Steering of passenger handling processes in an airport terminal

Dr.-Ing. Stefan Theiss *

German Aerospace Center (DLR), Institute of Air Transport and Airport Research

Abstract

The paper describes the development of a concept, which provides the possibility of monitoring and steering the handling processes in a Terminal. With the turnaround in mind, the punctual arrival of the passengers at the departure gate as higher level command variable is in focus. The developed concept with the associated methodology is demonstrated through the example of a simulation of defined scenarios. Beside the normal operation, typical irregularity situations are included in the development of the scenarios. Also, future development in the field of passenger handling is taken into account. Parameters will be prepared for the development of the concept and the associated methodology, which allow the evaluation of the status at the different handling stations. Afterwards, data values will be assigned in the form of a Level of Service (LOS). The Level of Service provides the evaluation based on the quality of the passenger handling. Based on that, the developed algorithm and the implementation in a steering tool are described.

Keywords: Airport; Terminal; Simulation; Passenger Handling, Passenger Processes

Résumé

L'article décrit le développement d'un concept, qui donne la possibilité de surveiller et de piloter les processus de traitement dans un terminal. Avec le temps de rotation à l'esprit, l'arrivée ponctuelle des passagers à la porte d'embarquement comme variable de commande de niveau supérieur est au point. Le concept développé avec la méthodologie associée est démontré sur l'exemple d'une simulation de scénarios définis. A côté de l'opération normale, les situations d'irrégularités typiques sont comprises dans de développement des scénarios. Le développement futur dans le domaine de l'assistance des passagers est également pris en compte. Les paramètres seront préparés pour le développement du concept et de la méthodologie associée, permettant l'évaluation de la situation dans les différentes stations de traitement. Ensuite, les valeurs de données seront attribuées sous la forme d'un niveau de service (Level of Service, LOS). Le Level of Service fournit l'évaluation fondée sur la qualité de l'assistance des passagers. Sur la base de la description de l'algorithme mis au point et de la mise en œuvre dans un outil de pilotage.

Mots-clés : aéroport ; terminal ; simulation ; assistance des passagers ; processus des passagers

* Tel.: +49-2203-40-4553
E-mail address: stefan.theiss@dlr.de.

1. Introduction

The increasing competition between airlines and the resulting price war leads to high pressure on the former to operate economically. One way to achieve this is to minimize the ground time aircraft spend at an airport (turnaround). The completion of the turnaround at the right time and, thus, a punctual departure, depends on the passenger arriving at the departure gate in time [Th09]. The arrival time of the passengers at the gate is affected by the movement through the terminal building and the handling at the process stations. In order to monitor ground handling processes on the apron, several tools (e.g. Allegro) and systems (e.g. Airport-CDM) were implemented. But as of now, no overall monitoring and steering of the passenger handling process is taking place in an airport terminal.
Particularly critical is the delayed arrival of passengers at the departure gate; the so-called "Late Passenger", as this affects the boarding and thus drastically affects the turnaround [Wu10]. Approximately five to eight percent of all aircraft delays are a result of passengers arriving late at the departure gate [Mc05, De09].
The introduction of new procedures and technology in the areas of passenger handling processes, passenger guidance, and control of terminal processes are becoming more important. Passenger guidance and related publication of information to passengers have a significant impact on comfort during the trip [No78, Ne03, Se91].
In the following proposal, the development of a concept is presented which provides the possibility to monitor and control handling processes in the terminal building. An important focus is placed on both the turnaround process and the punctual arrival of passengers at the departure gate as a higher level objective. For the presentation, the concept and the involved methodology simulations are used. The simulation is demonstrated for defined sample scenarios. During the development of scenarios, irregularities in terminal operations also play a role, in addition to regular operation. Functionality is demonstrated by an example of simulation within an airport terminal.
An important area with regards to the use of a simulation of the terminal processes is also to determine the effects that arise through the implementation of new developments in the field of passenger handling. The trend is characterized particularly by the increasing automation in the field of passenger handling [AC10, IA08, SI09].

2. Basics for steering of terminal processes

2.1. Evaluation of passenger handling processes

Starting point for development of the methodology is a concept whereby the punctual boarding of passengers requires their punctual appearance at the departure gate. Basically, the arrival of passengers at a certain point in the terminal depends on their time of arrival at the airport, plus the time they have spent in the terminal. The dwell time of passengers in an airport terminal is dependent on the required times of the individual processing stations, the relevant waiting time, and walking space.
The meaningful assessment of the actual status at the terminal concerning passenger handling is an essential basis for the steering of terminal processes. Basically, for the monitoring of passenger handling processes, the classic parameters from the field of planning an airport terminal building are offered. These are, for example [IA95, Co05, We03]

- Occupancy rate of areas for movement and waiting,
- Path length and walking time,
- Waiting time(s),
- Dwell time (processing- and waiting time) at handling stations.

Marking of the occupancy rate of areas within the terminal building is usually affected by the so-called Level of Service (LOS) [IA95]. This is the ratio of available space to the number of persons (m^2/PAX). In this context, the use of this occupancy rate for the steering of the terminal processes is inappropriate. The level of service reflects the comfort during movement, and the time spent in terminal areas or handling facilities. Hence, no direct conclusion for the flow of passengers, or for the derivation of steering decisions, is possible. Instead, a parameter which takes into account the dwell time of passengers in the terminal or on certain terminal facilities is needed. This evaluation includes the so-called 'throughput' time as a possibility.

The determination of this throughput time is done as a static parameter, so it represents the Minimum Throughput Time (MTT). This consists of processing times, and the minimum walking time, which results from minimum sidewalk length and assumed walking speed. Through the use of simulations, the waiting time and delays due to interaction of people during their movement can be taken into account. Therefore, it is possible to determine the Estimated Throughput Time (ETT) as a dynamic parameter.
For the evaluation and steering of terminal processes, the waiting time has the advantage that it is already used as a parameter for the assessment of handling processes and so already established. In addition to this, there are existing documents and works (e.g. IATA) [IA95, Pa99, Mu86] that define certain quality parameters (as Level of Service), based on the waiting time and the specific process or handling station.

2.2. Evaluation of passenger handling processes

With regards to the development of a concept as support for steering of terminal processes, the structuring of the controllable parameters is necessary. This is important for defining the framework to be taken for the steering decisions. A distinction is made between so-called passive and active parameters. The passive parameters are not controllable short-term or in the context of a possible operational steering. They include, for example:

- Layout of the terminal properties
- Number of (total) available counters / lanes at process stations
- Number of departure gates
- Flight plan (including possible deviations)
- Passenger properties (Flight type, arrival characteristics et cetera)
- Passenger handling guidelines (security, airlines)

In addition, there is the group of active factors that are changeable and therefore can be taken into account as possible steering parameters during operations. They include, for example:

- Handling concept (Common / Per-Flight)
- Number of opened counters / lanes
- Handling / process times
- Available staff / period for allocation
- Assignment of passenger to resources of a process station
- Passenger guidance

It should be noted that not all active parameters can be changed during operations in terms of a steering decision. This includes, for instance, the handling concept. There is the theoretical possibility of changes, but these are only partially recognizable in practice. In addition, the area for changing active factors is partly limited by the passive parameter. For example, it could be the number of possible counters that can be opened at a process station. It is only possible to open a maximum number of counters that are actually available as part of the infrastructure within the terminal building.

3. Concept for steering terminal processes

After definition of the frame in which steering of terminal processes is possible, the concept will be carried out. Initially, it concerns the determination of situations in which a steering is necessary. Thereby the higher level objective, according to the problem definition, is arrival of the passengers at the departure gate. Solely based on this information, it is not possible to determine at which point the delay will be caused, and thus the approach where steering is possible. For this reason, an evaluation scale has been developed which allows for identification of critical elements in terminal operations. In addition, the evaluation based on those parameters is not only the detection of the critical point, but also a starting point for the development of steering decisions in the area of terminal processes.
The development methodology is based on waiting or dwell-times at terminal facilities. The dwell time corresponds to the throughput time of a handling facility. It consists of process time and possible waiting time. Analogous to the area-based level of service, a classification of these times is possible in terms of preferred quality criteria. By defining time limits for the preferred quality with regard to waiting or dwell-times, a methodology can be developed for evaluating the handling processes, as well as the determination of steering decisions.

In order to implement this methodology in the context of a concept for steering of terminal processes, the collection of these parameters in the terminal building is necessary. An important problem in the implementation of technologies that allow a continuous determination of the position of passengers in the terminal building, and the status during the handling process, is the issue of protection of data privacy. The administration is different in each country. While such technologies are already in use in the UK, an implementation in Germany appears unlikely due to data privacy reasons [Kl09].
Because of these data privacy concerns, the comprehensive use of technologies for collecting individual personal information cannot be expected in Europe. However, there is the opportunity to use technology for the collection of information in an anonymous form.
As a starting point, a system that is based on the determination of the number of people (anonymously) in a waiting area would be preferred. For example, by analysis of camera images, the number of people in a terminal area (e.g. waiting area before check-in) is derived. Based on this information, we the so-called Estimated Waiting Time (EWT) must be determined depending on

- the number of waiting passengers,
- the number of open counters/lanes and
- the process time

for the relevant handling facility. This value applies to the person who lines up at the end of the queue at that moment, under the condition that the number of open counters/lanes remains constant during the entire waiting period.
The use of this method is fundamentally independent from the type and design of the waiting area, as well as the line-up of the waiting passengers. Since only the number of waiting passengers is of interest, it is irrelevant whether the people are waiting in queues or unordered [Fr87]. In the field of passenger handling in an airport terminal, it is assumed that an ordered line-up of passengers in the form of queues is taking place. As basis for the steering program, a single queue is provided (see Figure 1). The single queue offers the benefit of grouping of people waiting for a larger number of service counters, and therefore of elements for steering decisions.

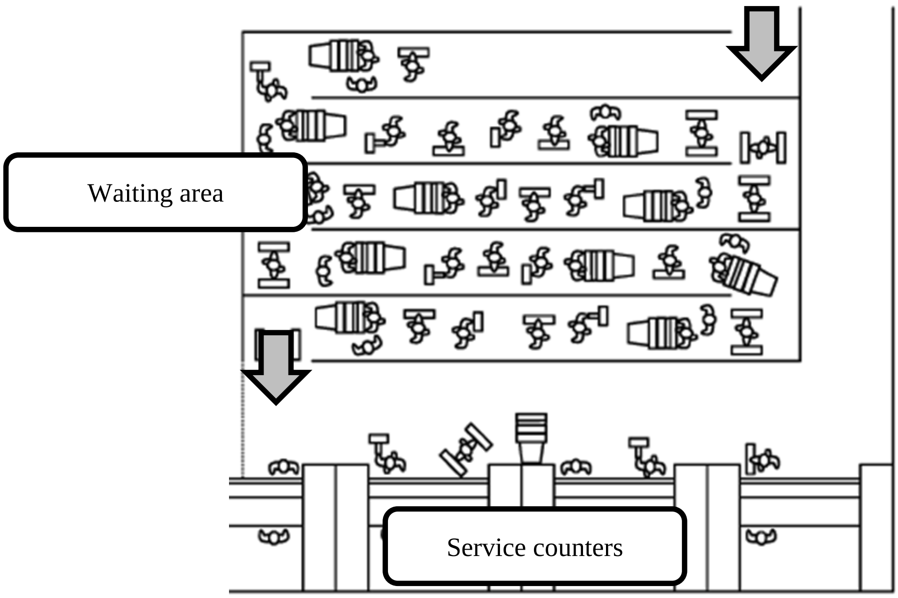

Fig. 1 Single Queue using the example of Check-In [IA95]

The control of the handling processes is carried out over predetermined quality levels in relation to the targeted range of the waiting time of the passengers. In order to establish quality parameters for waiting times, the level of service concept is also used. The high acceptance of classic levels of service (occupancy rate) is based on the availability of generalities values. These have, depending on the handling facility, different values [IA95]. The use of different values is related to the function of the terminal area, such as movement areas, waiting areas or dwell areas. This kind of differentiation can also be found in the Level of Service for waiting times. One

difference, however, is that there are not yet generalities values and a classification which are used worldwide equally.
With a view to the steering of terminal processes, the use of a three-stage level of service concept is provided based on the perception-response model (see Figure 2), as it is part of the work of Park [PA99] and Mumayiz [Mu86]. The presetting occurs on the establishment of two time limits (waiting time), which serve as boundaries. These time limits are the basis of the steering methodology. The exceeding of the second time limit (T2) means the waiting time or throughput time is too high, resulting in the need to provide more resources (e.g. counter/lanes) at the respective handling facility. If the waiting time or throughput time falls under the first time limit (T1), the handling quality reaches a level that allows the closure of resources.

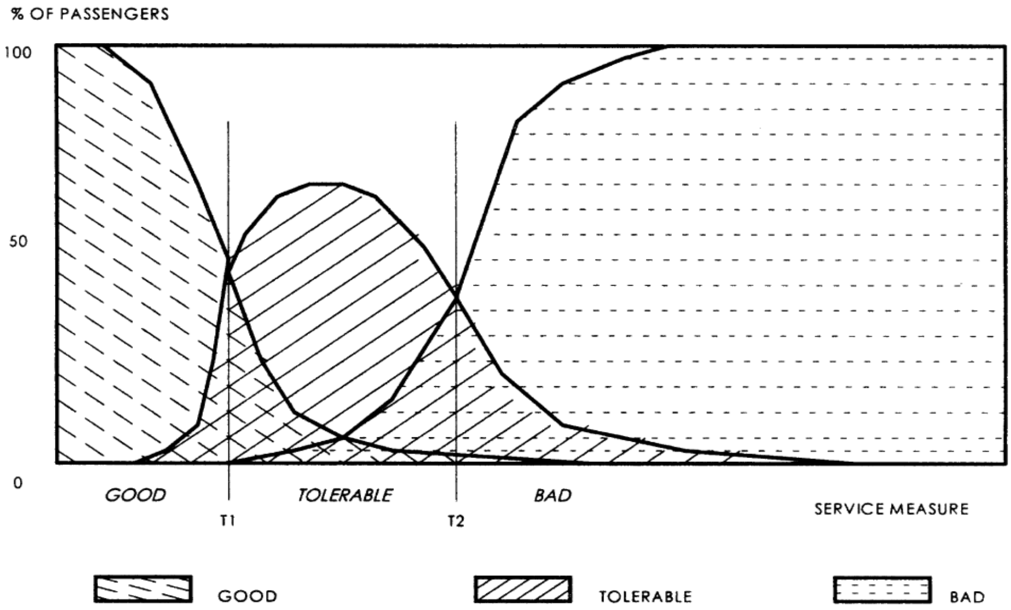

Fig. 2 functionality Perception-Response Model [Pa99]

4. Simulation of the steering of terminal processes

4.1. Simulation model

For the development of the simulation model in this study, the macroscopic simulation software Powersim [Po09] was used. Looking at the aimed short times for the simulation runs, as well as the anonymous state of information available on the status of the passengers during the handling process, the use of a macroscopic simulation for the development of the model is sufficient.
A few main issues of the simulation model in Powersim are a representation of the infrastructure in an airport terminal, the handling processes, and the passenger flows. In addition, a temporary user interface (display) was created. Besides the displays for the presentation and interpretation of simulation results, there are displays which are used for implementation and control of the simulation scenarios.
The simulation model also offers the opportunity to represent irregularity scenarios. It is possible to adjust the following parameters on the display irregularity from a certain time and for a predetermined period of time:

- Distribution of passengers at check-in
- Closing of automated handling facilities (CUSS)
- Change in process times
- Change in walking times

A total of seven so-called displays can be utilized. Over three of the displays, the control of the simulation is carried out. Four displays are available for analysis during and after the simulation runs.
A key element of the simulation model is the development of steering decisions. This functionality is implemented for each process station, with the exception of automated devices (e.g. check-in kiosks). The implementation in the simulation model is based on the determination of the Estimated Waiting Time (EWT) in

the form of an "If-Then" functionality. This has to be seen in relation to target values that are defined as Level of Service for the waiting time. The definition occurs in the form of two time limits (Time1, Time2). If the maximum acceptable waiting time (Time2) is exceeded, additional counters have to be opened. In the case of falling below a certain waiting time (Time1), it is possible to close one or more counters.
With regard to possible steering decisions in the simulation model, it has to be considered that an immediate opening or closing of service counters is not possible in reality. For this reason, there is the option to define, for the various handling facilities, the time periods which are necessary in order to inform and to provide the required staff.

4.2. Implementation of Simulation

At this point, the use of a developed concept for steering of terminal processes is demonstrated by the example of Düsseldorf Airport. Besides the consideration of the regular terminal operation, the study of irregular situations is the main objective. This is implemented using different irregular scenarios, which have to be included in the simulation. The aim is to evaluate the result of steering decisions. For the study of irregular scenarios, the simulation model in Powersim contains the possible implementation of irregular situations that affect the terminal processes around the passenger handling.
As a starting point and possibility of comparison, the simulation of a reference scenario ("terminal today") is used. We are aware of advancing technological development in the field of passenger handling; therefore, there will also be a second reference scenario, “terminal future”, which should take the medium-term development in the handling processes into account.
The development of the reference scenario "terminal future" is especially influenced by the increasing degree of automation in the field of terminal processes. This includes, for example, a change in the passenger handling at the check-in due to the increased use of check-in kiosks or off-airport check-in [AC10, SI10].

4.2.1. Infrastructure
The Düsseldorf Airport terminal has a central component in the departure hall with a check-in area. This is followed by three piers (A, B, C), each with a separate entrance and security control. The handling of the flights, and thus the airline passengers, is dedicated to certain areas of the terminal building. In the case of Lufthansa and its Star Alliance partners, the flights and passengers will be handled only in Pier A.
Due to the structure of the passenger handling (common use with single queue), the simulation model is limited to the presentation of Pier A, and the check-in area lying in front of Pier A. The handling of passengers at the check-in counters can be classified into four groups. The classification depends on the booking class and the previous use of the possibility of off-airport check-in. The so-called premium passengers are also divided into first and business class. Based on the different groups, the following number of counters is available:

- First Class: 4 Counters
- Business Class: 10 Counters
- Economy Class / Baggage-Drop: 20 Counters

The check-in area for the economy class passengers and the baggage drop is not strictly separated. Here, a variable allocation of the counters is possible. In addition, for the passenger handling there are 27 check-in kiosks available, without the possibility of baggage drop. The passengers in economy class cannot use traditional desks at the check-in desk. Passengers must use a check-in kiosk before they drop off their baggage at the counter. Because of this, there is no separation between counters for economy class and baggage drop.
A real flight plan was used as an input for the simulation. The flight plan included the real flight events from the scheduling period of winter 2010/11 using the example of Monday, 22nd November 2010.

4.2.2. Simulation of irregular scenarios
Besides the presentation of the implementation of typical irregular situations in the simulation, the evaluation of the simulation results is shown. The evaluation is done as a comparative analysis between the current (terminal today) and future state (terminal future) in the terminal processes.
The simulation of irregular scenarios took place in two steps. In the first step, the simulation run took place as a "rigid" simulation with deactivated "if-then" mode. The calculated results of the simulation were then used as parameters for a comparison, which allowed an evaluation of the "heaviness" of the irregular situation. In the second step of the simulation, a run was done with activated "if-then" mode and the same input values. The

results of the second simulation run were comparable to those of the first run. This made it possible to assess the optimization potential of the steering decisions.
For the simulation of the irregular scenario, the period of time that is required for the opening and closing of counters has to be set. This period takes into account the time which is needed for the opening of counters in a real operation. Across the simulation of all irregular scenarios, the following assumptions apply for the realization of a steering decision:

- Time open counter: 10 minutes
- Time close counter: 5 minutes

The simulation of irregular scenarios is demonstrated through the example of the irregular scenario "booking system failure".

Scenario ”booking system failure”
Part of this scenario is the failure of an airline reservation system. For example, the global failure of the central check-in system of Lufthansa in 2009 [SZ09]. Here, the central reservation system of the airline was down for four hours. During this blackout, the use of the booking and ticketing system was not possible. Therefore, the CUTE and CUSS systems (check-in kiosks) were not available for the handling of passengers. So the process of check-in had to be done manually with pen and paper.
The implementation of the irregular situation is done through a change of the handling parameters during the period of disruption. The need for this is a realistic assessment of the impact of the irregularity. An essential factor is the switch to a manual passenger handling. This concerns the issuing of boarding passes and baggage tags for checked baggage. This results in a change in the process time at the check-in desks. The irregular situation due to manual handling was described as follows in the simulation:

- increase in the process time at the counter from 60 (baggage drop) / 120 (check-in) seconds to 180 seconds per passenger
- redirecting of passengers from check-in kiosks to check-in counters

The period of disruption lasted 90 minutes, starting at 5:00 and ending at 6:30. According to the distribution of departing passengers over the day, the irregularity took place during the period of time with the highest demand. The "if-then" mode is activated in each case from 5:00 to 8:00. The results of the simulation runs are presented in Table 1.

Table 1. Results irregular scenario „booking system failure“

Parameter	„Today“ (rigid)	„Today“ (if then)	„Future“ (rigid)	„Future“ (if then)
Number delayed flights (5:00 – 8:00)	34	29	33	26
Number late Passenger (5:00 – 8:00)	1050	988	851	774
Delay minutes PAX (5:00 – 8:00)	61.246 min	56.354 min	48.825 min	42.741 min
Mean delay per flight (5:00 – 8:00)	83,6 min	83,9 min	76,8 min	68,5 min
Counter minutes Check-In Business	1987 min	2610 min	1211 min	1695 min
Counter minutes Check-In First	1054 min	1259 min	1025 min	1147 min
Counter minutes Check-In Baggage Drop	8494 min	8644 min	7432 min	7796 min

In the results from Table 1, it should be noted that when specifying the average delay of delayed departures, the number of late departures plays a role. For example, in scenario "terminal today", no improvement of the value

was offered. The number of late departures decreased here from 34 to 29. Thus, the determination of the average delay was based on a lower number of flights. The impact resulting from the disruption of the reservation system could be reduced with the activated “if-then” function. This could also been seen in a lower value of the total delay minutes in relation to the passengers. The number of affected flights and passengers were also lower in both cases.
The failure of the reservation system leads in two cases, "terminal today" and "terminal future", to a significant degradation of handling quality and ultimately delays in the arrival of passengers at the departure gate. The steering of the terminal processes as a result of the activated "if-then" function led, in both cases, to an improvement of the handling operation. In both cases, however, an unacceptable level of delay remained.
Figure 3 shows the functionality of the steering through the example of the opened counters in the business class check-in area. As a result of the extended handling time and diversion of passengers who have been affected by the failure of the check-in kiosks, instead of two counters open during regular operation, ten counters were available. However, this would also require five times the quantity of staff at this handling facility.
Because of this irregular situation, the number of passengers is carried out in the period of the greatest load; the ability of steering is limited by the number of available counters. As seen in Figure 3, ten counters were open - if only temporarily. At this point it is not possible to open more check-in counters.

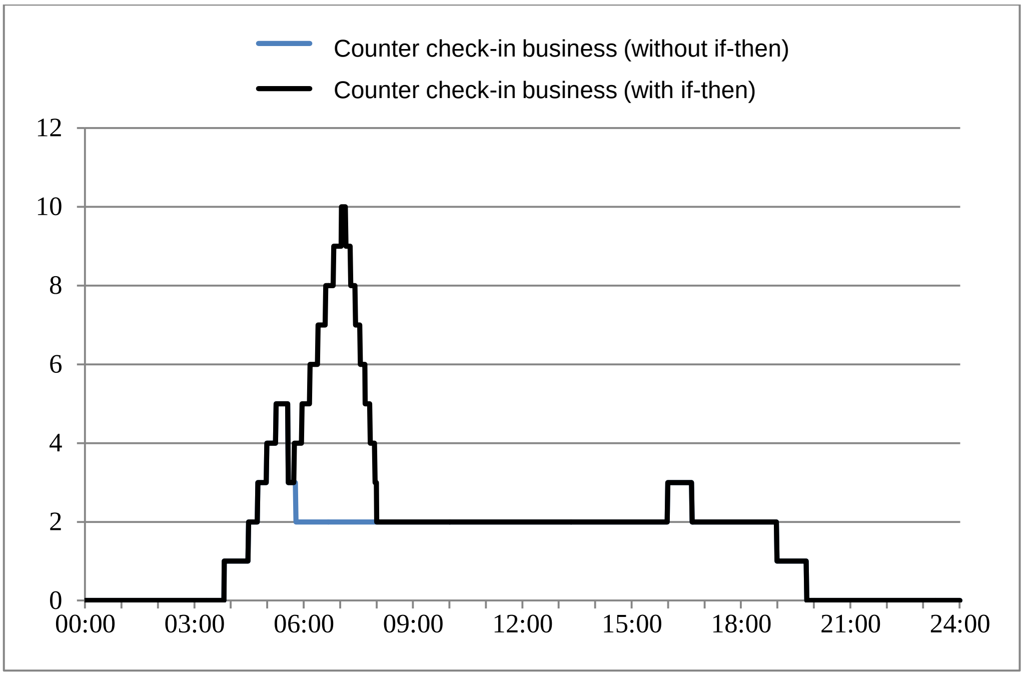

Fig. 3 Counter check-in business class irregular scenario „booking system failure"

The breakdown of the reservation system, and the resulting irregularity at the area of check-in, had no effect on the subsequent processes (security and passport control). The defined Level of Service for the required waiting times were not exceeded, so that there were no steering decisions.
The impact that resulted from the failure of the reservation system caused such a strong irregularity in the passenger handling that late departures could not be avoided even by steering of the terminal processes. Also, a reduction of the period of time for the realization of steering decisions to five minutes did not change this.

5. Summary

With the developed approach and the methodology behind steering decisions, a tool is presented which helps to support the management of the terminal processes. An essential point for the use of the steering methodology in operational use is the evaluation based on a measurable parameter. This is the number of people in a waiting area from which the expected waiting time can be derived. Based on the developed concept, further investigations are necessary to achieve practicality.

The analysis of simulation runs showed that the use of known criteria for the Level of Service as a control parameter is partly insufficient. For the evaluation of estimated waiting times in relation to the number of open service counters, the steering reacts to these values with a certain "inertia". Therefore, the use of reduced values, with respect to airport-specific characteristics, has to be investigated for future use of a management program for this concept.
An important area in connection with the use of the steering program is to determine effects which result from the implementation of new developments in the field of passenger handling. Increasing automation and the use of new technical processes in the field of passenger handling can, for example, influence the arrival of passengers at the airport [Sc10] or the throughput of single handling facilities [Fa08]. An example of this is the off-airport check-in [TR08]. These developments reinforce the need to capture and evaluate the current status of passenger handling in a terminal building to possibly act with steering decisions.
It is furthermore possible that the behaviour of passengers can change as a result of the steering of terminal processes for the passenger handling. The preferential treatment of delayed passengers can lead to an increase of their confidence in the handling process. This can then result in the problem of their planning their arrival at the airport with only a very narrow time margin [Ko06, Ro07].
The connection between the steering of terminal processes and the question of whether an optimization of passenger handling will affect the future behaviour of passengers is important.
In the future, management of handling processes as an integral part of the Total Airport Management (TAM) will become increasingly important. The concept developed within this work regarding the steering of terminal processes represents one possible element of a so-called Airport Operations and Control Center (AOCC). A later use in airport operations requires the implementation of an AOCC at the airport. This organizational integration is the basis of a comprehensive management overlooking all procedures within an airport. The developed concept thereby presents a first approach, such as the handling processes in an airport terminal being systematically monitored and controlled.
In addition to the organizational integration of operational processes, focus should be placed on creating the technical conditions. The implementation of technology in order to capture the current status of the passenger handling provides the basis for the evaluation and steering of terminal processes. In addition to the technical possibility of monitoring the individual waiting areas, the legal background (data protection, etc.) must be observed.

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