Ticket reservation posts on train platforms: an assessment using the microscopic pedestrian simulation tool Nomad

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Abstract
The new train operator on the High Speed Line South between Amsterdam Central Station and Brussels will introduce a special tariff system including an obligatory reservation. However, not all locations where tickets are sold will be able to provide a reservation ticket, making it necessary to provide reservation tickets on the platform using dedicated ticket reservation posts. The effects of these reservation posts on passenger flows on the platform have been investigated using the microscopic pedestrian simulation tool NOMAD as well as the use of the reservation posts. Simulations have been performed for three platforms in three stations (Amsterdam, Rotterdam and the airport station Schiphol). This paper presents the assessment methodology and shows simulation results for Schiphol station. The conclusions are drawn based on the simulation results for all stations.

Various scenarios have been compared with different passenger demands using the ticket reservation posts and different service times. Also, the optimal amount and location of ticket reservation posts have been investigated. A number of assessment criteria have been calculated using the simulation results (total load of reservation posts, queue lengths per reservation post, number of passengers missing the train, average waiting time per passenger at a reservation post and average service time per passenger at a reservation post), resulting in an objective and quantitative comparison of the scenarios and custom made conclusions and recommendations.

The case study also shows the added value of the microscopic pedestrian simulation tool NOMAD in comparing scenarios in a quantitative way.

INTRODUCTION
NS Hispeed is the train operator on the High Speed Line South between Amsterdam Central Station and Brussels. NS Hispeed will operate international trains and national trains between the stations of Amsterdam, Schiphol, Rotterdam and Breda. A special tariff system will be introduced including an obligatory reservation, both for international and domestic trains. Tickets will be sold on the internet, using dedicated Hispeed counters and via existing counters and ticket machines of Dutch Railways (NS). However, NS ticket machines will not be able to provide the corresponding reservations. Therefore, among other devices, dedicated ticket reservation posts are under development. These posts will be able to read public transport chip cards and/or bar codes and, after an approval by the back office, to provide a reservation. The reservation posts will be located on the platform.

It is most likely that the reservation posts (at maximum three clusters of six posts) will affect passenger flows and transfer capacity on the platform. This leads to the following research questions:

- What are the consequences of the reservation posts for the passenger flows on the platform?
- What advantages and disadvantages may influence further decision making on whether or not to proceed with the development of the reservation posts?

Since the reservation post is still under development, a simulation study has been performed. A simple queuing model will not suffice, since the choice for a reservation post depends on its location and the walking time towards it. The applied model should therefore include both choice behavior and walking behavior, which explains our choice for the microscopic pedestrian simulation tool NOMAD (1-4), which does not only include walking behavior, but it also describes waiting behavior, activity choice and performance and route choice. NOMAD has been developed at the department of Transport & Planning of the Delft University of Technology. The model describes the individual pedestrian behavior in detail, including pedestrian interactions and interactions between pedestrians and their environment. The behavior depends on individual pedestrian characteristics (walking speed, size) and the characteristics of the environment. The behavioral model in NOMAD has been based on empirical pedestrian data (5).

In the Netherlands, the reservation posts are located in Amsterdam Central Station, Schiphol station, Rotterdam Central Station and Breda station. Since most hindrance is expected on the most crowded platforms where the Hispeed trains stop, the simulation study is limited to platform 15 of Amsterdam Central Station, platform 5/6 of Schiphol station and platform 12 of Rotterdam Central Station.

To give directions for further technical developments of the reservation posts, the simulation study includes different scenarios in which both the reservation post characteristics (service time, number and location of reservation posts) and passenger flow characteristics (total number of boarding and alighting passengers, percentage of passengers using the reservation post) are varied.

This paper will focus on the simulation results in Schiphol, since the research methodology is similar for the two other stations (Amsterdam and Rotterdam). However, the conclusions are drawn based on simulation results for all stations. The paper also shows the application possibilities of a pedestrian simulation tool. For the complete report on the assessment of reservation posts, we refer to (6).
The paper starts with an overview of the passenger processes on the platform included in the simulation model. Then, we will describe the situation on the platform in Schiphol, followed by an outline of the different scenarios and an overview of the assessment criteria. Next, simulation results for Schiphol are shown and discussed. We will finish with conclusions and recommendations.

**MODELED PASSENGER PROCESSES ON THE PLATFORM**

This section describes the different processes included in the simulation model. Since the main research aim is to investigate the hindrance of reservation posts on passenger flows on the platform, the simulation is limited to the part of the train platform where the posts are located and where the train stops. In the planned timetable, high speed trains run each ten minutes during peak hours. For each train, a similar process occurs on the platform. Therefore, each simulation is limited to these ten minutes and the arrival and departure of a single train. To model stochastic aspects of the process, multiple simulation runs are performed for a single scenario. The different processes related to passenger on the platform are shown in FIGURE 1.

**FIGURE 1 Processes of passengers on the platform.**

Starting immediately after the departure of the preceding train, passengers arrive on the platform using the stairs, escalators and inclined moving walkways. Some passengers already possess a reservation ticket. The reservation indicates the chair number and the number of the train compartment, while on the platform the location of each train door and the corresponding train compartment is pointed out. The passengers with a reservation therefore walk straight towards a waiting location on the platform near their destination door. The passengers without a reservation first walk towards the nearest reservation post. The reservation posts issue random chair and compartment numbers, thus the assigned chair is not necessarily in the neighborhood of the reservation post. The passenger is thus free to choose a reservation post, and so passengers will only take into account walking distance and waiting time in the choice for a reservation post. The passengers will try to minimize the time loss for obtaining a reservation by choosing the nearest reservation post with the minimum waiting queue. After obtaining a reservation these passengers also walk to a waiting location nearby their destination door. When the train arrives, all passengers walk towards their destination door. First, passengers alight at this door. The alighting passengers walk towards one of the platform exits, choosing according to a predefined distribution. The boarding passengers are then able to board. Ten minutes after the start of the simulation, the train will leave and the simulation ends. Passengers without a reservation are not allowed to board, and consequently miss the train. When the train departure moment approaches, passengers with a reservation will board the train via the nearest door and walk inside of the train towards their reserved chair.
SCHIPHOL STATION SIMULATION STUDY SET-UP

The platform where the high speed trains stop is also used for trains of Dutch Railways. The passengers for these trains are included in the simulation model, since they may hinder or may be hindered by Hispeed passengers. Although the assignment of platforms to trains is dynamic in Schiphol, passengers will know the platform number the moment they arrive on the platform. FIGURE 2a shows an overview of platform 5/6 in Schiphol. The light grey area indicates the platform. The brown areas are not available for pedestrians: they either represent obstacles on the platforms (escalators, columns) or the tracks next to the platform. The train is indicated in red, while the white squares indicate locations of doors.

Four entrances lead towards the platform, indicated in green in FIGURE 2b. The middle two entrances are escalators, while the outer two access points consist of inclined moving walkways. Three groups of reservation posts have been planned for Schiphol, see Figure 3. Each group consists of two clusters of reservation posts, located with the backs towards each other. This way, the waiting queues are perpendicular to the platform edge.

The train service is executed with a newly developed high speed train (Albatros, see FIGURE 4a). Both the location of the train doors and the number of seats per compartment are important for the simulations. The passengers are distributed over the different doors depending on the number of seats in the corresponding
compartment: the more seats a door leads to, the more passengers have this door as destination. FIGURE 4b shows the door locations and the number of seats per compartment. In total, the train has 546 seats.

![The Albatros high speed train.](image)

a. The Albatros high speed train.

![Overview of the high speed train with the number of seats per compartment.](image)

b. Overview of the high speed train with the number of seats per compartment.

**FIGURE 4 The Albatros high speed train.**

The number of boarding and alighting passengers is based on the busiest moment of the day. For Schiphol, the largest expected number of boarding passengers is 273, while 109 passengers alight from the high speed train. In the worst case situation, the number of boarding passengers increases to 328. The simulation model also includes 350 Dutch Railways passengers, staying on the platform.

The duration of a simulation run is ten minutes: the time between the arrivals of two consecutive trains. The second train arrives eight minutes after the departure of the first train. Two types of passengers can be distinguished: international passengers arriving early, and national commuters who are used to travelling, are familiar with the timetable and arrive in general later on the platform. During the first five minutes 25% of the passengers will arrive on the platform. These passengers either missed the previous train or have a reservation and want to be sure to be in time for this train (e.g. in case of an international trip). In the following four minutes 70% of the passengers arrive: the commuters. During the last minute 5% of the passengers will arrive, late coming passengers who might have just missed another train. The passenger arrival pattern has been based on the expertise of the train operator and is shown in FIGURE 5.
FIGURE 5 Distribution of passenger arrivals over time.

CONSIDERED SIMULATION SCENARIOS
Different scenarios have been compared to a reference scenario in the simulation study. Several variables are subject to change, where in the reference scenario each variable has the most likely value. In each scenario, only one of the variables is changed, so changes in the simulation results can be explicitly attributed to the changed variable. Table 1 shows an overview of the variables and the values. The italic values are included in the reference scenario.

TABLE 1 Overview of the Simulation Variables.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Values</th>
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<tbody>
<tr>
<td>Use of reservation post</td>
<td>40%; 50%; 60%; 70%; 80%; 95%</td>
</tr>
<tr>
<td>Service time of reservation post</td>
<td>100% 7 seconds</td>
</tr>
<tr>
<td></td>
<td>100% 15 seconds</td>
</tr>
<tr>
<td></td>
<td>75% 7 seconds; 25% 15 seconds</td>
</tr>
</tbody>
</table>

In addition, three more scenarios have been defined. In the first scenario the number of boarding passengers has been increased to indicate the robustness of the reservation posts in more crowded situations, in which not only more passengers use the reservation post, but also more passengers are present on the platform. The second scenario is a worst case situation, in which not only a very high percentage of the passengers uses the reservation post (95%), but also the service times are high (on average 15 seconds for every passenger). In the third and last scenario, passengers can obtain reservations when travelling together at one of the reservation posts. All other posts (as in the other scenarios) just issue a single reservation, where passengers travelling together obtain individual reservations and, most likely, they will not get adjacent seats.

ASSESSMENT CRITERIA
For a structured identification of the assessment objectives, first of all we establish what types of objectives are to be considered: technical assessment, impact assessment, user acceptance assessment, socio-economic evaluation, market assessment, and financial assessment (7).

For the purpose of this study, we focus on the impact assessment and the user acceptance. The most important actors in the impact assessment are the train operator and the passenger. In the table below, an overview is given of the assessment questions, the assessment questions focused on a single topic, and the assessment indicators.
### TABLE 2  Overview of Assessment Questions and Indicators

<table>
<thead>
<tr>
<th>Assessment question</th>
<th>Question focused on single topic</th>
<th>Assessment indicator</th>
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<tr>
<td>How efficient is the use of the reservation posts?</td>
<td>How long are the reservation posts occupied?</td>
<td>Total load of all reservation posts in passenger minutes.</td>
</tr>
<tr>
<td></td>
<td>How long are the queues in front of the reservation posts?</td>
<td>Queue lengths over time of individual reservation posts.</td>
</tr>
<tr>
<td>How does the use of reservation posts affect the operational process?</td>
<td>How many passengers miss the train?</td>
<td>Number of passengers missing the train.</td>
</tr>
<tr>
<td></td>
<td>How long do passengers wait in front of the reservation post?</td>
<td>Number of passengers not arriving at their destination door.</td>
</tr>
<tr>
<td>How long is the delay for the passengers due to the reservation post?</td>
<td>How long do passengers need to get their ticket?</td>
<td>Average waiting time per passenger at a reservation post.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average service time per passenger at a reservation post.</td>
</tr>
</tbody>
</table>

Since the service time is part of the input, we focus on the average waiting time per passenger. In the following, the abovementioned assessment indicators are discussed in more detail.

**Total load of all reservation posts**

The most important criterion relates to the load of all reservation posts. FIGURE 6 shows the dynamic process of occupancy and waiting queues at a reservation post. The blue arrows indicate the service times at the reservation post: since all pedestrians at the reservation post will be served according to a first-come-first-serve strategy, the bottom row of occupancy rectangles includes all passengers (A to G). When the reservation post is occupied at the arrival of a passenger, this passenger will join the queue (rectangles on top of the first row) and wait until the passenger at the post is served. The red arrows indicate the waiting time of the passengers, the height of the rectangles indicates the queue length. The surface of the graph indicates the load of the reservation post, consisting of both service time and waiting time. For the total load of all reservation posts in a scenario, the loads of the individual reservation posts are added.

![FIGURE 6 Load of a reservation post over time.](image)

**Average time of a passenger at a reservation post**

The average time of a passenger at a reservation post consists of the service time and the waiting time. It can be calculated by dividing the total load of the reservation posts by the number of passengers that have acquired a reservation. Since the average service time at a reservation post is known (model input), the average waiting time at a post can be derived.
Efficiency of the use of single reservation posts

The efficiency of the use of a single reservation post corresponds to the load of the each individual post (see FIGURE 7). Each bar indicates a reservation post, the number of which is indicated along the x-axis. The height of each column corresponds to 600 seconds, the total simulation duration. The colors indicate the number of passengers in front of a reservation post and the height indicates how long this number has been present (in total). The number of passengers includes the person that is served by the reservation post, thus when two passengers are present, one passenger is served and the other passenger is waiting.

Number of passengers missing the train

The hindrance or the effect of obtaining reservations on the platforms is also expressed by the number of passengers missing the train, being the fourth criterion. We distinguish two groups of passengers missing the train. The first group possesses a reservation, but arrives too late on the platform to board even the nearest door. The second group of passengers does not yet have a reservation: they are either on their way to a reservation post or they are in a queue to obtain the reservation. Passengers with a reservation that have not arrived at their destination door are assumed to board the nearest door and to walk to their seat inside the train. These passengers are indicated as ‘not at destination’. This number is also used as an assessment criterion, since movements inside the train should be minimized.

![FIGURE 7 Load of the reservation posts in the reference scenario for Schiphol.](image_url)

SIMULATION RESULTS

This section shows some of the simulation results for Schiphol. FIGURE 8 shows the total load of the reservation posts for the different scenarios. The blue bars indicate the load averaged over the twenty simulation runs, while the dark red bars indicate the maximum load resulting from the worst case simulation run. As expected, the load increases when the numbers of passengers using the reservation post increase. The figure indicates that an increase in the service time at a reservation post has a larger impact than the increase in the numbers of passengers using a reservation post. The load increases more than proportionally in the worst case situation with 95% of the passengers using the reservation post and a long service time (15 seconds).
FIGURE 8  Total load of the reservation posts in Schiphol.

FIGURE 9 shows the average time a passenger needs at the reservation post for all scenarios. The dark blue bar indicates the total time, while the red bars indicate the average waiting time. The figure shows that the waiting time only slightly increases when more passengers use the reservation post. However, an increase in the service time and an increase in the total number of boarding passengers does increase the waiting time considerably. In all scenarios, the waiting time is much smaller than the service time of the reservation posts.

FIGURE 9  Average time for passengers at a reservation post in Schiphol.

Figure 11 shows the number of passengers that either missed the train or did not arrive at their destination door. In the worst case scenario about ten passengers miss the train, while in the other scenarios passengers miss their train only incidentally. This implies that the number of reservation posts is sufficient and that the posts are well located.
The load of individual reservation posts in the reference scenario has been shown in FIGURE 7. What is most striking is that none of the reservation posts is used for more than 40% of the time. Clusters five and six have the lowest occupancy. Within these clusters reservation posts located on the right are hardly used, since these have the largest distance to the platform access points. The conclusion can be drawn that the number of reservation posts can be reduced without decreasing passenger service.

FIGURE 11 shows the average time passengers need at a reservation post as a function of the number of reservation posts on the platform. The reference scenario is taken as a starting point. Then, the reservation post with the lowest load is removed from the simulation, and the next simulations are run. A reduction to eleven posts does not affect the average time at a reservation post. When ten reservation posts are operational at the platform, the average time increases, but only when the number of operational posts is reduced to eight, a considerable increase is visible in the average time per passenger.
This is also seen from the number of passengers that missed the train (Figure 13). At seven reservation posts, the number of passengers that do not reach their destination door slightly increases. If the number of reservation posts further decreases to six then the number of passengers that are missing the train increases considerably. This leads to the conclusion that for Schiphol station, eight reservation posts suffice (plus probably an extra one to compensate for posts being out of service).

> FIGURE 12 Number of passengers that either missed the train or did not arrive at their destination door as a function of the number of reservation posts on the platform.

CONCLUSIONS AND RECOMMENDATIONS

The aim of this paper is to show the assessment of ticket reservation posts on passenger flows on train platforms. Also, the applicability of the microscopic pedestrian simulation tool NOMAD to answer real life design questions is discussed. Simulations have been performed on the most crowded platforms where high speed trains stop in the stations of Amsterdam, Schiphol and Rotterdam. Different scenarios have been compared, where both the number of passengers using the reservation posts and the service times of the reservation posts have been varied. The assessment criteria were the total load of all reservation posts, the load of individual reservation posts, the average times passengers need to acquire their reservation and the number of passengers who missed their train or did not arrive at their destination door.

The simulation results were as expected, but the added value of the simulation study is the quantification of the differences of the various scenarios. Also, it is possible to compare influences of different types of variables, such as the number of passengers using the reservation posts and the service time. For all stations, the number of reservation posts is sufficient to handle the passengers. An increase in the service time at a reservation post has a larger impact than an increase in the number of passengers using the reservation post. The waiting time at the reservation posts increases only slightly when more passengers use the reservation post, where an increase in service time leads to larger increases in waiting time. However, the waiting time is much shorter than the service time at the reservation posts. The use of the reservation post depends highly on the location: reservation posts located nearest to the platform entrances are most often used. The walking time to reservation posts further away weights heavier than extra waiting time. When both the location of the reservation posts and the platform entrances are situated in the middle of the platform, the number of passengers missing the train due to their visit of the reservation post is very small. Otherwise, this number may increase heavily (up to a few dozen). Most reservation posts appear to be empty most of the time. The number of reservation post can for all stations be halved with only a slight increase in waiting time.

Apart from a review of the planned situation and most likely variations therein (the scenarios), we have investigated the reduction of the number of reservation posts and the impact on passenger service. This also
resulted in insights into the best locations for the reservation posts, since these reservation posts appeared to be most heavily used.

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REFERENCES