.3. Modification of passenger distribution at individual service desks at the rush hour

Passenger traffic during the rush hour (13:00…14:00) is characterized by the highest frequency (more than 800 passengers), resulting in long queues of passengers waiting for service. Therefore, the stability of the system will be most at risk during this time frame. The simulation performed was to estimate the impact of moving some passengers from FBD to SBD desks. The results obtained were compared to passenger service levels published by IATA. IATA has set the following optimum service desk queue times:

- self-service boarding pass/tagging desk or SBD: 0… 2 min;
- BD or FBD desks: 0…5 min;
- check-in desk or EC: 10…20 min.

The analysis was performed for the assumed scenarios. Table 5 shows the simulation results of Scenario 2 at 13:00…14:00 considering eight of the twelve FBD desks.

Table 5 indicates that the queuing time for SBD is within the IATA guidelines for initial traffic only. When some traffic is moved, the queue times become far too long. The waiting time for FBD desks is also too long in most scenarios considered – the waiting time is almost twice as long as suggested.

An analogous simulation was performed for Scenario 3. During the same time frame, 8 FBD and 4 SBD desks were analysed (2 more were added). Queue times for each were then compared to IATA requirements. Table 6 shows the results of the studies conducted for Scenario 3 for various passenger traffic alternatives.

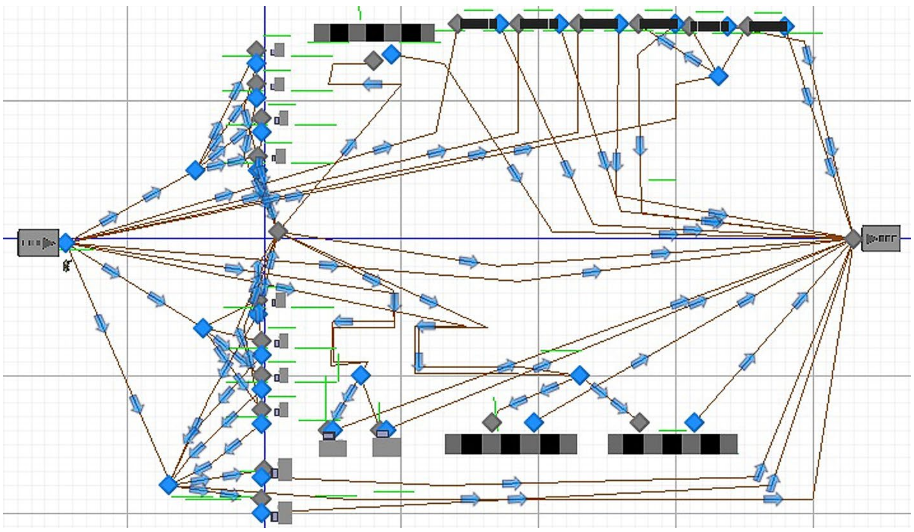

Figure 7. Layout of desks upgraded with 2 additional SBD machines

Table 4. Summary of time spent in the system and waiting in the queue for Scenario 3

Desk	Minimal time in system [min:s]	Mean time in system [min:s]	Maximal time in system [min:s]	Minimal waiting in the queue [min:s]	Mean waiting time in queue [min:s]	Maximal waiting time in queue [min:s]
FBD	0:57	1:56	3:00	0:00	2:46	4:57
SBD	0:37	1:06	1:46	0:00	0:11	1:34
SC	0:47	1:47	2:50	0:00	0:08	1:15
FC	1:15	2:11	3:07	0:00	2:06	8:34
EC	1:06	2:13	3:13	0:00	12:28	24:44
SA	1:01	2:19	3:40	0:00	4:41	10:31
Staff	0:54	2:03	2:55	0:00	0:38	3:16

Table 5. Passenger traffic simulation results for Scenario 2, 13:00…14:00

Desk	Mean rate of arrival | mean service rate [passengers]	ρ	Mean waiting time in the queue [min:s]
Initial traffic			
FBD	245|237	0.129	8:29
SBD	77|77	0.500	1:26
Moving 50% of traffic			
FBD	131|131	0.125	4:24
SBD	187|115	0.866	11:32
Moving 25% of traffic			
FBD	185|185	0.125	5:53
SBD	138|111	0.621	5:51
Moving 5% of traffic			
FBD	232|229	0.127	6:58
SBD	92|92	0.500	2:47

Table 6. Passenger traffic simulation results for Scenario 3, 13:00…14:00

Desk	Mean rate of arrival | mean service rate [passengers]	ρ	Mean waiting time in the queue [min:s]
Initial traffic			
FBD	241|233	0.129	8:18
SBD	86|86	0.250	0:35
Moving all of traffic			
FBD	0|0	0.000	0:00
SBD	346|213	0.406	11:45
Moving 50% of traffic			
FBD	143|143	0.125	4:10
SBD	184|184	0.250	4:16
Moving 30% of traffic			
FBD	175|175	0.125	4:39
SBD	159|159	0.250	1:47

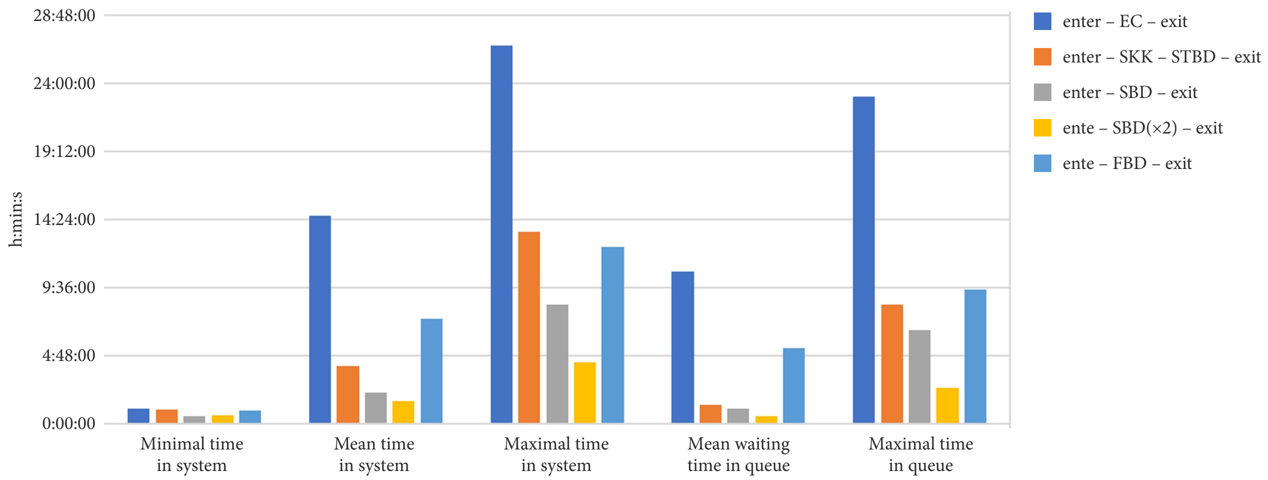

Figure 8. The diagram of the comparison time

The analysis of the initially adopted traffic showed that for the 2 SBD desks, the queuing time for these desks is within the guidelines proposed by IATA. The queuing time for FBD desks is long again. Due to the doubling of the number of SBD devices, the simulation of the passenger schedule change began by moving all traffic from the FBD desks to the SBD desks mentioned above. This traffic was then reduced in search of a common consensus on queue wait times by obtaining queue wait times that fall within the ranges defined by IATA.

2.4. Analysis of results obtained

The simulations conducted have shown several aspects related to the characteristics of the introduction of SBD desks as well as the current FBD desks. Taking into account the dwell time in the system (this is the time from the passenger arriving to leaving, i.e., completing the check-in process) for the entire departure wave, the introduction of SBD desks in place of ST desks allows to save this time, despite the fact that the time of waiting in queues is similar. The time comparison is shown in the diagram (Figure 8).

Replacing the ST desks would not only result in a reduction in passenger dwell time in the system, but also there would be no need to wait in 2 queues (to the SSK to print a bag tag and to the ST desk where an employee would drop-off the passenger's baggage). Waiting in 2 queues would not be a necessity, in case the passenger already had a boarding pass. Otherwise, they would have to go to a SSK to print their boarding pass.

SBD stations could be an interesting alternative for those using FBD – the average service time at SBD is almost double that of FBD. Moreover, the waiting time in queues is also shorter. Considering the most passenger-loaded hour of the departure wave: 13:00...14:00, even with the heaviest load on the SBD machines, as well as the FBD desks, the systems remain stable. Therefore, the attempt to change the distribution of passengers at these desks had the objective of checking the waiting time in the queue. At the same time, a distribution of passengers was proposed in view of IATA's requirements for an optimal level of service at check-in desks – in this case, queuing time was taken into account. If the ST desks were replaced with exactly 2 SBD units, the queue time at the FBD desks would be higher than IATA assumed. Simulations showed that moving about 5% of the traffic from the FBD desks to the SBD desk would provide slightly shorter queue times (less than 7 min), and for the SBD, the time would be less than 3 min – both of which would be slightly longer than IATA is proposing. The addition of 2 more SBD devices would not initially result in significant changes – queue times at the FBD desk would look the same as with 2 SBD devices. Wait times at SBD desks would be reduced by 2 times. Moving 30% of passenger traffic from the FBD desks would establish queue times, both at this desk and at the SBD, within the standards given by IATA.

Conclusions

Providing passengers with safe and fast service is a priority for both carriers and airport managers. Modifying the service desks to improve ticket and baggage handling will not only make it easier for travellers to use the new facilities, but will streamline the entire process. Moreover, travellers will spend less time in queues, which will contribute to less time spent in the check-in area. The replacement of ST desks with SBD devices may contribute to improved passenger comfort.

The simulations conducted showed 2 faces of the current layout of the baggage handling points as well as the proposed modifications: the direct replacement of the ST machines and the addition of 2 more machines of this type in the next scenario. The analysis created a specification of dwell and queue times and estimated the stability of the system. An important consideration is that the modified desks allow to save time if you go directly to the drop station. The study indicated that the new type of machines proposed for use could capture 40% of the passengers using the adjacent FBD desks. If 2 more machines are added for use, they could completely cover the demand for FBD. Increased traffic would involve longer waits in queues for machines. The conducted research will contribute to the improvement of passengers' comfort in the terminal area. The performed analyses may also be used to improve aircraft maintenance processes at parking spaces. A similar area was analysed in an article on the implementation of the Internet of Things (Mrňa *et al.* 2021), indicating that the implementation of the concept can speed up the passenger service process. Air carriers strive to automate the process of ticket and baggage handling and minimize the contact between the employee and the traveller. It also affects the economic part of airport operations, especially regional airports (Remencová, Novák Sedláčková 2021). In addition, the COVID-19 pandemic worsened the economic situation of airports; hence it is important to research the process of passenger service in order to rebuild the profitability of airports. Currently, air traffic is gradually increasing, the more the research on the passenger service process may be important in implementing the automation of the ticket and baggage handling process and organizing innovative passenger and baggage handling devices.

Author contributions

The authors confirm contribution to the article as follows:
- study conception and design: *Anna Kwasiborska* and *Sylwester Gładyś*;
- preparation of model in SIMIO analysis: *Izabela Kalbarczyk*;
- interpretation of results: *Izabela Kalbarczyk* and *Sylwester Gładyś*;
- draft manuscript preparation: *Anna Kwasiborska*.

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