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Study on optimizing the number of self-service bag drop kiosks for rail using the example of the Next Generation Station

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Abstract

Carrying large pieces of baggage makes rail travel more difficult for many passengers. A self-service bag drop similar to that at the airport could improve the attractiveness of high-speed rail and encourage more people to travel by train. We use microscopic simulations of a generic train station to answer the question of how many kiosks are necessary to ensure shortest possible waiting times.

Keywords: self-service bag drop; passenger simulation; train station; Next Generation Station.

1 Introduction

Carrying large pieces of baggage on trains causes longer boarding and train stopping times, difficulties in stowing baggage, blocked seats and aisles. This reduces passenger comfort. A self-service bag drop similar to that at the airport could improve the attractiveness of high-speed rail and encourage more people to travel by train.

Already at the beginning of the railroad age, railroad companies developed solutions for the transport of passenger baggage. This service, which has existed for over 150 years, is no longer an integral part of rail passenger transport today [1]. Baggage concepts in which passenger baggage is transported directly on the train - detached from the passenger - still exist today in isolated cases at Amtrak in the USA or at EuroStar. The passenger has to allow between 30-120 min for the drop-off. The travel chain is not continuous [2, 3].

In Germany, passenger baggage is currently transported either on the train by the passenger himself or by the service provider Hermes with a one-day lead or rather follow-up time. In comparison, baggage delivery services in Japan offer customers same-day delivery for 12.000 locations [4].

City check-in concepts such as at Kowloon Station in Hong Kong or at the City Airport Train (CAT) at Wien Mitte station show that an end-to-end baggage chain to the airport is already working today, although these concepts are characterized by large manual efforts in baggage handling [5, 6].

The AIRail concept of Lufthansa, DB, and Fraport, in which flight baggage could already be checked in at some train stations for departure in Frankfurt, is no longer offered for the above-mentioned reason among others. In contrast, airlines and airport operators expect an increase for automation in baggage drop-off at airports in the future [7], which could bring the cross-modal consideration of passenger and passenger baggage into focus.

As part of the Next Generation Train (NGT) research project, a double-deck vehicle concept for a high-speed train (HST) was developed on the basis of passenger flow simulations. This includes a separate and automated baggage transport system - similar to that used in air transport - which enables short passenger changeover times with a high number of passengers and fulfils the requirement for the shortest possible downtimes of the trains in the adapted railway station called Next Generation Station (NGS) [8, 9].

2 Methods

We use microscopic simulations of a generic train station, the NGS, to answer the question of how many kiosks are necessary to ensure shortest possible waiting times for long-distance passengers. To this end values as expected waiting times in the queue, queue length, and necessary waiting area are computed.
Within the model passengers proceed to the self-service bag drop and are required to scan the barcode, place their baggage on the conveyor belt, and attach the printed bag tag. A self-service bag drop kiosk only one passenger can be processed at once. Figure 1 shows the simulation flow.

From [10] we derive for the self-service bag drop process time a normal distribution with mean value 2.23 min and standard deviation of 1.11 min.
We assume that between 6:00 - 23:00 each 5 min an NGT departure from the NGS. Compared to the main station in Frankfurt (Main), Germany, about 12 ICE trains also depart per hour during peak travel times [11], which means a similar performance in terms of the number of vehicles per day.
The number of passengers on individual trains is taken to be normally distributed with mean value half of the maximum capacity (800 passengers) and standard deviation of 150 passengers. We picked one selection of the abovementioned distribution resulting in a total of 82.148 passengers. Figure 2 shows this selection of passengers with baggage, where 62 % of all passengers are assumed to have baggage [12].

Figure 1: Simulation flow.

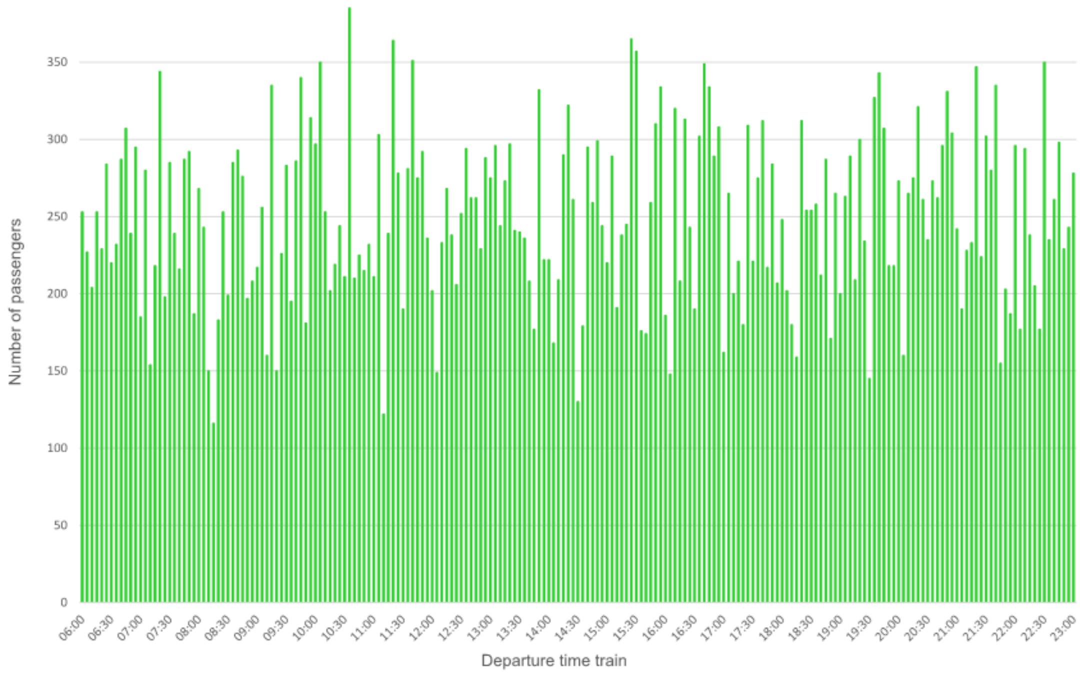

Figure 2: Number of passengers generated with baggage per train.

We suppose further that passengers arrive with a cut-off normal distribution with mean value 30 min before train departure with a standard deviation of 4 min, minimum 15 min, and maximum 45 min. The value 15 min is chosen to ensure that there is enough time to finish the bag drop process and to proceed to the train. The individual walking speed is chosen according to a distribution derived from [13] and the body proportions of passengers with baggage is set to a circle with radius 0.5 m.
We used for the analysis and assessment of the results the Level-of-Service-Concept (LoS) from the International Air Transport Association (IATA) which classifies the service times at the process points and the waiting area provided for this purpose into three categories. A maximum waiting time of 5 min is used as an acceptable waiting time for the self-service bag drop at the kiosks as an evaluation benchmark (Table 1).

Level of Service	Waiting time	Waiting area	Description
Overdesign	0 min	> 1.8 m^2/person	overabundance
Optimum	0 – 5 min	1.3 – 1.8 m^2/person	acceptable
Suboptimal	> 5 min	< 1.3 m^2/person	unacceptable

Table 1: Standards for waiting times and waiting area for the self-service bag drop according to LoS of IATA [14].

3 Results

To incorporate the statistical variation, mean of 5 simulations and standard deviation are used. The waiting time of a passenger is determined by the time difference of entering the common queue and starting the bag drop process. For each passenger this results in a function mapping the waiting period to the point in time given by leaving the queue in front of the bag drop kiosk.

To capture the waiting time of all passengers, we considered the timespan from 5 a.m. to 12 p.m. Strong variations of the waiting time were flattened by computing the mean of the waiting time of all passengers leaving the queue within a 10-minute block. Furthermore, the cumulated queue length is calculated during each 10-minute block.

Successive simulation up to 125 kiosks reveals that from 110 kiosks on the waiting queue that accumulated until 12 p.m. can be handled. From 117 kiosks on the average waiting time throughout the considered day is below 5 min. However, if we look at the average waiting times within the 10-minute ranges shown in Figure 3, we see larger time spans with an unacceptable waiting time.

Only a number of 125 kiosks comply the requirement LoS Optimum within all 10-minute periods, i.e. a lower number of kiosks leads to waiting times higher than 5 min. Even if the mean throughout the whole day is less than 5 min, there may be periods of 1-2 h with a higher waiting time.

We picked one selection of the distribution of passengers on individual trains as shown in Figure 2. Peaks in this selection potentially leads to a longer waiting time. Therefore, four more selections were made to investigate the dependency on the selection. Waiting time and queue length computed as above are combined and shown in Figure 4. The variation shown in this figure are derived from the individual standards divisions by estimating the combined waiting time and queue length. The variations of the graph waiting time exceed the 5 min boundary of LoS Optimum.

Since the variation violates the desired LoS, we have successively simulated up to 140 kiosks. Only this number of kiosks ensure the waiting time with its variation to be less than 5 min as can be seen in Figure 5. To meet the area requirements of LoS Optimum, the waiting area for 140 kiosks need to be at least 1,140 m^2.

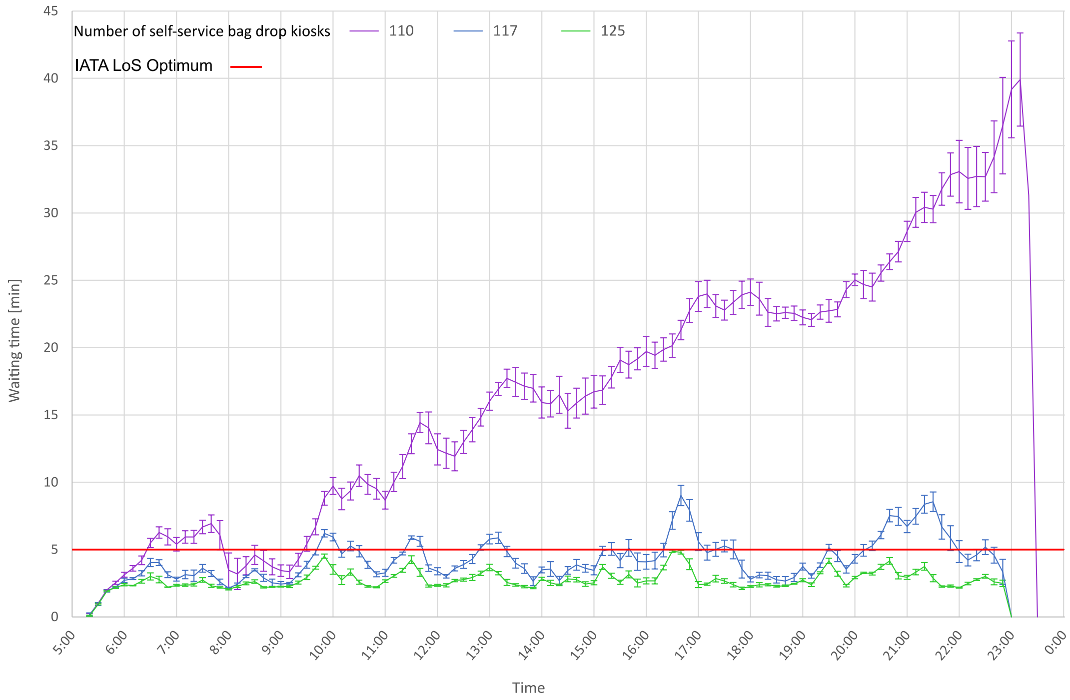

Figure 3: Mean waiting time with standard deviation at self-service bag drop kiosks during 10-minute periods throughout the day.

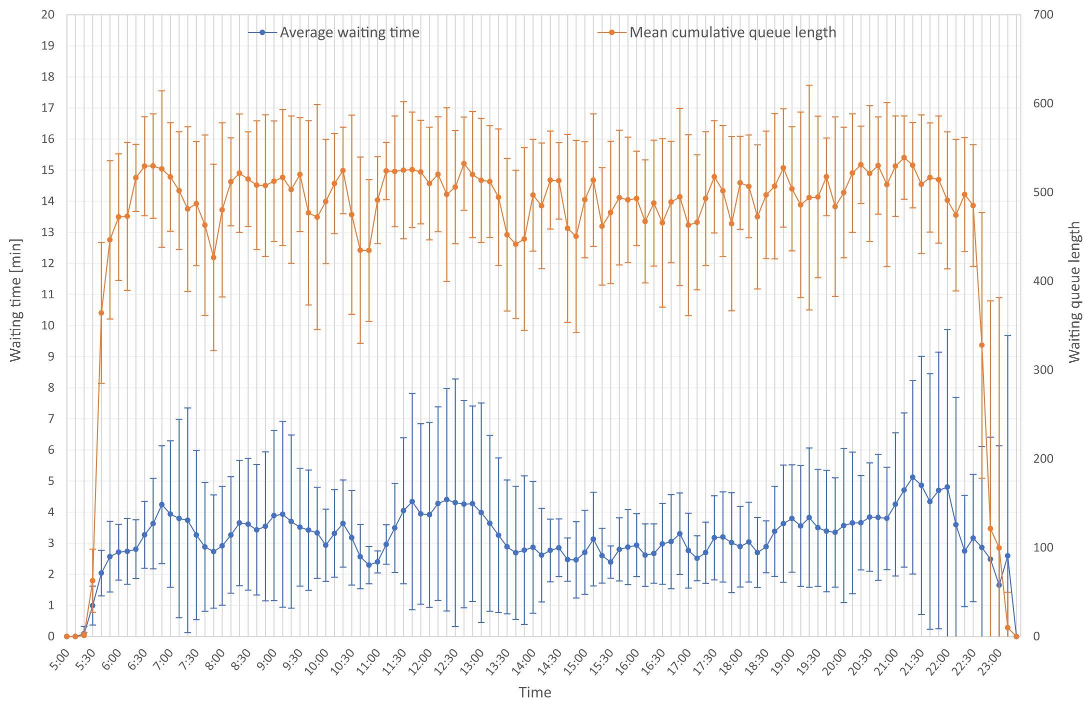

Figure 4: Mean waiting time and mean cumulative queue length related to a 10-minute range with variation for selections 1-5 at 125 self-service bag drop kiosks.

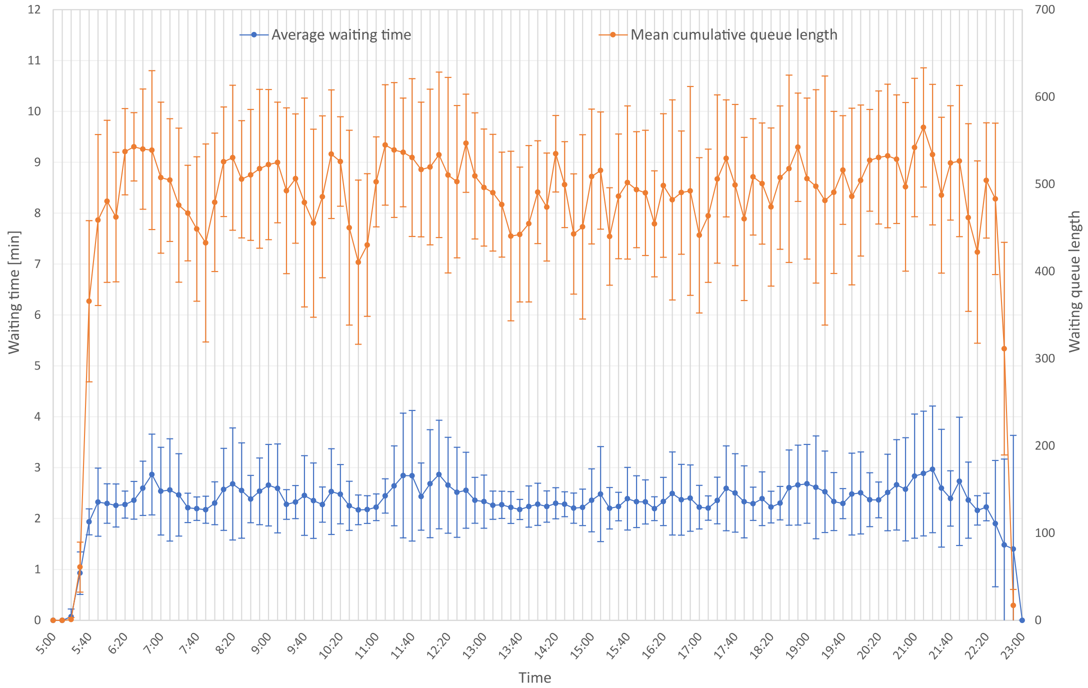

Figure 5: Mean waiting time and mean cumulative queue length related to a 10-minute range with variation for selections 1-5 at 140 self-service bag drop kiosks.

4 Conclusions and Contributions

In this work, we have developed a method to determine the IATA Level of Service Optimum for self-service bag drop off at the intermodal traffic hub rail station with the help of microscopic simulations.

In course of this, we have developed a simulation model that considers as input parameters real data from the airport and train station real systems. These include the distribution of self-service bag drop process time, the walking speed and the number of passengers with baggage over the course of the day, as well as their arrival distribution in relation to the respective train.

In the simulations, we have varied the number of self-service bag drop kiosks for different samples of the entry distribution. In order to include the statistical deviation of the results, each simulation was run several times.

Under the given conditions, a total of 140 of self-service bag drop kiosks for approx. 51,000 passengers with checked baggage and a waiting area of at least 1,140 m² are required throughout the day in order to achieve IATA's Level of Service Optimum for the Next Generation Station.

The quality of the results can be improved for all intermodal traffic hubs by means of specific input parameters. These include, for example, more up-to-date data/measurements regarding of self-service bag drop process time at airports and the storage of more detailed operating concepts.

The location and distribution of self-service bag drop kiosks also depends on the operating concept or modal split. Whether passengers arrive at the station alone or in

a group depends on the transportation medium used to get there and can sometimes result in large passenger volumes.
Further simulations should consider the application of new technologies such as RFID or FaceID for self-service bag drop at transportation hubs to study their impact.
To further develop the overall concept, additional studies are currently being conducted on the Next Generation Station baggage concept, including designing the baggage system in the train and evaluating its applicability to the automatic transport of goods in high-speed trains.

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