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Field Experiments with Train Stopping Positions at Schiphol Airport Train Station in Amsterdam, Netherlands

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The train station beneath Schiphol Airport in Amsterdam, Netherlands, is one of the fastest-growing ones in the country. Passenger growth has resulted in severe congestion at platforms, a situation that hinders passenger processes at the platform, particularly the boarding and alighting processes. This situation has a negative impact on station dwell times. Inefficient movement of pedestrian traffic at Schiphol Airport train station, a primary hub in the national railway network, has negative consequences for many trains and passengers in that network. In the short term, efficiency improvements are the only viable option to cope with passenger growth. An unfavorable stopping position for trains has been identified as a potential source of the inefficiency. The station layout causes concentrations of boarding passengers at doors in the front sections of trains. Because of these concentrations, the exchange of passengers and the station dwell times take longer at this station than necessary. Because existing research did not provide generalized insights, Netherlands Railways and Delft University of Technology in the Netherlands have conducted a series of field experiments. The main objective was to test whether adjustments of the train stopping position along the platform would result in lower station dwell times because of a more efficient process of passenger exchange. A slight adjustment of train stopping position resulted in a 20% decrease of station dwell times during peak demand and contributed to railway capacity. Moreover, dwell time variation decreased by approximately 50% and thereby promoted more robust train operations (punctuality).

The train station beneath Schiphol Airport in Amsterdam, Netherlands, is among the fastest-growing ones in the country. Schiphol Airport train station is the sixth largest station in the country, with 24 million alighting and boarding train passengers and 4.5 million train–train transfers per year. It is considered a bottleneck in the national railway network. Passenger growth (+150% since 1992) has resulted in severe congestion in the station's pedestrian infrastructure. This congestion hinders passengers' processes at the platform, particularly the boarding and alighting processes, and has a negative impact on station dwell times.

Inefficient movement of pedestrian traffic at Schiphol Airport train station, a primary hub in the national railway network, has negative consequences for many trains and passengers in the Netherlands. (Figure 1). Because the station is situated in a rail tunnel under the airport, capacity expansion by enlarging platforms and vertical infrastructure capacity would be expensive and take years to build.

In the short term, efficiency improvements are the only viable option to cope with passenger growth. An unfavorable stopping position for trains has been identified as a potential source of inefficiency. The locations of the platform entries—escalators and stairways that connect the railway tunnel to the surface level—have been observed to cause concentrations of boarding passengers at the doors of the front sections of trains. Because trains in the Netherlands depart when all passengers have boarded, these concentrations were expected to have a negative impact on station dwell times. Moreover, because Schiphol Airport train station is used by many airline passengers, the presence of luggage could be a relevant factor.

Because knowledge on this topic is limited, Netherlands Railways and Delft (the Netherlands) University of Technology have conducted a series of field experiments. The objective of these experiments was to do systematic testing of several train stopping positions and then assess the impact on the station dwell times. The results of the field experiment are presented in this paper.

The paper structure is as follows: the next section contains a review of previous research and is followed by a description of Schiphol Airport train station. Next, the setup of the field experiment is described, and then the selection of observations, sample sizes, and statistical tests are discussed. Outcomes are then presented, and the paper concludes with the practical and scientific implications of this field experiment.

REVIEW OF PREVIOUS RESEARCH

The capacity of a railway line is determined by the minimum time between two trains, referred to as the "headway." The lower this headway is, the more trains per hour can run on the same line. Other things being equal, headways tend to be higher at train stations than at the line between train stations, as in most cases, train stations are not designed for simultaneous stopping of trains in the same direction (*1*). Therefore, the capacity of an entire line is determined by the station that causes the largest headways.

Although labeled differently, three categories of factors that determine station capacity have been identified by both Vuchic (*1*) and Parkinson and Fischer (*2*). The first is the operating safety regime that defines the signalized track sections and introduces operating buffer times between trains. The operating safety regime is aimed at keeping the safety risks within acceptable margins. The second category consists of the dynamic characteristics of the rolling stock. Together with the operating safety regime, acceleration characteristics define the minimum time between the departure of two trains.

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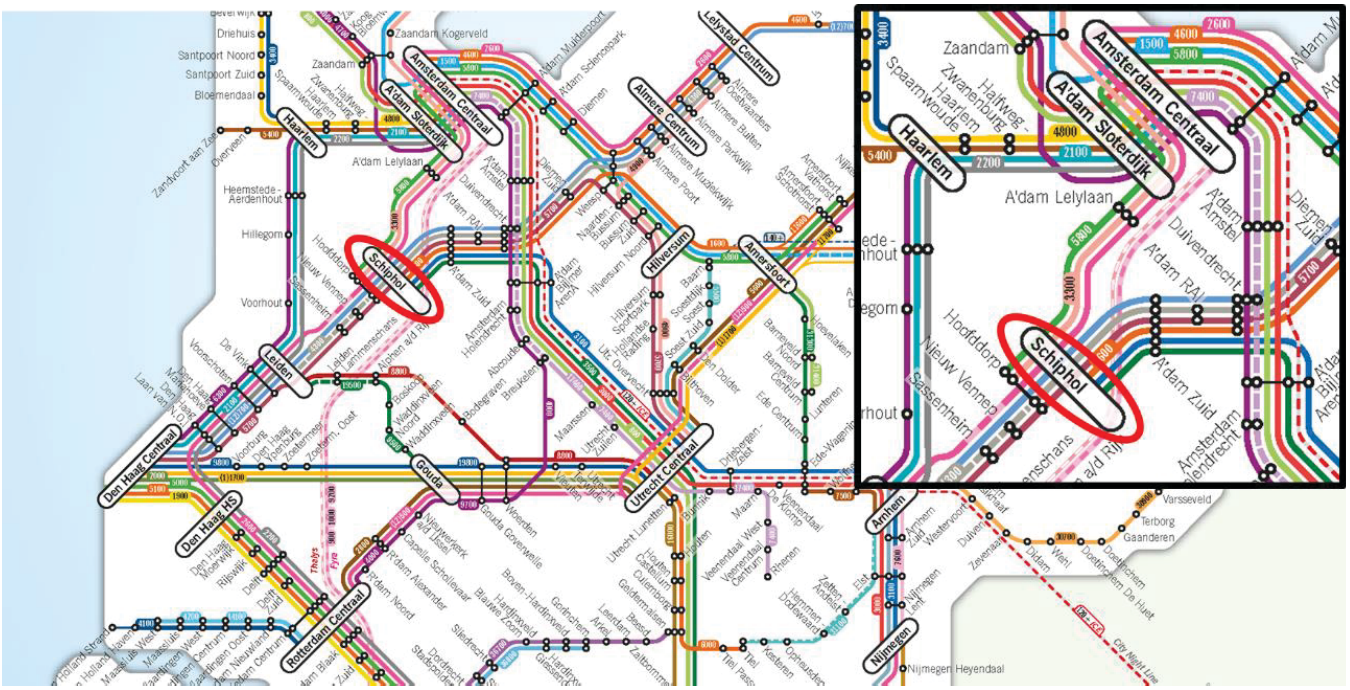


FIGURE 1 Schiphol Airport train station in Dutch railway network.

Similarly, braking characteristics define the minimum time between the arrival of two trains.

The train standing time at the station is the third category. This time is defined by the preparation for passenger exchange after arrival, the passenger exchange, and the preparation for train departure. The first and last of the three categories are considered system factors determined by technical characteristics of the train unit (e.g., door opening time) or by processes controlled by the operator (e.g., staff behavior and arrival–departure procedures). The passenger exchange time is determined by the interaction between trains and pedestrians. This factor is partially beyond control of the operator.

The passenger exchange time can be defined as a function of the number of alighting and boarding passengers, the number of doors in the train unit, the platform-to-vehicle floor-height difference, the fare-collection system, the design of the doors, in-train door areas and aisles, and the mix of passenger flow (*1, 2*). As the number of passengers and their distribution across train doors are the main issues for this study, the remainder of this section provides elaboration on these factors. Because of the case-specific factor of the presence of luggage, it is also included.

Lam et al. investigated the relationship between the number of passengers and the train dwell time at three subway stations in Hong Kong (*3*). They reported a well-fitted generalized linear equation for the station dwell time at the city's Mass Transit Railway stations on the basis of the number of alighting and boarding passengers. A similar study was performed by Puong in relation to the Massachusetts Bay Transportation Authority and showed that a nonlinear polynomial function based on the average number of standees per door results in a better approximation of the total boarding time (*4*). Studies by Lehnhoff and Janssen (*5*) in the subway of Berlin and Olsson and Haugland (*6*) in the greater Oslo, Norway, area also reported strong and significant relationships between the number of passengers and the station dwell time, although no mathematical functions were reported.

In these previous studies, a uniform distribution of boarding passengers was assumed, implicitly or explicitly. Several other researchers have investigated the impact of a nonuniform distribution. In research at two light-rail transit stations in Calgary, Alberta, Canada, Wirasinghe and Szplett found that the distribution of alighting and boarding passengers across train doors has a significant impact on station dwell times (*7*). In data from a suburban station, they reported usage of the maximum train door to be 15% higher than the average train door. They showed that well-positioned platform entrances are important for keeping station dwell times as low as possible. Wiggenraad reported concentrations of boarding passengers at the platform entrances in his study at seven train stations in the Netherlands (*8*). Between 15% and 28% of boarding and alighting passengers was observed to take the most-used train door during a station dwell. Moreover, the effect of clusters of passengers—boardings–alightings within 3 s of their predecessor—at specific doors was investigated in this study. The findings did not confirm whether an equal distribution of boarding passengers across the platform results in shorter dwell times of trains. Therefore, this issue is left as a topic for further research. Lee et al. stated that the alighting distribution is a "reflection of previous boarding" and noted that strategic boarding behavior may have an influence (*9*). This behavior refers to passengers boarding a train at station A at a location that is optimal for alighting and exiting at station B. Boarding passengers were reported to concentrate at the train doors close to the platform entrances.

In relation to the presence of luggage, Lee et al. reported a (slightly) higher average boarding time because of luggage at Schiphol Airport train station compared with that at the Delft station (*9*). The researchers concluded that the effect of luggage becomes critical when the height difference between platform and train floor becomes large. In laboratory experiments, Daamen et al. performed an in-depth investigation of the effect of luggage (*10*). They reported that the presence of luggage caused a decrease in boarding and alighting capacity of up to

25%. This finding is consistent with the findings of Heinz in both the subway of Stockholm, Sweden, and regional and intercity trains on the Swedish national rail network (*11*).

This literature review has revealed that boarding and alighting times are important factors for train dwell time at stations, which in turn is a dominant element in the capacity of the entire rail line. No generalized model can currently predict the impact of interventions in the passenger process on the standing time of trains at the station for specific cases, for example, the effects of interventions to improve efficiency at Schiphol Airport train station. Only Puong reported on the impact of efforts to reduce station dwell times by interventions in the passenger boarding and alighting processes (*4*). In his literature review, he reports that the Metropolitan Transportation Authority of New York has improved station dwell times by 10% during rush hours at Grand Central Station. Neither a reference nor details about the interventions have been reported.

CASE DESCRIPTION

Schiphol Airport train station consists of three central platforms (Figure 2*a*) that provide six platform tracks for trains to stop, three in each direction. The lower-numbered tracks are used by trains heading toward Amsterdam and Utrecht, Netherlands, and the higher-numbered tracks are used by trains heading for The Hague and Rotterdam, Netherlands. During peak hours, each platform track is used by approximately eight (heavy-rail) trains per hour, or approximately 24 trains per hour per direction and 48 trains per hour for the station. To allow the maximum train length in Europe [a two-set Thalys (TGV) train of 400 m], each platform (track) is 430 m long. Because of the maximum length of trains operating in the Netherlands, only 300 m are currently used.

Trains that run through Schiphol are very diverse. However, three train types are dominant. The first and second types are double-deck intercity trains (Figure 2*b*) and single-deck regional trains (Figure 2*c*) that run on the conventional rail network. The third type consists of single-deck intercity direct trains that run between Rotterdam and Amsterdam via the high-speed south line (Figure 2*d*). Figure 2 includes the main characteristics of each type of train service.

In the Netherlands, passengers at train stations do not receive any information about the train composition (e.g., length, single or double deck, door positions) because of the diversity in rolling stock and train lengths and technical limitations to present real-time, dynamic information about train composition and stopping positions at the platforms.

The passenger exchange process is based on simultaneous alighting and boarding at all train doors. Under normal circumstances, train or station personnel do not actively intervene in the alighting and boarding processes. At Schiphol Airport train station, most departing passengers enter the platform via the two escalators at the Amsterdam side of the platform (right side of Figure 2*a*).

At Schiphol Airport train station, train traffic at the outer unidirectional platforms is controlled by a system that automatically assigns trains to platform tracks on the basis of the first-come, first-served principle. It is designed to maximize utilization of the railway lines around Schiphol Airport and to unburden train traffic controllers (*12*). Until approximately 3 min before train arrival, the specific track (i.e., Track 1 or 2, 5 or 6) from which a train will depart is unknown. The platform is known, so the uncertainty is only in the side of the platform from which a train will leave. When a train has been assigned to a particular track, the train information screens are updated and inform passengers waiting on the platform. This system has implications for the behavior of boarding passengers.

The majority of passengers—familiar or unfamiliar with Schiphol Airport train station—tend to wait at the central sections of the platform, close to the escalators and stairs, where the information screens are also located. Most departing passengers use the two escalators at the Amsterdam side of the platforms because of the layout of the station hall on the ground level. The combination of these behavioral effects results in concentrations of boarding passengers at the doors of the first cars of each train.

SETUP OF FIELD EXPERIMENT

The objective of the experiment was to test whether adjustments of the train stopping position along the platform results in lower station dwell times. Adjusting the stopping position of a train makes more doors available for boarding passengers waiting at the Amsterdam end of the platform. This group is a large share of total boarding passengers (because of the station's layout), and such an intervention was expected to trigger a more favorable distribution of boarding passengers across train doors. As this change results in a more efficient use of total door and platform capacity, station dwell times we are expected to decrease.

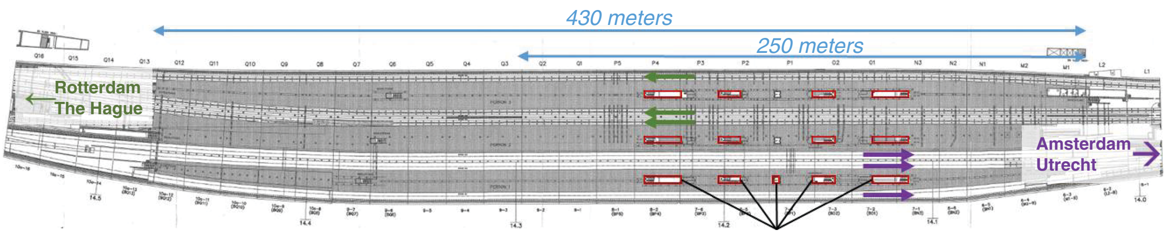
In the Netherlands, the train stopping positions are communicated to the driver by signs placed beside the tracks. Each platform at Schiphol Airport train station has multiple signs because the train stopping positions depend on the length of the train. Train position signs can be temporarily overruled by the placement of a blue signal at the platform (Figure 3*a*). In this situation, the driver is requested to stop at the position of the signal (Figure 3*b*). In Dutch railway regulations, both the signs and the blue signal are considered recommendations. The regular red–yellow–green signals are mandatory signs.

The experiment was performed at Platform 1–2 because it is the narrowest one at the train station. Its limited width was expected to generate the largest (if any) effect from the adjusted train stopping location on the alighting and boarding processes (Figure 3*c*).

On the basis of the scheduled train composition (rolling stock type and train length), for the experiment, each train was assigned a stopping location that was either the original stop location according to the track signs (control group) or the adjusted stop location 50 m downstream (experimental group). Figure 3, *d* and *e*, illustrates the difference in train positions for two double-deck, six-car intercity services from Schiphol Airport train station to Amsterdam Central Station.

The field experiments were performed during the weeks of September 9 to 13 and September 16 to 20, 2013. The days of September 23 to 26 served as a backup pool that could be used if the experiment could not be performed on a particular day during the first 2 weeks.

As passenger traffic is highest during workdays, the experiments were limited to those days. Within the workdays, passenger traffic peaks between 08:00 and 09:00, when many commuters arrive or transfer at Schiphol Airport train station. During this hour, the number of departing train passengers is relatively small although not insignificant. Passenger traffic peaks again between 10:00 and 11:30, after the morning peak of flights arrives at the airport. With a 1- to 2-h delay, a flight arrival peak results in a peak in departing train passengers at Schiphol Airport train station. During this hour, the number of arriving train passengers is low although not



(a)

Intercity service characteristics
- Double-deck, electrical multiple unit
- 4 to 12 cars per train (1 to 3 units)
- Length of 100 to 300 m
- Wide doors, 2 sets per car
- 2-step height difference between vehicle floor and platform

(b)

Regional train service characteristics
- Single-deck, electrical multiple unit
- 4 to 12 cars per train (1 to 3 units)
- Length of 70 to 210 m
- Wide doors, 1 or 2 sets per car
- No height difference between vehicle floor and platform

(c)

Intercity direct service characteristics
- Single-deck, pulled cars
- Engine with 6 cars
- Length of 175 m
- Mix of narrow and wide doors, 2 sets per car
- 2-step height difference between vehicle floor and platform

(d)

FIGURE 2 Platform layout and characteristics of train services at Schiphol Airport train station: (*a*) platform size and directions, (*b*) intercity service, (*c*) regional service, and (*d*) intercity direct service.

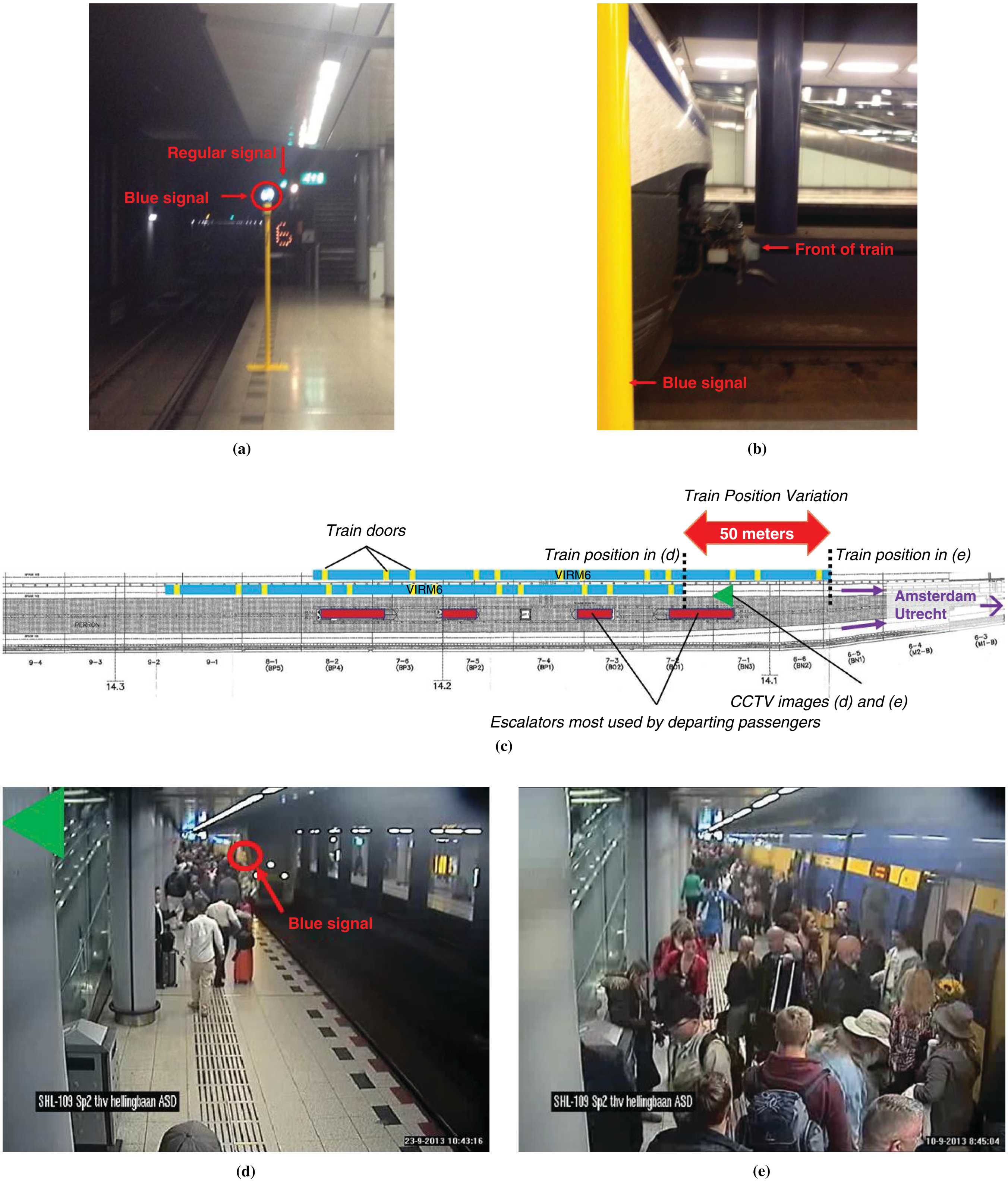


FIGURE 3 Signals and adjustment of train stopping position: (*a*) blue signal and regular signal, (*b*) side view of front of train at blue signal, (*c*) variation in train stopping position, (*d*) example of passenger distribution with original stopping position, and (*e*) example of passenger distribution with adjusted stopping position (CCTV = closed-circuit television).

insignificant. From 09:00 to 10:00, the train arrivals and departures are balanced.

Because Schiphol Airport train station is part of the national railway network, trains do not arrive at Schiphol at regular intervals. The experiments were limited to trains arriving and departing in the 11 min between 10 and 21 min after the hour and 40 and 51 min after the hour. These time blocks have the most intense train traffic, with four trains scheduled to arrive and depart. Moreover, these blocks include all common train types at Schiphol Airport train station and common passenger characteristics (Table 1). The time between the 11-min blocks was used to adjust the positions of the blue signals on both sides of the platform.

During the experiment, four types of data were collected: visual recordings, rail traffic management data, security camera footage, and tickets sales data. Visual recordings for each train stop were made by the research team. For each train, a member of the research team recorded operational deviations (e.g., a different train length or rolling stock type), operational issues (e.g., defective rolling stock), and the stopping position (i.e., deviations from the blue signal location). Realized arrival times and departure times of each train have been derived from track occupation data from the rail traffic management system. By comparing the realized arrival and departure times with the train schedule, arrival and departure delays and standing times at the platform were calculated. Time stamps of the color changes of the signals at the end of both platform sides were obtained from the rail traffic management system. Security camera footage (closed-circuit television) has been used to verify the train stopping position and to check for events that might cause a validity issue for the test results.

Ticket sales data were used to classify the days of the field experiment as either peak or nonpeak. This classification acted as a proxy for passenger demand. Until mid-2014, the fare collection system in the Netherlands was based on paper tickets (singles and returns) for infrequent travelers and visitors, while most frequent travelers used a season card. Validation before boarding a train was not required for most paper tickets and season cards, and in-train validation was based on random, visual inspection by train staff without registrations. Therefore, data on the numbers of alighting and boarding passengers of each train were not available.

For several reasons, passengers were not informed about the experiment. First, doing so could have resulted in a bias because of adjustments in behavior as a result of awareness about the interventions (Hawthorne effect). Second, changing train stopping positions by using a blue signal is a standard operational and commonly used intervention in the Netherlands and does not require any communication to passengers. Third, behavior of individual passengers was not recorded during the experiment, as individual trains were the unit of observation. Therefore, no (potential) privacy issues were identified. Fourth, specialized, licensed staff was present to supervise the field experiment. When, for any reason, an intervention in the stopping position of a train was expected to result in an elevated safety risk, the intervention was not executed and the train was excluded from the sample.

SELECTION OF OBSERVATIONS, SAMPLE SIZES, AND STATISTICAL TESTS

The main methodological challenge with experiments in an operational environment is to isolate the impact of an independent variable on a dependent variable from exogenous factors (*13*). When this isolation is done incorrectly, exogenous factors can unintendedly be attributed to the causal relationship and result in biased research outcomes. In this study, the train stop location was the independent variable. The station dwell time was the dependent variable. The boarding and alighting processes are intervening (mediator) variables. All other factors are exogenous variables. On the basis of the literature review, the following categories of exogenous factors were identified for this experiment:

1. Passenger characteristics, particularly the presence of luggage and the mix of boarding and alighting passengers. Both luggage and bidirectional flows cause a decrease in pedestrian flows, which result in an increase in a train's station dwell time. To control for these factors, the experiment was performed on the same platform and a time frame selected that resulted in constant and representative passenger characteristics (Table 1).
2. Train characteristics, particularly the number of doors; the platform-to-vehicle floor-height difference; and the design of doors, in-train door areas, and aisles. As in Item 1, these factors have an influence on pedestrian flows and a train's station dwell time. To control for these factors, the entire experiment was performed on the same platform and a time frame selected that resulted in representative train characteristics (Table 1).
3. Platform layout, specifically insufficient space on the platform, which can have an adverse impact on the pedestrian flows at the platform. Because arriving passengers have to alight before departing passengers can board the train, insufficient platform space has a

TABLE 1 Train and Passenger Characteristics

Minute	Service Series (Figure 1)	Direction	Train Characteristics (Figure 2)	Typical Alighting Passenger Characteristics	Typical Boarding Passenger Characteristics
.10/.40	4,300	Amsterdam CBD (South) and convention center (RAI)	SPR (Figure 2*c*)	Mix of commuters and Dutch airline passengers with luggage	Dutch and non-Dutch business passengers with or without luggage
.13/.43	2,600	Amsterdam Central	IC (Figure 2*b*)	Mix of commuters and Dutch airline passengers with luggage	Non-Dutch tourists with luggage
.16/.46	3,500	Utrecht Central	IC (Figure 2*b*)	None; service starts at Schiphol.	Commuters and Dutch airline passengers with luggage
.21/.51	900	Amsterdam Central	ICd (Figure 2*d*)	Commuters and Dutch airline passengers with luggage	Non-Dutch tourists with luggage

NOTE: CBD = central business district; RAI = Amsterdam RAI Exhibition and Convention Center; SPR = regional train service; IC = intercity train service; ICd = intercity direct train service.

direct impact on a train's station dwell time. To control for this factor, the experiment was performed on only one platform (Figure 3*c*).

4. Any actions by train or station staff to speed up the boarding and alighting processes results in variations in the station dwell time that cannot be attributed to the stopping position of the train. Instructions from the research team prevented staff interventions. Trains for which staff intervened in the boarding and alighting processes (e.g., because of safety procedures) were excluded from the sample.

5. When a train arrives ahead of schedule, it waits at the platform until the scheduled departing time, whether passengers are waiting on the platform or not. During the experiment, this situation did not occur because all trains at Schiphol Airport train station intentionally arrived slightly behind schedule to maximize track capacity. Similarly, a red signal at the platform end (Figure 3*a*) keeps a train at the platform even when no passengers are boarding and alighting any longer. To control for this factor, trains that (still) had a red signal at the end of the platform 60 s or more after arrival were excluded from the sample.

6. Operational issues, varying from defective rolling stock to incidents on the platform that have consequences for the departure procedure, can extend the platform standing time of a train beyond that required for the alighting and boarding of passengers. When any of these issues occurred, the train was excluded from the sample.

7. To minimize disobeying of the blue signal, each train driver was reminded of the experiment by a phone call from traffic control as the train approached Schiphol Airport train station. If the driver positioned the train at an incorrect position despite the reminder, the observation was either excluded from the sample or moved from the experimental to the control group.

8. Variations in the number of boarding and alighting passengers are expected to result in variations in the train standing time at the platform. Causes of variations are twofold. First, delays or cancellations of trains cause peak loads of respectively delayed trains and trains that arrive after a canceled service. To control for this factor delayed trains were excluded from the sample. Moreover, days with multiple service cancellations per hour were excluded. During the experiment, a severe service disruption occurred on Monday, September 9, because of a track failure. Therefore, the experiment was canceled for that day and was instead run on Monday, September 23. Second, variation in traffic demand is a cause of variation in passenger numbers. To control for this factor peak and nonpeak times were defined and observations stratified accordingly. Because data on passenger numbers per train were unavailable, a proxy based on hourly ticket sales was used. To classify each day as peak or nonpeak, the ratios of the morning ticket sales (08:00 to 12:00) of each day to the mean morning tickets sales of all experiment days were calculated. A day was classified as peak when this ratio was greater than 1 (busier than average) and as nonpeak when it was less than 1 (less busy than average) (Table 2).

Figure 4 illustrates the composition of the sample of observations. The gross sample of the field experiment consisted of 280 observations (10 days times 28 trains per day). Because of the presence of one or more exogenous factors, 84 observations were potentially biased. After their removal from the sample, the net sample consisted of 196 observations. Of those, 119 were classed as nonpeak (60%) and 77 as peak demand (40%) observations. The nonpeak sample consisted of 99 control group observations (train stopping at the original position) and 20 experimental group observations (train stopping at the adjusted position). The uneven distribution of observations between the experimental and the control groups was caused by a regrouping of trains because of operational issues during the first 2 days of the experiment. Although low, a sample size of 20 observations for the experimental group was considered sufficient for statistical testing. The peak sample consisted of 47 control group and 30 experimental group observations. Sample sizes were too small for testing subsets of observations (i.e., different train compositions).

RESULTS

To test for significant differences in the observed mean station dwell time, four independent-sample *t*-tests were performed (Figure 4). First, to check the validity of the peak and nonpeak classifications, a *t*-test was applied to the full sample of 196 observations, grouped in 119 nonpeak and 77 peak observations (Test 1). The test results revealed that the mean difference of the station dwell time was 17 s: 131 s for days with high passenger volumes and 114 s during days with low passenger volumes (Table 3). The two-tailed significance of .03 indicates that this difference is systematic. The 95% confidence interval of the difference is [–32, –2]. This result is consistent with the findings of previous research.

Second, a *t*-test was applied to the full sample of 196 observations, grouped in 146 original-position (control group) and 50 adjusted-position (experimental group) observations (Table 4). The two-tailed significance of .39 indicates that this difference cannot definitely be attributed to the change in train positions but can also be caused by random variation. A third *t*-test was applied to observations on nonpeak day only (119 observations). Similar to the second *t*-test results, no statistically significant difference between both groups was found.

TABLE 2 Classification in Nonpeak and Peak Days

Hour	Tue. 9/10	Wed. 9/11	Thu. 9/12	Fri. 9/13	Mon. 9/16	Tue. 9/17	Wed. 9/18	Thu. 9/19	Fri. 9/20	Mon. 9/23
8:00	0.80	0.86	1.19	1.29	1.06	1.04	0.88	1.09	0.97	0.82
9:00	0.85	0.81	1.09	1.26	1.12	0.92	0.84	0.90	1.33	0.87
10:00	0.66	0.82	1.16	1.27	1.02	0.92	0.89	1.05	1.26	0.94
11:00	0.68	0.85	1.20	1.12	1.04	0.98	0.90	0.96	1.21	1.05
8:00–11:00	0.76	0.83	1.16	1.24	1.07	0.96	0.87	0.99	1.21	0.92
Day's classification	NP	NP	P	P	P	NP	NP	NP	P	NP

NOTE: NP = nonpeak day; P = peak day.

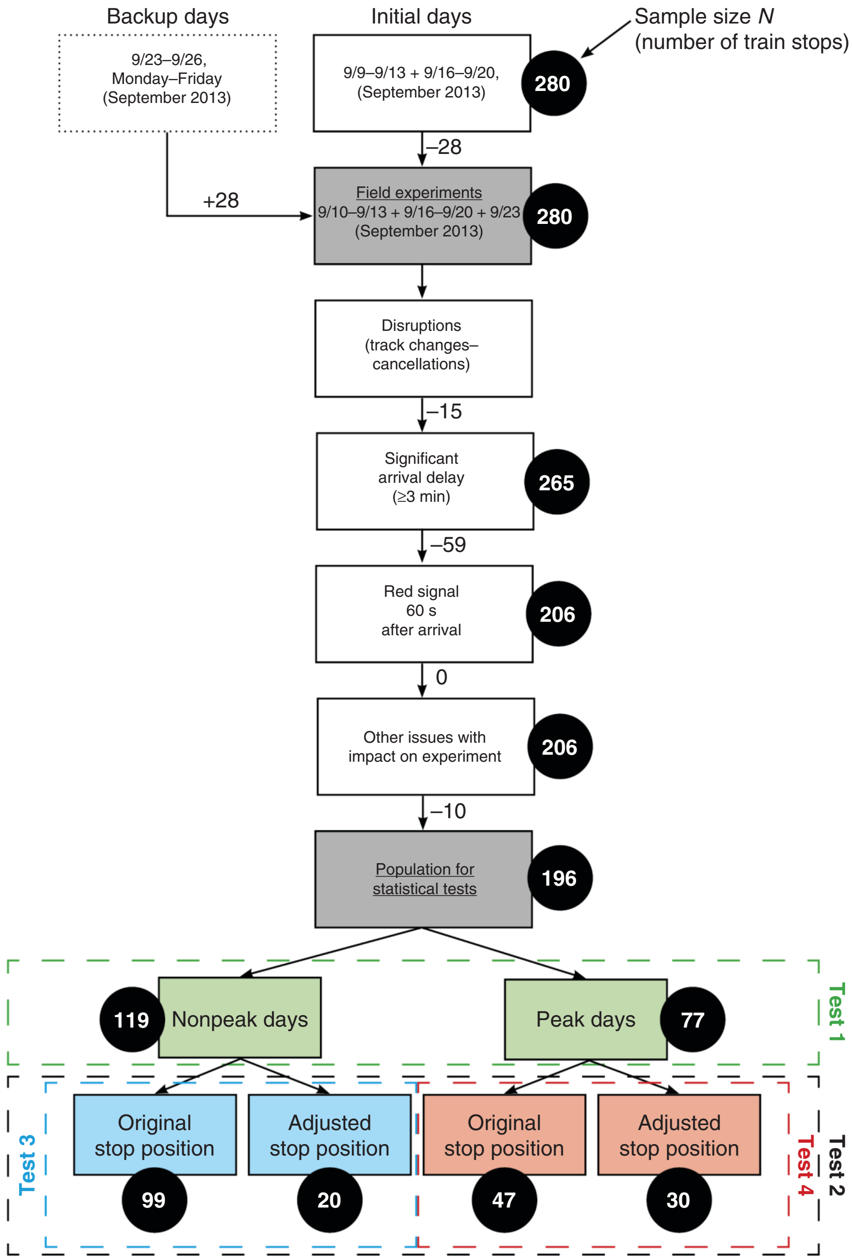


FIGURE 4 Overview of selection of observations, sample sizes, and statistical tests.

TABLE 3 Results of Statistical Test: Nonpeak Day Versus Peak Day Demand

	Nonpeak Demand			Peak Demand			Independent Samples *T*-Test					
Test	μ (s)	σ (s)	*N*	μ (s)	σ (s)	*N*	*t*	df	Sig.	Δμ	95L	95U
1. Demand^{NEV}	114	45	119	131	57	77	–2.3	135	.03	–17	–32	–2

NOTE: NEV = variances are not assumed (based on Levene's Test for equality of variances); sig. = 2-tailed significance; 95L/U = lower–upper boundary of 95% confidence interval of the difference; df = degrees of freedom.

TABLE 4 Results of Statistical Tests: Current Versus Adjusted Stop Position of Trains

	Original Position			Adjusted Position			Independent Samples *T*-Test					
Test	μ (s)	σ (s)	*N*	μ (s)	σ (s)	*N*	*t*	df	Sig.	Δμ	95L	95U
2. Full N^{EV}	122	56	146	115	32	50	0.9	194	.39	7	–9	24
3. Nonpeak^{NEV}	112	47	99	122	32	20	–1.1	37	.28	–10	–27	8
4. Peak^{EV}	144	66	47	112	31	30	2.6	75	.01	32	7	59

NOTE: EV = variances are assumed (based on Levene's Test for equality of variances).

The fourth *t*-test was applied to observations on peak days only (77 observations). The test statistics indicated that station dwell times of the trains in the experimental group were significantly lower (two-tailed significance of .01) than those of trains in the control group. The mean difference was 32 s, and the 95% confidence interval of the average difference ranged from 7 to 59 s. The standard deviation of the average station dwell times of the experimental group (31 s) was more than 50% lower than the standard deviation of the control group (66 s).

CONCLUSIONS

The results of this field experiment indicate that an adjustment of the train stopping position by approximately 50 m in the downstream direction decreases station dwell times by 30 s when passenger demand is high. Mean station dwell times decrease from 144 to 112 s. This effect does not occur when passenger demand is low.

Moreover, the results indicate that variation in station dwell time decreases by more than 50% with an adjusted stopping position for the trains. A decline in variation in dwell time contributes to more-robust train operations. Again, this effect does not occur when passenger demand is low.

From a practical perspective, the findings of this study prove that passenger processes at the platform can have a significant impact on train traffic operations. Because Schiphol Airport train station is a main bottleneck in various railway lines in the Netherlands, a decrease of head times by 30 s generates additional railway capacity. Similarly, a reduction in the variation of dwell time resulted in a high punctuality that contributed to customer satisfaction.

From a scientific perspective, one may conclude that the findings of this field experiment are consistent with the findings of previous research. Higher passenger numbers have been confirmed to cause longer station dwell times. In addition, uneven passenger distributions across train doors have been confirmed to have a significant and measurable impact.

Although the results are valuable for both science and practice, this experiment has not generated insights into the underlying dynamics that cause station dwell times to change when the train stopping location is changed. Moreover, as passenger data per train were unavailable, determining and quantifying the causal relationship between the station dwell time and the number of passengers, door distributions, and the characteristics of the passenger flows (e.g., uni- or bidirectional flows, presence of luggage) were not possible. These topics are open for future research.

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