PASSENGER BOARDING TIME, MOBILITY AND DWELL TIME FOR HIGH SPEED 2

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High Speed 2 (HS2) has a challenging dwell time of 2 minutes at some of its stations. Achieving this will be influenced by a number of factors including the platform-train interface and the relative heights of each. This paper will describe the research relating to the effect of the height difference and the provision of steps on the dwell time. The project also looked at the impact of passenger demographics and passengers with luggage on boarding and alighting times. The main experimental research was conducted in collaboration with University College London, using the PAMELA research facility to build a rig of the train and platform for testing with subjects. We also conducted a number of real life observations at train stations within the UK to validate the experimental findings. The research programme also included a literature review and observational study to examine issues around mobility and ageing that affect walking speed and movement around the station. This also used another CCD/HS2 research project that looked at the demographics of the future passenger population and how this would impact on passenger movements. The research programme made a number of recommendations around the configuration of the platform-train interface to optimise boarding times.

Introduction

A key component of the operational plan for HS2 is the provision for a 2 minute dwell time at intermediate stations. For Phase 1 of the project this includes Old Oak Common Station and Birmingham Interchange. The ability to achieve this dwell time on a consistent basis is critically important for achieving the planned capacity, delivering the right passenger experience and end-to-end journey times.

The optimum solution for minimising boarding time and improving accessibility is level access from platform to train. However, the HS2 project is required to comply with the European Technical Specification for Interoperability (TSI). The relevant TSIs for train design and station design specify the platform height to be adopted. The nature of the design of most high-speed trains and specifically their interior floor height necessitates stepped access from a TSI-compliant platform. For HS2, the train design is also conflicted in having to accommodate the normal UK station platform heights when the "classic" HS2 train service stops at non-HS2 stations.

The achievement of a particular dwell time is a complex interaction of engineering, environment, systems and human behaviour. The passengers boarding or alighting from the train is only one part of the process. The 2-minute dwell time is actually the time from 'wheel stop to wheel start'. So it includes the time for the doors to unlock and open, for the doors to be closed again and all safety checks to be carried out before the train departs. The time remaining for passengers to physically board and alight was calculated at 1 minute 35 seconds.

There are many design factors that influence passenger behaviours and therefore, the boarding and alighting time. These include the exterior door width, the entry step height, platform gap, the layout of the vestibule, how and where luggage is stored, how passengers find their seat and the quality of information provided to passengers on the platform and on board.

The project was designed to answer the following research questions:

- What is the effect of the height difference between platform and train and the provision of steps on the dwell time?
- How is the dwell time impacted, under the different platform-train interface conditions, by the demographics of the passenger population?
- What is the effect of luggage on boarding and alighting times?

Method

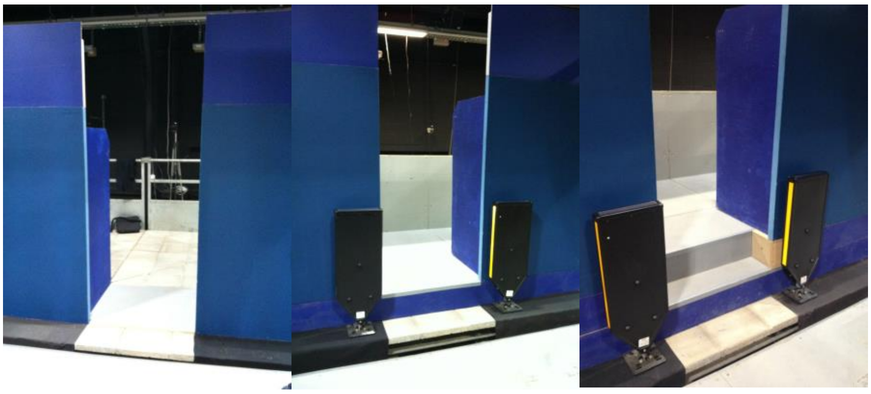
The project undertook a controlled, experimental study and validated the findings with a real-life observational exercise.

Experimental Study

CCD and HS2 collaborated with University College London using their PAMELA test facility. A mock-up of the train and platform was constructed that provided a single door entrance to the train and allowed three vertical heights of the platform-train interface to be tested. The rig design was based on a constant height of the train interior floor of 1,240mm from the railhead. The rig design also assumed an 80mm horizontal gap from train step to platform. A door width of 900mm was provided to reflect typical high-speed train designs.

The experiment examined three variants of platform height and platform-train interface (photographs are provided in Figure 1 and an illustration in Figure 2):

1. Level access – a platform height of 1,200mm with a 300mm horizontal gap filler step on the train exterior resulting in a small 20mm lip at the door. One key assumption was that level access would not be totally level or flat.
2. UK platforms – a platform height of 890mm with a 300mm step on the train exterior at 1,010mm
3. European TSI platform – a platform height of 730mm with a 300mm step on the train exterior at 780mm, an interior step at 1,010mm and a final step into the train interior.



Level Access One Step (UK) Two Steps (TSI)

Figure 1: Photographs of the Three Rig Configurations

The experimental study was conducted with 60 participants with a demographic split as shown below. Due to the timescale of the project it was not possible to align the participant recruitment accurately with anticipated passenger demographics.

- Ages 20-27 – 15% of participants
- Ages 28-37 – 26%
- Ages 38-47 – 22%
- Ages 48-57 – 10%
- Ages 58-65 – 20%
- >65 – 6%

The participants were randomly assigned a piece of luggage to carry during some of the test conditions. For health & safety reasons the luggage was not loaded and therefore, the impact of luggage weight will be less than in the real world. The types of luggage were as follows with the approximate proportion allocated to the participants:

- Rucksack (45%)
- Small suitcase (wheeled airline-style hand luggage) (17%)
- Large wheeled suitcase (17%)
- Pushchair (9%)
- No luggage (12%)

Three different loading scenarios were tested for each of the three rig conditions:

1. Full boarding – all 60 participants boarding the train from the platform
2. Mixed boarding & alighting – 30 passengers boarding and 30 alighting
3. Full alighting – all 60 participants alighting from the train

Over the test period 130 experimental runs were conducted resulting in 7,800 passenger movements. At the end of each testing day, participants were provided with a questionnaire to rank how difficult the found boarding and alighting under each condition.

More information can be found on the experimental design and the detailed results in Holloway, C., Thoreau, R., Roan, T-R., Boampong, D., Watts, D. & Tyler, N. (2015).

Observational Study

To complement the experimental study, a number of real life observations were made of passengers boarding and alighting. Observations were made at the following sites with different rolling stock observed at each:

- Paddington station – Class 332 Heathrow Express
- St Pancras International station – Class 373 Eurostar and Class 395 Javelin
- Ebbsfleet International station - Class 373 Eurostar and Class 395 Javelin
- Swindon station – MKIII coach
- York station – MKIII coach, Class 220/221 Voyager & Class 365 Networker
- Derby station – Class 222 Meridian
- Stratford International station – Class 373 Eurostar and Class 395 Javelin
- Watford Junction station – Class 350.

The study selected the stations to provide a mix of intermediate and terminating stations and a mix of intercity and urban services. The Heathrow Express at Paddington was selected as the level access condition.

The study observed 465 individual trains arriving and departing and recorded over 1,000 passenger movements. During the observations video recordings were taken and were analysed with the Observer XT software to get timings for individual passengers to board or alight. The luggage carried by each passenger timed was recorded along with a subjective estimate of their demographic grouping.

Experimental Study Results

Effect of Steps on Dwell Time

The mean time for all the passengers under the three conditions, based on the experimental condition of mixed boarding and alighting with luggage, was:

- 2.9 seconds per passenger for level access
- 3.5 seconds per passenger for the UK platform height condition
- 3.9 seconds per passenger for the TSI compliant platform height.

These figures, therefore suggest, that with level access it would be possible for 33 passengers to board or alight at each doorway during the 95 seconds assumed as the usable dwell time period. Under the UK platform condition, this would fall to 27 passengers; and under the TSI condition 24 passengers could board/alight.

HS2 demand modelling suggest, for example, that at Birmingham Interchange station the worst case would be 31 passengers needing to board or alight per doorway, with a more normal demand of 26 passengers. This study suggests that only the level access condition could reliably meet both of these demand conditions with the TSI compliant condition failing on both. It should be noted that the number of passengers per doorway is dictated by the number of doors on the train and this has not yet been determined for HS2.

The results for the all boarding and all alighting condition show that alighting is quicker than boarding with a notable difference in level access (3.0 seconds per passengers boarding vs 2.2 seconds per passenger alighting). This speed difference is decreased when steps are introduced.

Impact of Luggage on Time

The influence of different luggage types on dwell time in each condition is shown in Figures 2 and 3.

In the worst case scenario with all luggage included there is a general increase in dwell time as the difference in the height between train and platform increases together with the number of steps.

Each of the conditions show the same pattern that small luggage items like rucksacks have no real influence on boarding/alighting time when compared to passengers with no luggage.

The larger luggage, especially when carried in hand, does impact. Under level access, there was a 40% increase in the time for a person with a large suitcase compared with someone with no luggage. Perhaps not surprisingly, there is a strong influence of time for the larger luggage items when negotiating steps into/from the train.

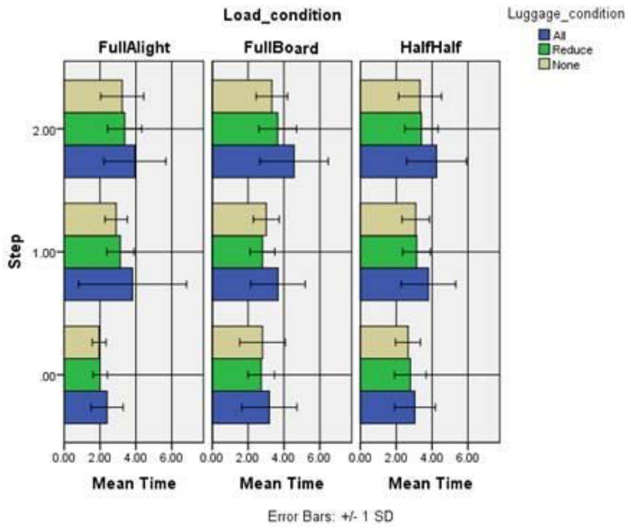


Figure 2: Mean Boarding/Alighting Times for All Conditions

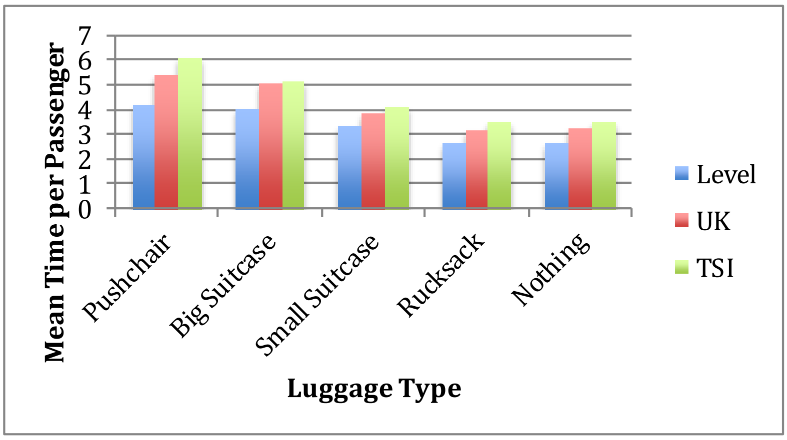


Figure 3: Mean Time by Luggage Type for Mixed Boarding & Alighting

Impact of Passenger Age

Within the mixed boarding/alighting condition, the average time for each of the demographic groups is shown in Figure 4.

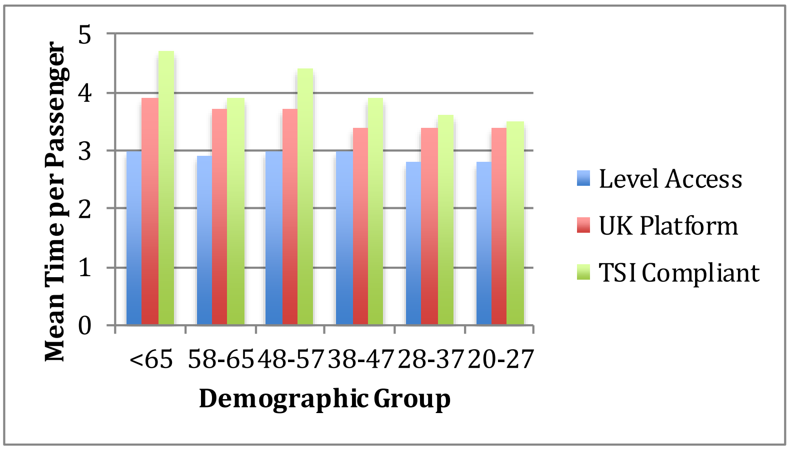


Figure 4: Mean Boarding/Alighting Time by Demographic Group

These results suggest that the impact of age on time to board/alight is marginal in the level access condition but the effect increases with the introduction of more steps with a more marked increase in time with the two steps in the TSI compliant condition. The time difference between youngest and oldest is 0.2 seconds in the level access condition which rises to 1.2 seconds in the TSI compliant condition.

To examine the potential impact of this time difference the study looked at two hypothetical services: a weekday morning service when the demographic split may lean towards a younger, working age group and an off-peak service where there may be more older passengers. The data was used to predict the time taken for 26 passengers to board or alight under the three conditions, see Table 1.

Table 1: Extrapolated Dwell Times for Demographic Variation

	Level Access	UK Platform	TSI Compliant
Commuter Train	75 seconds	91 seconds	101 seconds
Leisure Service	76 seconds	95 seconds	106 seconds

This is intended as a simplistic, illustrative model. However, it does demonstrate the significant impact of steps and how the dwell time is influenced by the demographic when there is a difference in platform and train heights.

When looking at the all boarding or all alighting conditions, the same pattern that was found with the luggage emerged: there was a stronger effect on time in the boarding condition when passengers are stepping up into the train when compared with when passengers are stepping down and alighting and this effect is increased with age.

The study also examined the interaction between luggage carried and passenger age. As one might expect, luggage, especially larger or heavier items had a larger impact on the timings for the older passengers.

Questionnaire Results
Over 50% of participants rated boarding and alighting as "very easy" when there was level access. Fewer rated it the same when they were carrying the large suitcase: the comments related not only to the weight but also to the relative size of the door and the suitcase. Generally, as steps were introduced people found the task more difficult, especially for those carrying a large suitcase or the pushchair. In the condition with more steps the comments shifted in intensity from simply "step too high" to "really a great effort required and proving a lot more difficult". There was no significant difference in how the participants perceived the difficulty of boarding vs alighting.

Observational Study

Boarding and Alighting Time
Figure 5 shows the observed mean boarding/alighting time by step condition and also shows, for comparison, the times from the experimental study.

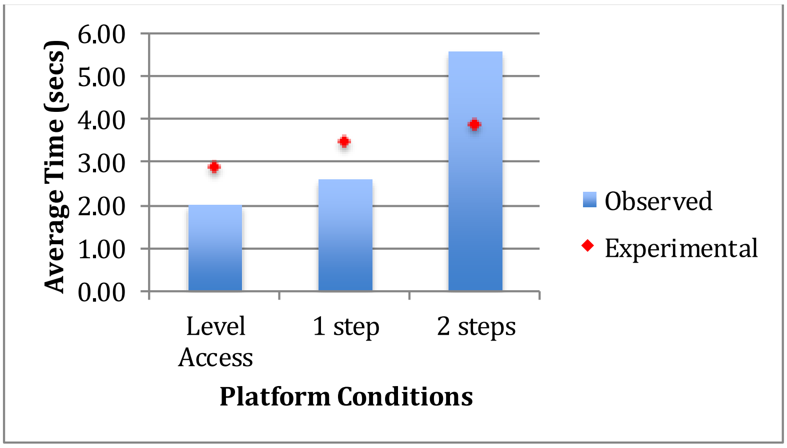


Figure 5: Observed Time by Step Condition

The observed data broadly supports the experimental data across the three step conditions. The times observed for level access and trains with only a single step were faster than the experimental results. This difference could be explained by the wider door widths on the trains observed when compared to the door width on the experimental rig (which was more comparable with door widths on long distance trains such as the Eurostar).

The observed time for boarding/alighting for trains with two steps was significantly slower in the real world observations than in the experimental results.

The results when examined by passenger demographic group followed a similar pattern to the experimental data with little difference in the level access condition and an increasing impact of age on speed with the introduction of steps.

The observational data was also examined to assess the impact of luggage on boarding and alighting speed. As with the experimental study, there was no significant impact of luggage type on time under the level access condition. Under the two-step conditions, there was an increased effect with the larger, heavier luggage which is also consistent with the experimental data. What was notable was that the observations for the trains with two steps suggested significantly longer boarding times for passengers with large luggage than was found in the experimental condition. This might be explained by the fact that empty luggage was used in the experimental study.

What was notable in the observations was the relative frequency of passengers who took a significantly longer time to board or alight – these were passengers with multiple items of luggage and often small children. The experimental study did not require participants to carry multiple pieces of luggage or children in addition to prams.

Discussion and Conclusions

The results of both the experimental study and the observations suggest that boarding and alighting times could be significantly longer than some of the previous studies used by HS2 and other transport organisations. Both studies showed that there is a significant impact when the platform height is different from the train height. The greater the height difference, and the more steps required, the more significant the impact on time. The observational study demonstrates that there is a wide variation in times to board and alight and that factors such as large luggage and passengers with small children in particular can easily increase the boarding time.

Both studies suggest that if HS2 trains are required to have steps to comply with the TSI there is an increased challenge to achieve the dwell time target, especially in peak periods.

Both studies showed the influence of age on speed of boarding and alighting. This is important to HS2 in the context of the aging population and the likely increase in older passengers by the time HS2 is operational. This is likely to add further risk to the dwell time target if there are steps from the platform to the train.

The experimental and observational studies demonstrated how larger and bulkier luggage could influence boarding and alighting speed when there are steps. It is difficult to forecast the profile of luggage that will be carried on HS2 trains and therefore the impact this might have. However, the observational study highlighted how passengers are often carrying multiple items of luggage. In the conditions with steps it was notable how difficult and slow it was to board. A key aim for HS2 is to improve the passenger experience – it was noted how poor the boarding experience was for those with lots of large luggage or small children when steps are present.

Another key objective for HS2 is to set a new benchmark for accessibility and independent travel. Other studies conducted by CCD have concluded that future transport systems like HS2 are likely to face a higher proportion of Passengers with Restricted Mobility (PRM) than is found today due to aging population and current obesity trends. The observational study noted how difficult boarding and alighting is for those with mobility problems or for other PRMs such as those travelling with small children. The study concluded that it is only by providing level access that HS2 can achieve the accessibility objectives that it has set.

The study made a number of observations in relation to train design and dwell time:

- A wider door width was observed to support easier and what appeared to be faster flows of people. Moving luggage through a wider door was notably easier.
- The observation noted how important it is for boarding to get people moving quickly through the vestibule and to their seat: the platform-train interface is only one part of the challenge.
- Under level access, for example at Paddington, there is still a small lip and a gap – to avoid trips and damage to luggage, the challenge is to design a truly smooth and level path from platform to train.
- One blockage to rapid boarding and alighting was observed to be passengers coming off the train and stopping to gain orientation – good information on-board can support better passenger behaviour
- Queuing behaviour of those on the platform can block and slow down the speed of those alighting.

The study concluded that, under most operating conditions, the HS2 dwell time targets are likely to be met irrespective of the platform-train interface. However, the recommendation is that level access is of significant benefit for ensuring that the dwell time target is reliably met and to improve the usability and accessibility of the train service.

References

Holloway, C., Thoreau, R., Roan, T-R., Boampong, D., Watts, D. & Tyler, N. 2015, *Effect of vertical step height on boarding and alighting time of train passengers*, Journal of Rail and Rapid Transit (In press) DOI: 10.1177/0954409715590480