Passenger Boarding & Dwell Time Research Report

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Issue & Revision Record

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London West Midlands

Passenger Boarding & Dwell Time Research Report

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List of acronyms

HEX	Heathrow Express
OCC	Old Oak Common station
PAMELA	Pedestrian Accessibility Movement Environment Laboratory

PRM	Persons of Reduced Mobility
TSI	Technical Specification for Interoperability
UCL	University College London

References

Title	Reference
Passenger Capability Statement	C240-PBR-HF-000-000001

1 Executive summary

1.1.1 This report documents an experimental and observational study to assess the predicted time required for passengers to board and alight future HS2 trains.

1.1.2 The study examines the time required to board & alight under three scenarios: level access, from train to current standard UK platform heights and from train to the European TSI compliant platform height.

1.1.3 The study concludes that under most normal loading conditions the dwell time target can be met irrespective of the platform-train interface.

1.1.4 The study found that the need for a single step at the UK platform height and two steps under the TSI compliant condition does have a significant effect on boarding & alighting time.

1.1.5 This effect is increased for older passengers and those with larger or multiple items of luggage.

1.1.6 The study therefore predicts that under the TSI compliant condition, there may be problems with the HS2 service consistently meeting its dwell time target at interchange stations when peak or abnormal loading conditions are found. This risk is increased if the proportion of older passengers is greater than forecast or if more large luggage is carried on the trains.

1.1.7 The study notes that the presence of steps has a significant negative impact on passenger experience and on accessibility. It is unlikely that HS2 will meet some of its ambitions for accessibility and independent travel if passengers are required to use steps to board the train.

1.1.8 The study concludes that to optimise boarding & alighting, to ensure the service meets the dwell time performance requirements and to deliver the high quality passenger experience that HS2 aspires to, that level access is the preferred solution.

2 Abbreviations and descriptions

2.1.1 The abbreviations, descriptions and project terminology used within this document can be found in the project dictionary.

3 Introduction

3.1 Purpose of the Study

3.1.1 A key component of the operational plan for the HS2 railway service is the provision for a 2-minute dwell time at intermediate stations and a 20-minute turnaround time at terminating stations.

3.1.2 In Phase 1 of the project, Old Oak Common Station and Birmingham Interchange station are the two intermediate stations. Euston Station and Birmingham Curzon Street are the two terminating stations.

3.1.3 Achieving the planned dwell time on a consistent basis is critically important for achieving railway capacity, delivering a reliable service to passengers and to the likely revenue model for the railway.

3.1.4 The optimum solution for minimising passenger boarding time and optimising accessibility is likely to be level access from platform to train. However, the HS2 project is required to comply with the European Technical Specification for Interoperability. The relevant TSIs for train design and station design (including accessibility by persons of restricted mobility) specify the platform height. The nature of the design of high speed trains and the train floor height produces stepped access from the TSI-compliant platform.

3.1.5 The train design is also potentially conflicted in having to accommodate the normal UK station platform heights when the “classic” train service uses non-HS2 stations.

3.1.6 This study was commissioned by HS2 to provide early objective data on the feasibility of the planned passenger numbers boarding and alighting the service within the allotted dwell time under various platform height conditions. The key question is whether the service can be delivered under the TSI compliant platform or if a higher platform is recommended, potentially supporting level access.

3.1.7 The study was conducted by CCD Design & Ergonomics Limited with support from University College London (UCL). HS2 provided guidance on the scenarios to be examined, the experimental design in relation to subject demographics, use of luggage and test conditions and on the stations used for the observations.

3.2 Dwell Time

3.2.1 The achievement of a particular dwell time for a train service is a complex interaction of engineering, systems and human behaviour. The passengers boarding or alighting from the train is only one part of the process.

3.2.2 The 2-minute dwell time for HS2 is the time from wheel stop to wheel start. So it also includes the time for the train doors to be released and to open; it includes the time for the doors to be closed again and any safety checks to be carried out before the train can be safely dispatched.

3.2.3 As a consequence, following discussion with HS2, this study has worked on the assumption that 1 minute 35 seconds is a representative time period for the passenger movements to take place.

3.2.4 In the recent Train Parameters Study conducted by Design Triangle for HS2, they undertook an initial literature search into the dwell time issue. They identified that the key factors influencing boarding time were exterior door width, entry step height, platform gap width and vestibule congestion. They suggested that door location, vestibule size, luggage storage location and the effectiveness of passenger information on the train and the platform were also important factors.

3.2.5 The Design Triangle research has suggested the boarding/alighting times vary from 1.4 seconds to 2.9 seconds per passenger[1], for passengers carrying a suitcase.

[1] The research is not specific about the influence of passenger age so this is assumed to be a general figure across the population. The research was also not specific about the platform height and consequent platform-train interface arrangement.

4 Research Questions

4.1.1 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?

4.1.2 The behavioural elements of the project aimed at studying passengers to understand more about topics including:

- The impact of grab handles inside the train doors when using steps
- The design of the train interior especially the vestibule area and luggage storage provision
- The impact of passengers negotiating the interior and finding their seat
- The design of the platform area
- The provision of passenger information
- The impact on Passengers of Reduced Mobility
- The impact on passenger experience

5 Methodology

5.1.1 The approach for the project was to undertake a controlled, experimental study and validate the findings with a real-life observational exercise.

5.2 Experimental Study

5.2.1 CCD engaged University College London to undertake the experimental study using their PAMELA facility (www.ucl.ac.uk/arg/pamela). This unique facility enabled the construction of basic mock-up of a single door entrance to the train and to model three vertical heights at the platform-train interface.

5.2.2 The rig design was based on a consistent height of the train interior at 1,240mm from the rail head. This height was selected to represent a known train design at the upper end of the floor height range. The rig also assumed that the horizontal gap from the train step to the platform would be 80mm in each condition.

5.2.3 The rig was constructed to simulate three variants of platform height and platform-train interface configuration[2] (see Figure 2):

a. Level Access – a platform height of 1,200mm with a 300mm wide step (horizontal gap filler) on the exterior of the train resulting in a 20mm lip at the door (this was retained to simulate some small level change resulting from the seal of the door). As these measurements showed it was assumed that level access was not totally level with a 40mm offset between platform and train floor heights.

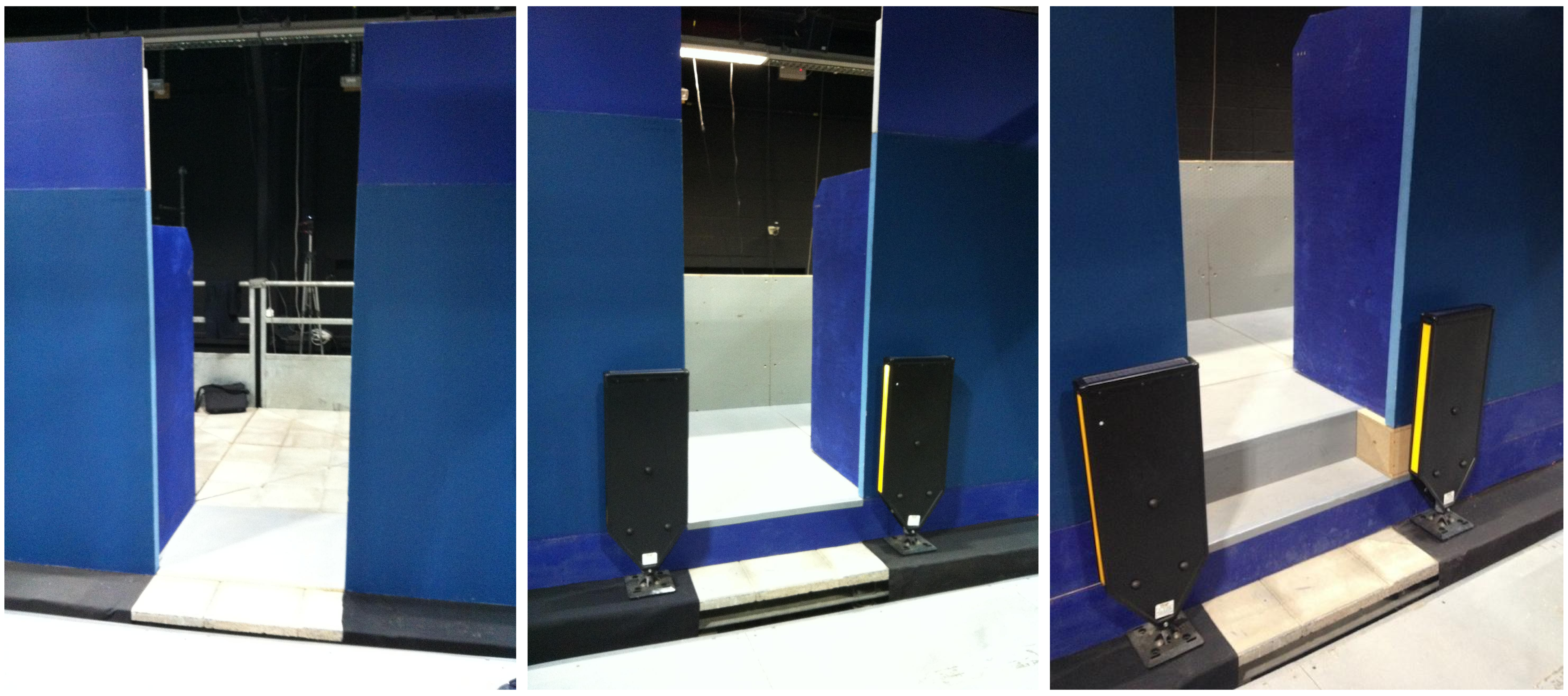
b. UK Platforms – a platform height of 890mm with a 300mm step on the exterior of the train at 1,010mm resulting in a further step up into the train interior

c. European TSI Platform – a platform height of 730mm with the 300mm external step at 780mm, an interior step within the train at 1,010mm and then a final step up into the train interior.

5.2.4 The three variants of the rig setup were tested over a single day for each of the conditions.

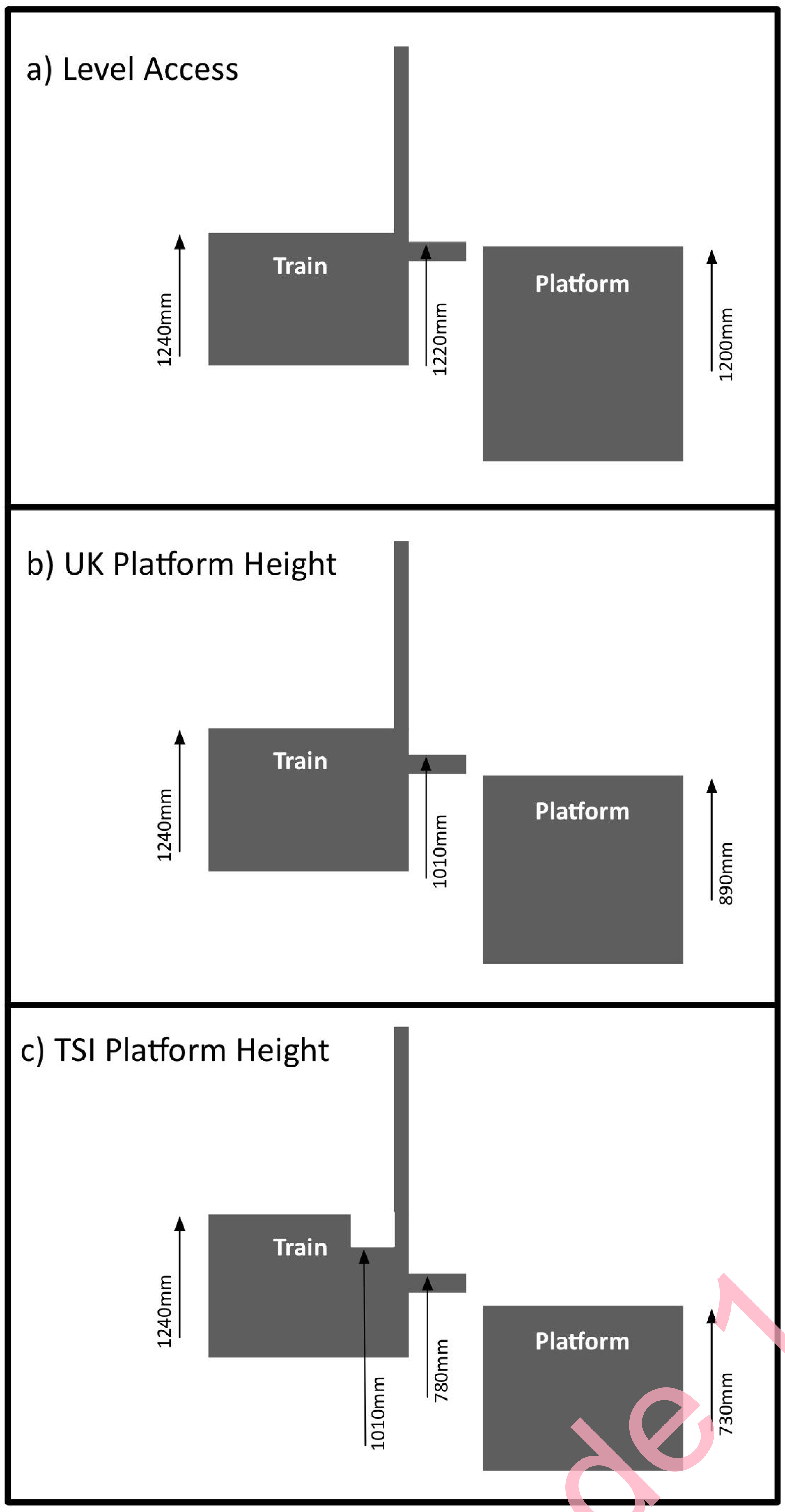
[2] The variants were designed with consideration of how both the Captive trains and the Classic Compatible trains would interface with the various platforms under worst case conditions. This included consideration of both the height and the horizontal offset of the platforms. The design of the trains will of course differ depending on the range of platform heights which must be accommodated, and this factor was taken into account. The platform heights chosen took account of the tolerances allowed such that the worse case arrangement was implemented.

Figure 1 Photographs of the Rig



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

Figure 2 Rig Configuration



5.2.5 The experimental study was conducted with 60 participants. The participants were recruited in six demographic groups:

- 20-27
- 28-37
- 38-47
- 48-57
- 58-65
- >65

5.2.6 The recruitment process and study timescales meant it was not possible to recruit equal numbers of participants across the three demographic groups. The approximate split between the demographic groups was:

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

5.2.7 The participants were randomly assigned a piece of luggage to carry during the trials. The types of luggage were as follows with the approximate proportion allocated to the participants:

- Rucksack (46%)
- Small suitcase (wheeled airline-style hand luggage) (17%)
- Large suitcase (large wheeled suitcase) (17%)
- Pushchair (a weighted stroller style pushchair) (9%)
- No luggage (12%)

5.2.8 Initially, it was attempted to ensure that each demographic group had a similar distribution of luggage types. In practice it was found that more elderly participants struggled with the large suitcases so were given smaller items of luggage.

5.2.9 Three different load scenarios were tested for each of the three rig conditions: (1) Full Board with all 60 participants starting on the platform and boarding the train; (2) Mixed Board/Alight with 30 passengers boarding and 30 passengers alighting; (3) Full Alight with all 60 passengers on the train and alighting.

5.2.10 Over the three days of testing, 130 experimental runs were conducted with

7,800 passenger movements. At least 5 test runs were undertaken for each experimental condition. Additional test runs were made with reduced luggage (no pushchairs or large suitcases) to gather more data on the impact of luggage.

5.2.11 For each of the test runs, the participants were played an audio track of a train arriving which included the audible door open signal. This provided some sense of realism and prepared the participants for action. At the point of door open, a barrier was removed and the participants could board or alight. The test was run until all participants had boarded or alighted to maximise the number of passenger movements.

5.2.12 The PAMELA facility is equipped with multiple video cameras. The video footage was analysed by the UCL team using Observer XT software. An overhead view of the platform-train interface was used to assess the individual timings for each passenger movement. A timing point was agreed with HS2 from when the passenger was approximately 500mm inside the train to when the passenger was fully outside of the train with both feet on the platform (and the reverse for passengers boarding).

5.2.13 At the end of each day of testing, the participants were given a brief questionnaire to rank how difficult they found boarding or alighting.

5.3 Observational Study

5.3.1 To complement the experimental study, a number of real-life observations were made of passengers boarding and alighting.

5.3.2 Observations were made over one day at each of the following rail stations:

- Paddington Station (Class 332 Heathrow Express)
- St Pancras International (Class 373 Eurostar & Class 395 Javelin)
- Ebbsfleet International (Class 373 Eurostar & Class 395 Javelin)
- Swindon (MK III coach)
- York (MK III coach, Class 220/221 Voyager & Class 365 Networker)
- Derby (Class 222 Meridian)
- Stratford International (Class 373 Eurostar & Class 395 Javelin)
- Watford Junction (Class 350)

5.3.3 The stations were selected to provide a mix of intermediate and terminating traffic and a mix of intercity and other services. Ebbsfleet was observed in the half term week to try and capture more of the holiday traffic going to and from Disneyland Paris. The Heathrow Express platform at Paddington was used to examine level access.

5.3.4 The following train types and services were observed:

Level Access

Class 332 - Heathrow Express

One Step

Class 395 Javelin

Class 365 Networker Express

Class 350

Two Steps

Class 222 Meridian

Class 373 Eurostar

Class 220/221 Voyager

MKIII coach

5.3.5 It is noted that across the train types there are differences within each group. For example, the step height for a Class 373 Eurostar is different and higher than the other "two step" trains observed. The number of observations made across all train types minimises any influence of this on the results.

5.3.6 The study observed 465 individual trains arriving/departing, which resulted in 1,088 passenger movements being recorded.

5.3.7 During each observation, the research team took video recordings of the passengers boarding or alighting the train. The video recordings were later analysed using the same Observer XT software used in the experimental study. As far as was practical, the timings used the same start-finish point for each passenger movement as the experimental study.

5.3.8 From the video analysis demographic group for each passenger was recorded along with the luggage they were carrying. It was not possible to ask each passenger his or her actual age so the research team made an estimate. Because of this only three demographic groups were used in the analysis: 18-39, 40-59 and >60.

5.3.9 The demographic pattern observed was similar to that used in the experimental study:

	Observation	Experimental
18 – 37	40%	41%
38 – 57	36%	32%
+58	24%	26%

5.3.10 The luggage observed had some variation with the balance used in the experimental study:

	Observation	Experimental
No luggage	3%	12%
Rucksack	66%	46%
Small suitcase	25%	17%
Large suitcase	5%	17%
Pushchair	1%	9%

5.3.11 During each of the observations, the research team captured insights into passenger behaviour in order to consider how they might impact on the dwell time issue. In this way, the observational work was structured to validate the experimental results and to provide a richer source of information.

6 Assumptions

6.1.1 The following assumptions were used in the study:

- The “doors open” part of the dwell time at intermediate stations for boarding & alighting is assumed to be 1 minute and 35 seconds.
- Typically, 1/3 of passengers board or alight at an intermediate station (this would equate to 367 passengers from a total load of 1100 passengers in a 400m train). At Birmingham Interchange, it is assumed that 1/3 of passengers could board and 1/3 could alight (733 passengers). It should be noted that this scenario is foreseen as unlikely but serves as a good worst-case test. At Old Oak Common, it is assumed that passengers would only be boarding (northbound trains) or alighting (southbound trains).[3]
- With current assumptions on train design, this could equate to 13 passengers boarding/alighting at each door or up to 26 at Birmingham Interchange. HS2 have proposed a 20% potential variation giving a worst case of 31 passengers per door at Birmingham.[1]
- It is assumed that all seats on the train will be pre-booked and that the HS2 booking system will optimise the distribution of passengers along the train.
- It is assumed that the passenger information on the platforms and passenger behaviours are such that all passengers are located at or near the correct door location as the train arrives.

6.1.2 It should be noted that the impact of some people within the definition of PRMs, in particular semi-mobile people moving slowly or people in wheelchairs, was not modelled in the study. Passengers in wheelchairs or using other mobility aids would require assistance to access trains within anything other than level access so it was not considered appropriate to include them in this study.

[3] These assumptions are carried across from the Design Triangle Train Parameters Study

7 Experimental Study Results

7.1.1 This section refers only to the results from the laboratory-based experimental study.

7.2 Effect of Steps on Dwell Time

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

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

7.2.2 This compares to the range of 1.4 to 2.9 seconds suggested by the previous Design Triangle study.

7.2.3 These figures would mean that, with level access, it would be possible for 33 people to board/alight in the 95 seconds assumed for the usable dwell time (based on the same demographic and luggage usage).

7.2.4 Under the UK platform condition, this would fall to 27 passengers. Under the TSI compliant condition this would fall further to 24 passengers.

7.2.5 In the assumptions in Section 6, it was suggested that at Birmingham Interchange the worst case would be 31 passengers needing to board or alight, with a more normal scenario of 26. The study results suggest that the TSI compliant condition would fail to deliver either of these loading scenarios. Further, the UK platform condition could deliver a supposed normal scenario but would fail to achieve a worst-case loading scenario[4].

7.2.6 When just considering ‘all boarding’ or ‘all alighting’, which are representative of scenarios at terminating stations and at Old Oak Common station, the following results were found:

	All Boarding	All Alighting
Level Access	3.0 secs	2.2 secs
UK Platform Height	3.3 secs	3.5 secs
TSI Compliant Platform	4.1 secs	3.7 secs

Table 1: Passenger Times for All Boarding/Alighting Conditions

7.2.7 These results suggest there is a speed benefit when alighting for the level access design. The speed effect is nullified by the introduction of one step (UK platform condition) when similar times to mixed or all boarding are achieved. For the TSI

[4] This assumes the demographic profile of passengers and use of luggage is comparable with the distribution in the experiment.

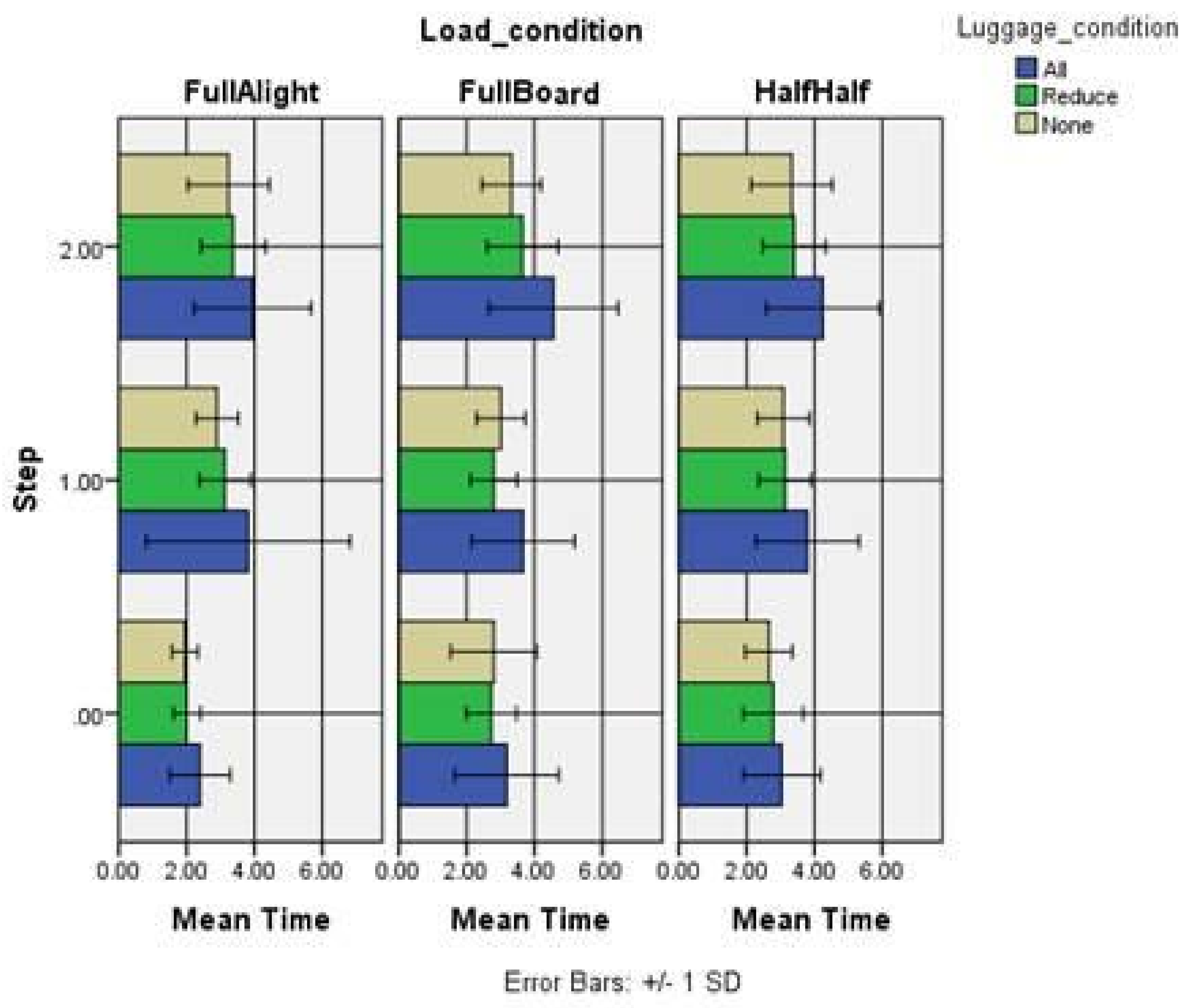
compliant condition, with two steps, the speed effect is reduced most noticeably in the board scenario.

7.3 Impact of Luggage on Time

7.3.1 The influence of different luggage types on dwell time for each of the 3 conditions is shown in Figure 3. The graph shows three scenarios which were run – all luggage types allocated amongst the passengers, reduced luggage (which removed the large suitcases and pushchairs), and no luggage.

7.3.2 In the worst-case scenario with all luggage included, there is a general increase in the dwell time as the difference in height between train and platform increases together with the number of steps. It was marginally quicker for all passengers to board than the conditions with all passengers alighting or the mixed condition.

Figure 3: Mean Boarding/Alighting Time for All Conditions



7.3.3 It can be seen that there was an increase of dwell time in all conditions when large suitcases and pushchairs were included suggesting a significant influence of those luggage types.

7.3.4 Figures 4, 5 and 6 show the impact of luggage on the three scenarios (mixed, all alighting, all boarding) across the three conditions.

Figure 4: Mean Time by Luggage Type for Mixed Boarding & Alighting

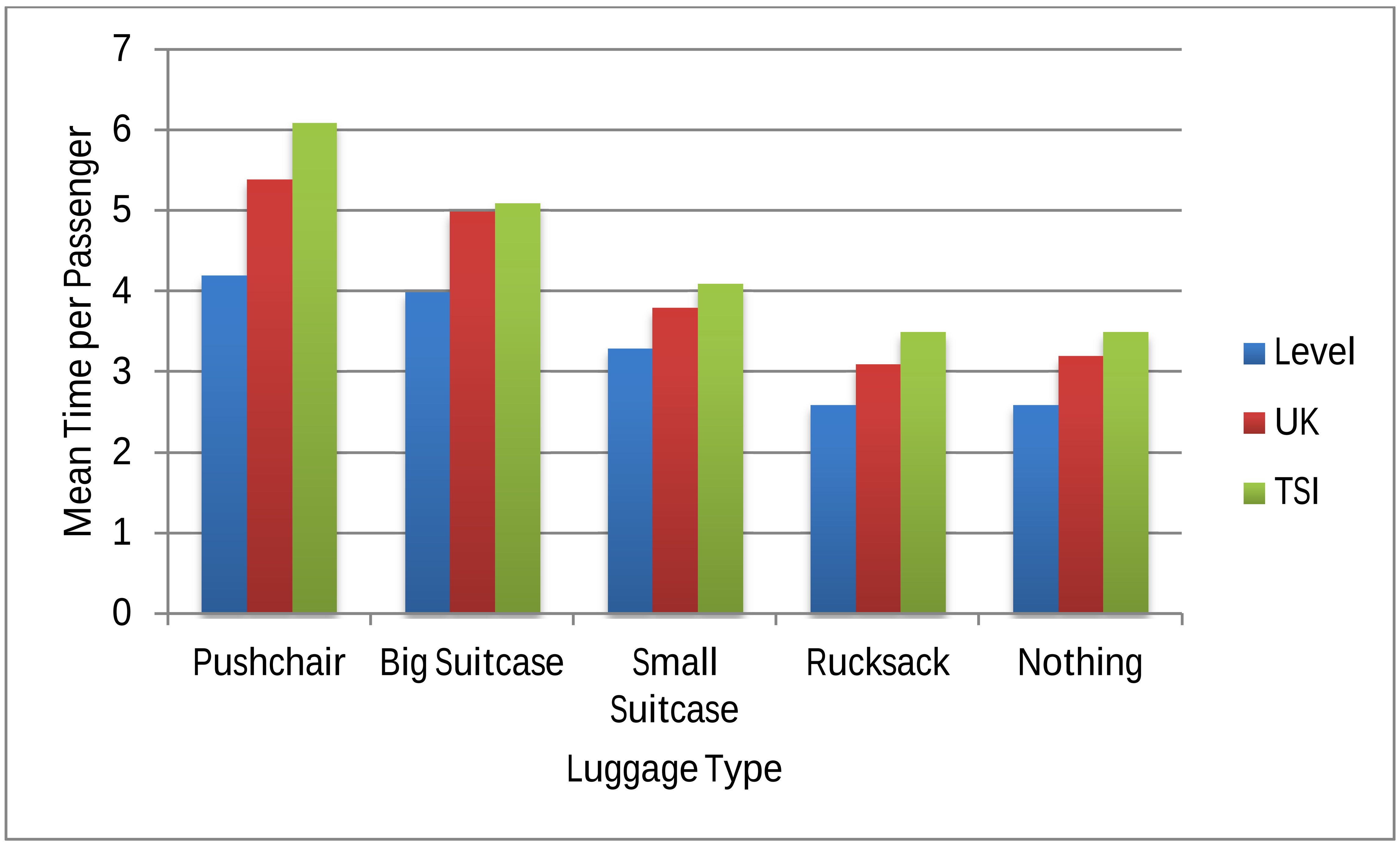


Figure 5: Mean Time by Luggage Type for All Boarding

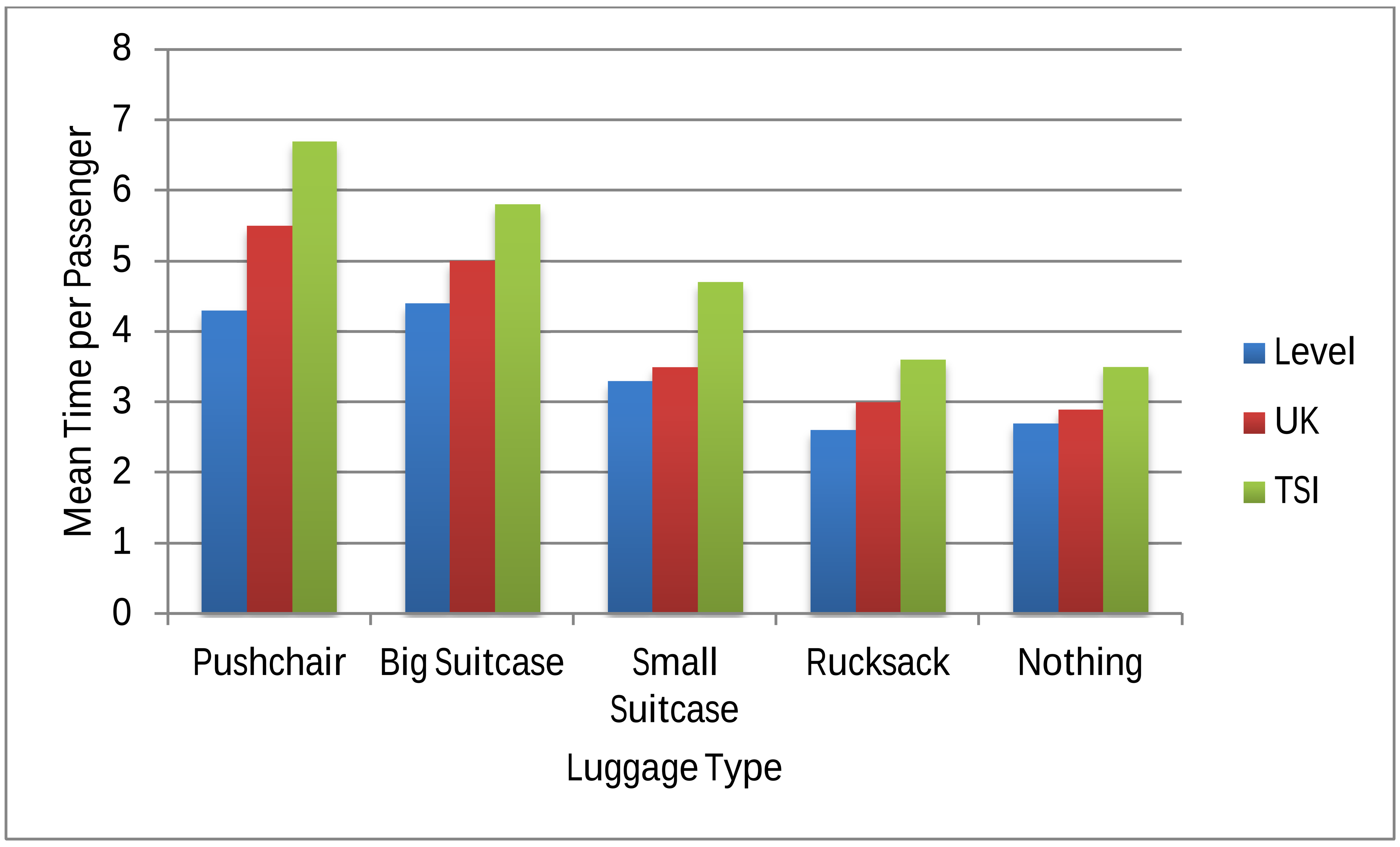
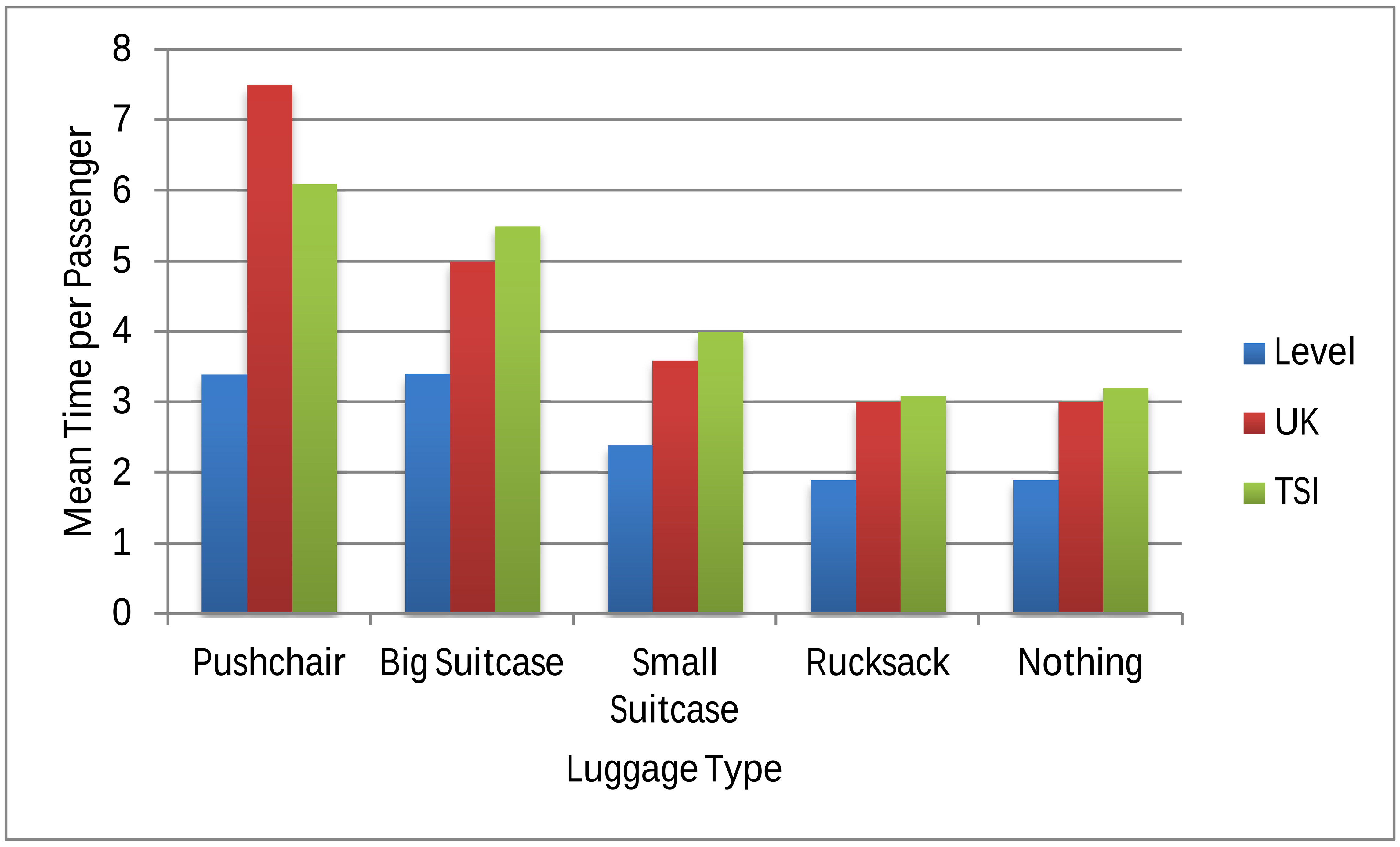


Figure 6: Mean Time by Luggage Type for All Alighting



7.3.5 Each of the scenarios show the same pattern that smaller luggage items like rucksacks have no significant influence in boarding/alighting time and are comparative to no luggage.

7.3.6 Larger luggage, especially when carried in hand, does have an impact on time. Under level access, in the mixed scenario, there was a 40% increase in the time for a person with no luggage to a person with a large suitcase. There was a 96% increase in time for no luggage on level access to carrying a large suitcase up two steps in the TSI compliant condition (2.6 seconds to 5.1 seconds).

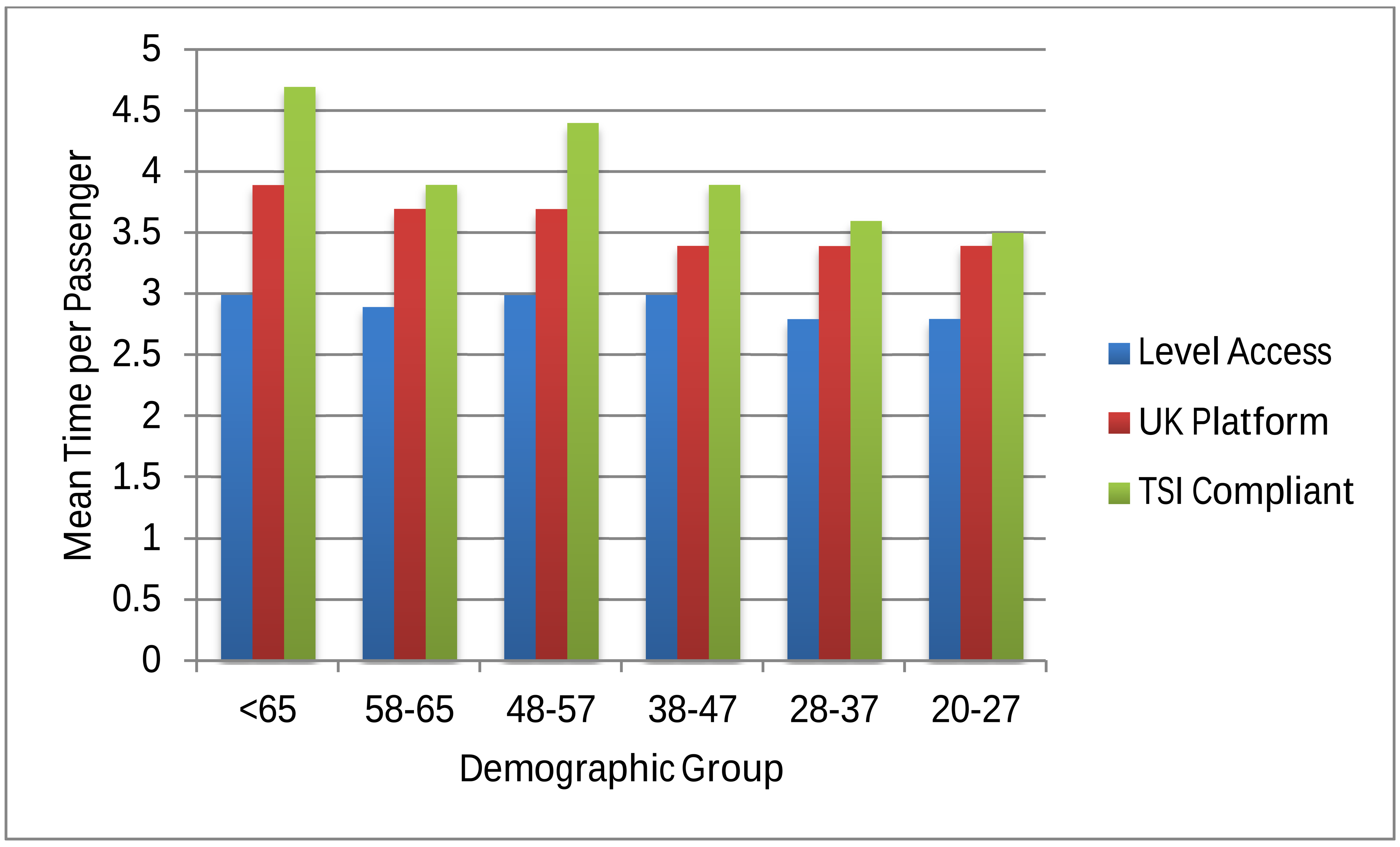
7.3.7 The times under the all alighting condition were generally faster than the all boarding suggesting it is easier and faster to carry luggage off trains rather than on.

7.3.8 It should be noted that there was a variation in the allocation of luggage types in the experimental study against the proportions seen in the observations. This would suggest that, at this time, there is more lightweight luggage carried on real trains than was used in the experimental study. However, the analysis above is based on individual times for passengers with each luggage type. The impact of the observations does not alter the results in the experimental study. But it does suggest that perhaps there will be less impact from the heavy luggage with only around ¼ of passengers currently travelling with it.

7.4 Impact of Passenger Age

7.4.1 Under the mixed boarding & alighting condition, the average time for each of the demographic groups is shown in Figure 7.

Figure 7: Mean Boarding/Alighting Time by Demographic



7.4.2 These results suggest that the impact of age is marginal in the level access scenario 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 groups is 0.2 seconds in the level access condition and rises to 1.2 seconds under the TSI compliant condition.

7.4.3 To extrapolate the potential impact, two potential services were looked at – a weekday commuter service where it is likely that the demographic split would lean towards those in the mid or younger groups, and a leisure service where the demographic might include more older passengers. The data for each scenario was examined to predict the time it would take for 26 passengers to board or alight under each of the three platform conditions.

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

Table 2: Extrapolated Dwell Times for Different Train Services based on Demographic Model

7.4.4 Whilst this is a relatively simplistic analysis[5], it reinforces how the demographic of the passengers has minimal impact on boarding/alighting time when there is

[5] This analysis did not include any specific distribution of luggage carried. It is based on the luggage distribution used in the experimental study.

level access but a more significant impact when there are steps to negotiate.

7.4.5 When looking at the only boarding or only alighting condition, the gap between the performances of youngest to oldest widens – see Figures 8 & 9. In all boarding, the oldest group were 1.7 seconds slower than the youngest group; in the all-alighting condition, the oldest group were 1.6 seconds slower.

Figure 8: Mean Time for All Boarding by Demographic

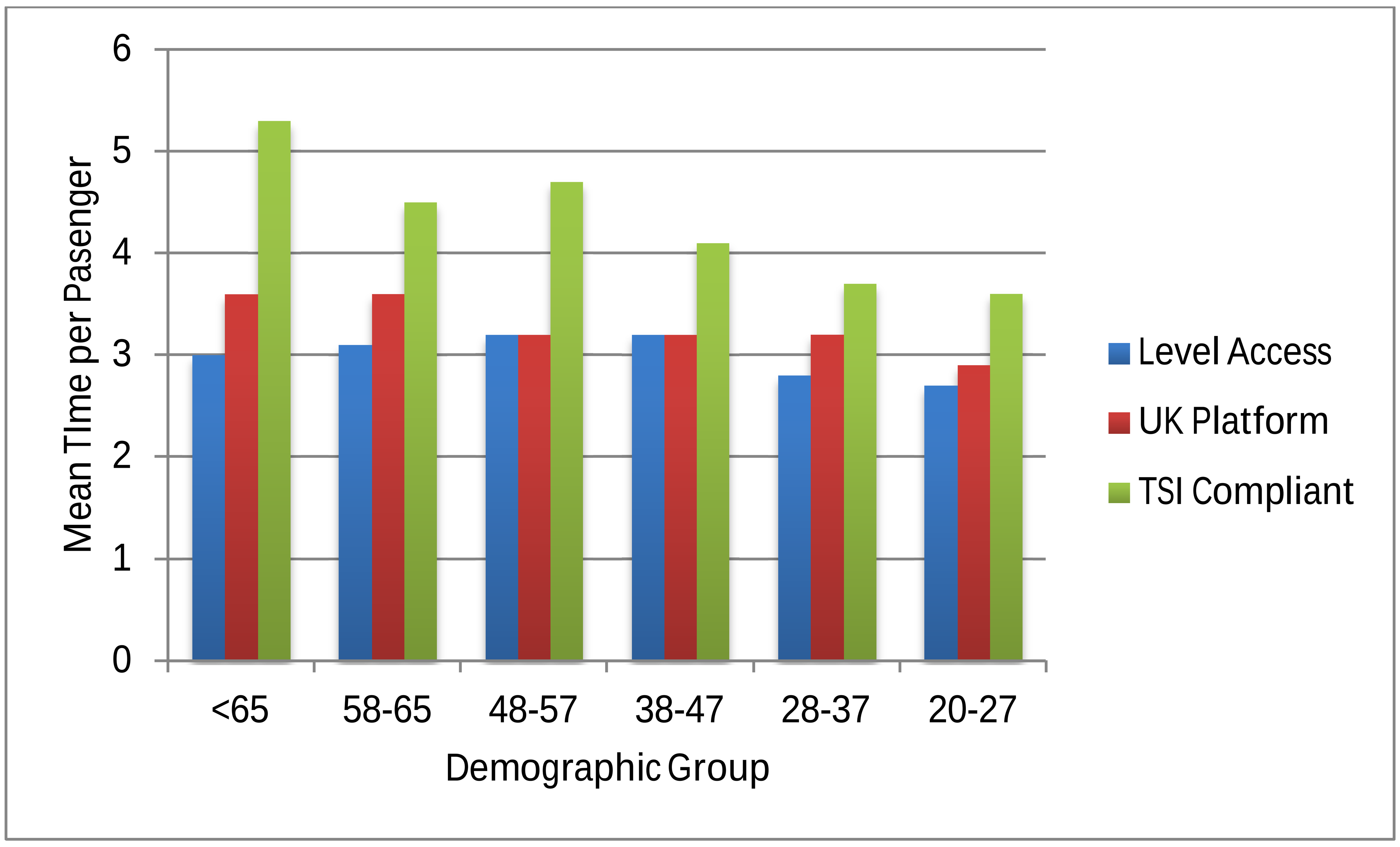
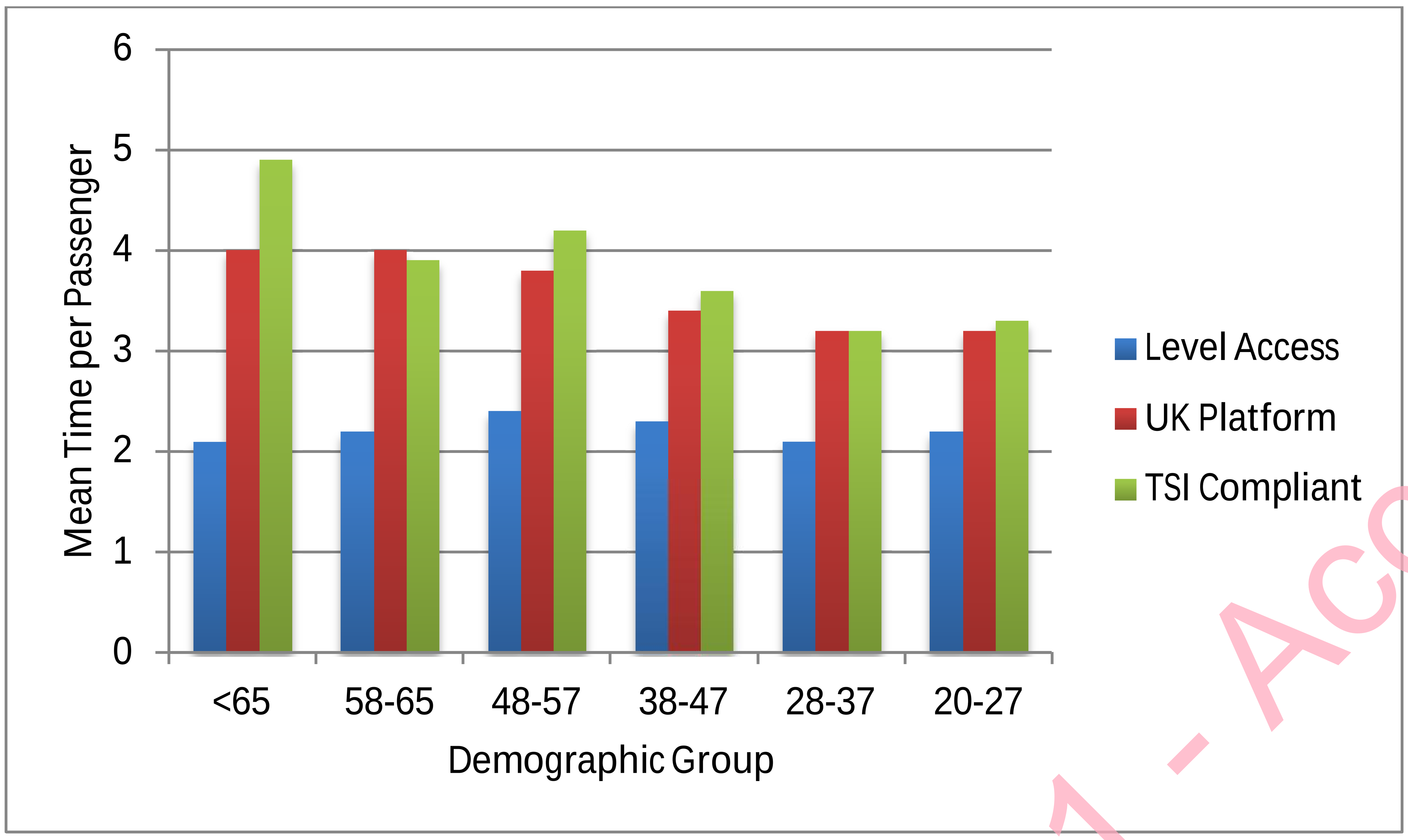


Figure 9: Mean Time for All Alighting by Demographic



7.4.6 Across all age groups, under full boarding, the impact of the two steps in the TSI compliant condition is significant over both the level access and UK platform heights, when compared with mixed boarding & alighting. Under full alighting both the single step to the UK platform height and the two steps of the TSI condition are significant. This suggests that boarding behaviour is more adversely affected by the higher two steps whereas alighting is generally affected by any number steps, when both are compared to level access.

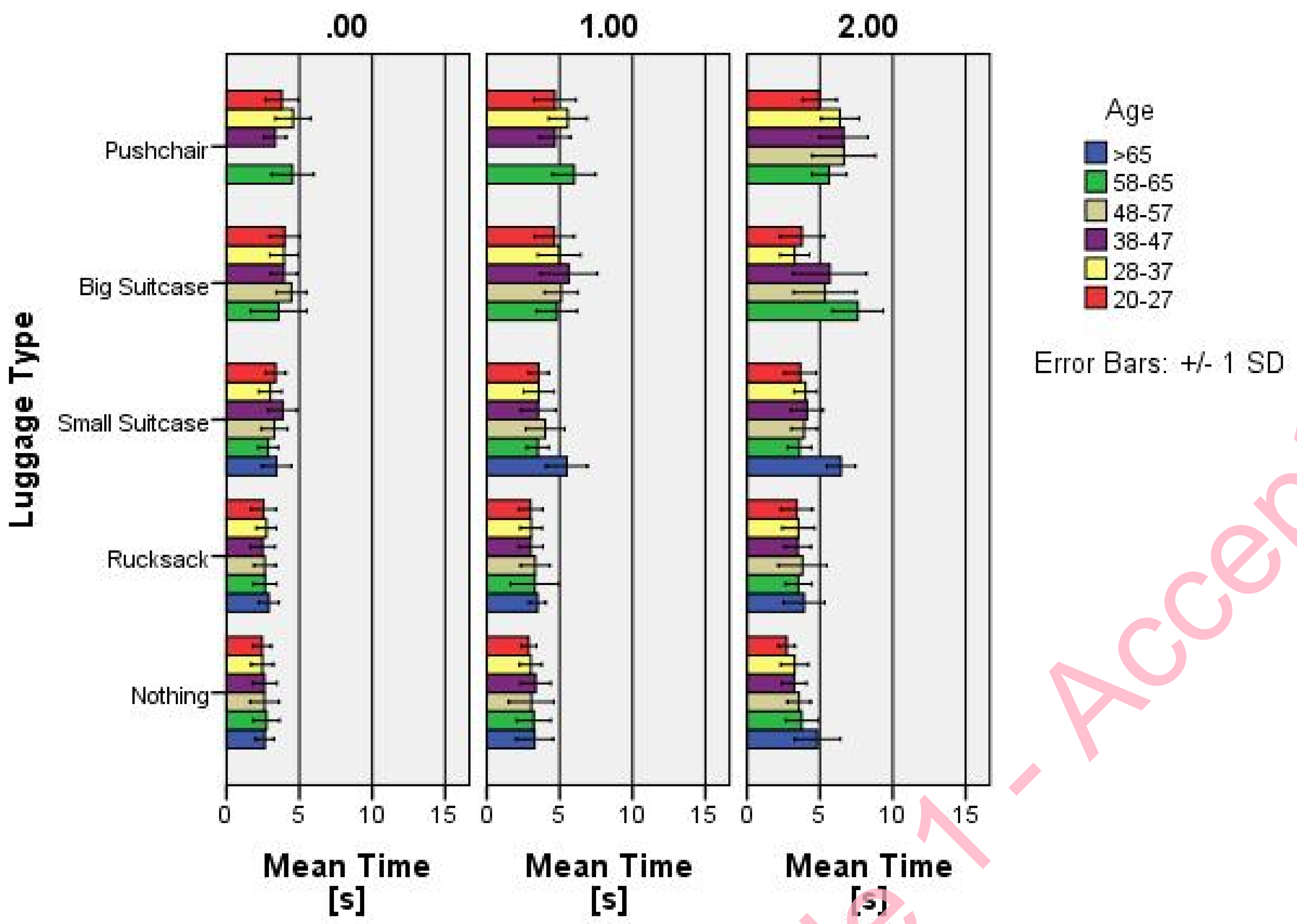
7.4.7 There was a close correlation between the demographic used in the experimental study against that observed. However it should be noted that the impact of the national aging demographic suggests that for HS2 the impact of older passengers will be more significant than it is for current train services.

7.5 Interaction Between Luggage & Passenger Age

7.5.1 The data from the study showed a strong relationship between the impact of luggage and passenger age. As one might expect, luggage, especially larger or heavier items, has a larger impact the older the passenger is.

7.5.2 The effect of the passenger-train interface and demographic on the mean time to board/alight for the mixed condition is shown in Figure 10.

Figure 10: Mean Boarding/Alighting Time by Condition & Demographic with Luggage



7.5.3 The results show that the mean passenger movement time is affected by the interaction between the age of the person and the type of luggage they are carrying. This effect of this interaction is then increased by the presence of steps.

7.5.4 There was no age related effect on passenger movement time in the level access condition.

7.5.5 With the presence of a step, those aged over 65 years of age increased their mean time to board or alight. Although there were no people aged over 65 carrying a large suitcase, there still appears to be a trend of increasing mean time to board/alight with increasing age when there are two steps in the TSI compliant condition.

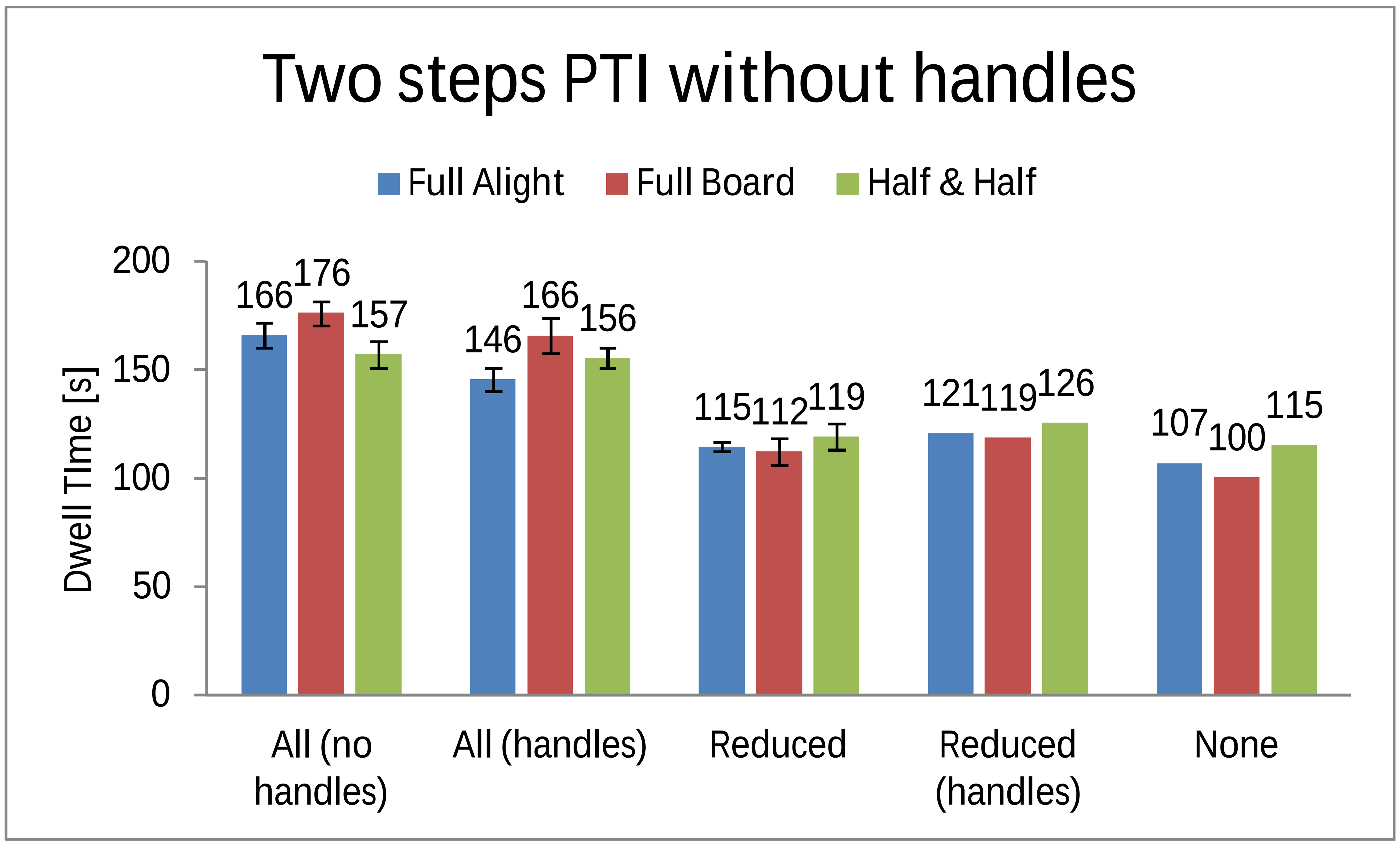
7.5.6 Those aged under 37 did not significantly increase their board or alight time when carrying a big suitcase as the number of steps increased. There was a slight increase in time under the one step condition. Observing participant behaviour suggests this is explained by the tendency to pull suitcases on to the train when there was one step against the preference to lift and carry the bags on with two steps. The pulling over one step slowed the boarding time when compared to carrying the bag.

7.6 Impact of Door Handles

7.6.1 The experimental data was also examined to look at the impact of grab handles on the train when there are two steps in order to see if this provides any performance improvement.

7.6.2 Figure 11 shows the data for the three loading conditions (full boarding, full alighting, mixed) with the TSI compliant arrangement and the three different luggage conditions (all luggage, reduced luggage, no luggage).

Figure 11: Impact of Grab Handles on Boarding/Alighting



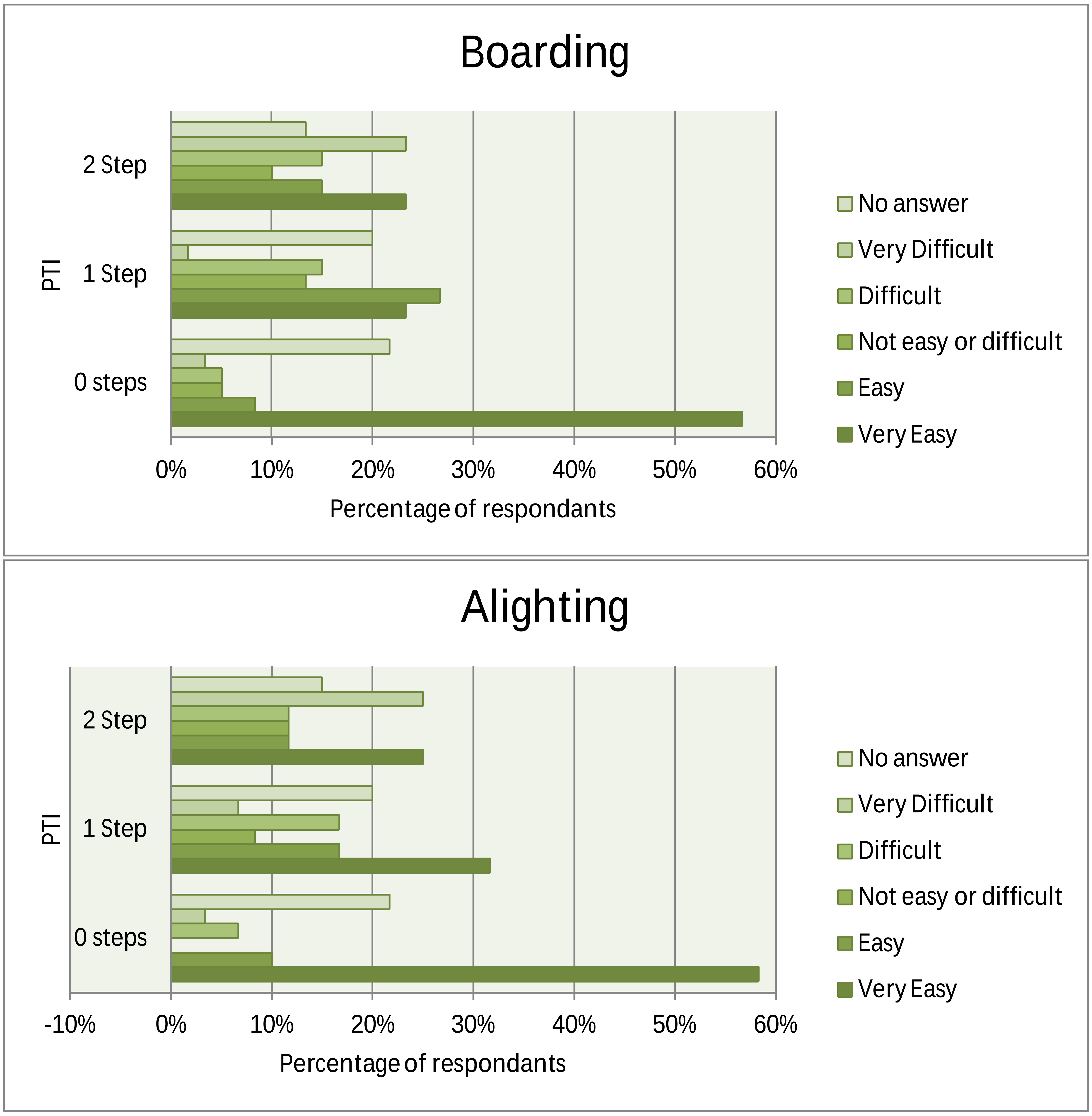
7.6.3 For the mixed boarding condition, there is minimal difference in performance in each scenario with or without handles.

7.6.4 The most significant impact is seen with all luggage during the all alighting scenario where there is a drop in time in the condition with the handles.

7.7 Questionnaire Results

7.7.1 At the end of each day of testing, participants were asked to rank on a scale of 1 to 5 how difficult they found boarding and alighting the train with 1 being very easy and 5 being very difficult. Figure 12 shows the results from the questionnaires.

Figure 12: Questionnaire Results on Perceived Difficulty of Boarding/Alighting



7.7.2 There were similar responses for perceived difficulty for both boarding and alighting.

7.7.3 Over 50% of participants rated boarding and alighting as ‘very easy’ when there was no vertical gap.

7.7.4 Only half those carrying a big suitcase ranked the task as ‘very easy’. The comments regarding the suitcases referred not only to the weight but also to the relative size of the door and the suitcase.

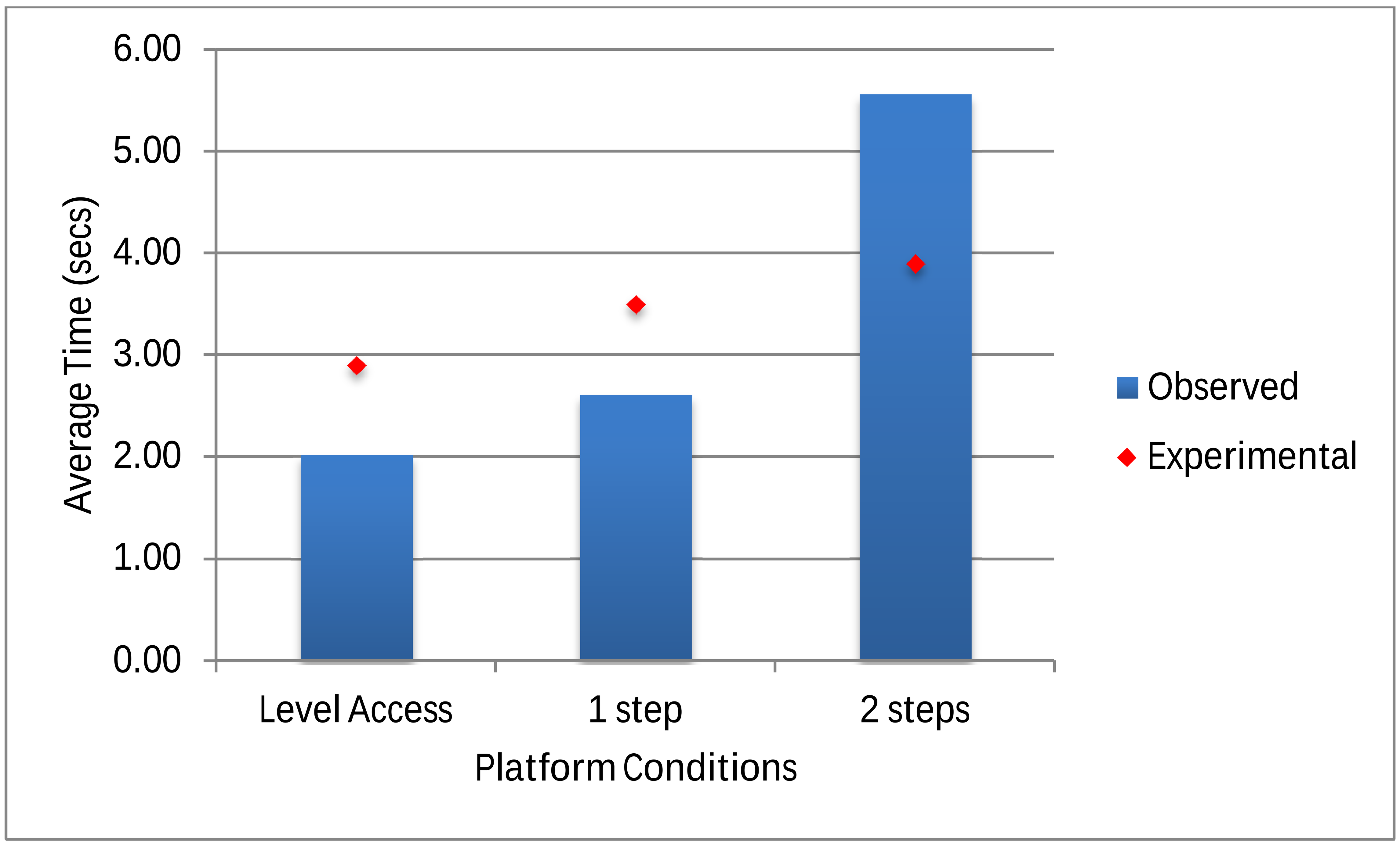
7.7.5 Generally as steps were introduced people found the task more difficult, this was especially the case for those carrying large suitcases and trying to board with a pushchair. With the shift from one step to two steps the comments shifted in intensity from simply ‘step too high’ to ‘really a great effort required and proving a lot more difficult'.

8 Observational Study

8.1 Boarding / Alighting Time

8.1.1 Figure 13 shows the observed mean boarding/alighting time by step condition. For ease of reference, the comparative times from the experimental study are shown as well.

Figure 14: Observed Time by Step Condition



8.1.2 The observed data broadly supports the experimental data. The times observed for level access and trains with only a single step were faster than the experimental results.

8.1.3 This speed difference could be explained by the wider door widths on the trains observed with level access and a single step when compared to the door width used on the experimental rig (900mm) – see section 9.5 for discussion on door widths.

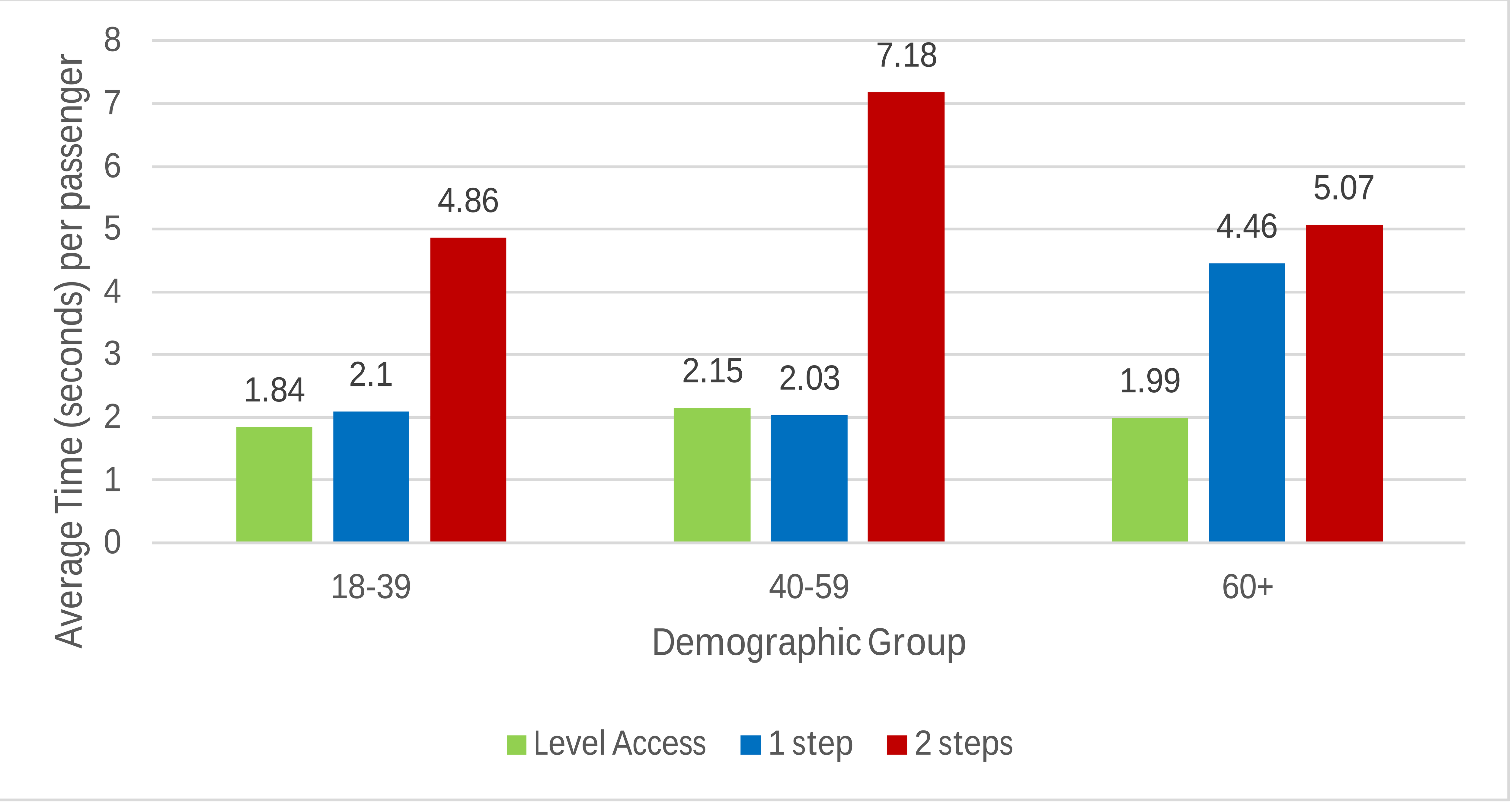
8.1.4 It should be noted that the comparison on the level access condition is limited as the observations were only conducted on the Heathrow Express service at Paddington. This is a terminating service and therefore trains were available to board for the whole turnaround time. Accordingly, boarding in particular, did not have a significant number of passengers looking to board at the same time. This minimised the ability to observe any impact of a queue of passengers already on the train backing-up to the door, which was an issue both on other observed services and during the experimental runs.

8.1.5 The observed performance for trains with two steps was significantly slower than the experimental results.

8.2 Impact of Passenger Age

8.2.1 The combined observed results for the passenger boarding/alighting time by demographic group is shown in Figure 14.

Figure 14: Observed Time by Demographic



8.2.2 The results follow a similar pattern to the experimental data with there being no significant demographic effect on boarding/alighting with level access but a more significant impact on the times with the introduction of steps.

8.2.3 For train services observed with a single step there is no real difference in performance for the younger and middle-aged groups. But the performance of the over 60 group worsened significantly. In the experiment there was a more linear increase in time vs age.

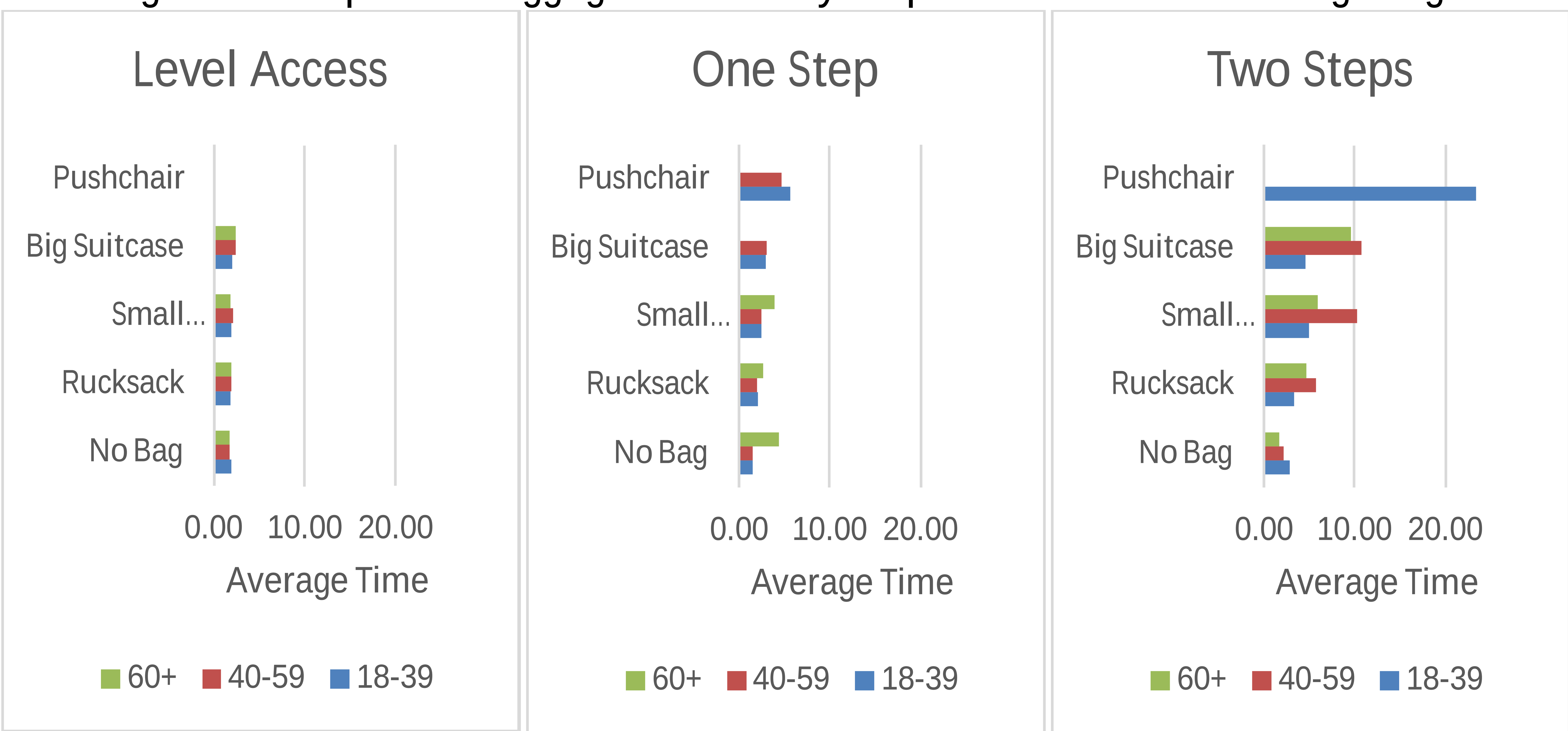
8.2.4 In the two-step condition, all groups were slower than level access or single step. It is noticeable that the slowest group is the 40-59 age group rather than the older 60+ group. The observations suggest that this is because that group was generally carrying more and larger luggage than the 60+ passengers (see Section 8.3 for the impact of luggage on the results).

8.3 Impact of Luggage

8.3.1 Figure 15 shows the change in average passenger movement times as observed with trains in each of the three step conditions. The figures are broken down by luggage type and by passenger age.

8.3.2 It should be noted that, when compared to the experimental study, the use of luggage was less controlled. We observed different amounts of each type, some passengers might be carrying multiple items of luggage and the weight of any luggage was not controlled.

Figure 15: Impact of Luggage on Time by Step Condition and Passenger Age



8.3.3 Under the level access condition, the observations support the experimental results that there is minimal performance difference by luggage type or age.

8.3.4 Under the two stepped conditions, the observed results show an increasing impact of larger, heavier luggage and the effect of age becomes more significant. This is consistent with the data in the experimental study.

8.3.5 What is notable about the observations is that with two steps the boarding time with larger luggage and for the older passengers is significantly longer than was seen in the experimental study.

8.3.6 The results for pushchairs under two steps are anomalous as there was one passenger who took a very long time to board (over one minute at St Pancras – see 9.3.5 for discussion on this). Removing these results from the analysis brings the average time for two steps back down to around 7 seconds, which is more consistent with other results.

8.3.7 One observation was that the more big and small suitcases were carried by the 40-59 age group than the other two groups.

8.3.8 In a similar way to the examination of the impact of age, it is indicative to look at a prediction of the time for the peak loading condition to board/alight with the proportion of luggage types. The table below shows the predicted time for the 26 passengers to board/alight under the three step conditions using the profile of luggage in the experimental study and the slightly different profile observed.

	Level Access	UK Platform	TSI Compliant
Experimental	80.3 secs	97.3 secs	106.4 secs
Observations	74.4 secs	88.3 secs	97.7 secs

Table 3: Extrapolated Dwell Times for Different Train Services based on Luggage Profile

9 Discussion & Conclusions

9.1 Impact of Platform Height on Dwell Time

9.1.1 The results of both the experimental and observational studies suggest that boarding/alighting times are likely to be longer than the previous research had suggested.

9.1.2 Both studies show that there is a significant impact when the platform height is different from the train height. The greater the difference, and the more steps required, the more significant the impact on time.

9.1.3 The observational study demonstrates that there is a wide variation in times to board & alight and that factors like luggage can easily increase the boarding time in particular.

9.1.4 Both studies suggest that if the HS2 trains are required to have steps then there is a risk that it may be difficult to board all of the passengers and consistently meet the dwell time targets in peak periods.

9.2 Impact of Passenger Age

9.2.1 The results of both the experimental and observational studies suggest that passenger age becomes a more significant factor with the introduction of steps.

9.2.2 When there is level access, the timings vary little by passenger age.

9.2.3 This is an important factor for HS2 as it suggests that services where there may be more older passengers (e.g. off peak) may again struggle to meet dwell time targets if the train features steps on the train up from the platform.

Figure 16: Elderly Passenger Boarding at Ebbsfleet

Figure 17 – Elderly Passenger Helps Partner to Board Before Collecting Luggage

9.2.4 This issue should be seen in the context of the aging population in the UK. The HS2 Passenger Capability Statement (C240-PBR-HF-REP-000-000001) highlighted that by the time HS2 becomes operational there will be a fifth more elderly people than young. Notably, the number of people over the age of 80 will have doubled by 2030 to around 8m.

9.2.5 Therefore, the study concludes that the performance of passengers boarding and alighting is likely to be more influenced by the slower speed of older passengers and therefore the need for steps will negatively impact on the dwell time performance.

9.2.6 It is noted that the provision of level access is likely to have significant benefits for passengers with wheelchairs or other mobility aids and gives the possibility of accessing the train without recourse to assistance from station staff.

9.3 Impact of Luggage

9.3.1 The experimental and observational studies were consistent in showing that larger and heavier luggage does start to have an impact on boarding/alighting time when steps are introduced. When there is level access, the impact of luggage is much less significant.

9.3.2 Smaller luggage, especially those not hand held (e.g. rucksacks), does not have a significant impact on boarding/alighting.

9.3.3 The observations, whilst confirming the impact of luggage on time to board or alight, also showed that perhaps the volume of heavy or bulky luggage is less than was used in the experimental study. It is difficult to predict the profile of luggage that will be carried by the future HS2 passengers. This study highlights the risk to dwell time when passengers are getting large luggage on or off with steps to negotiate.

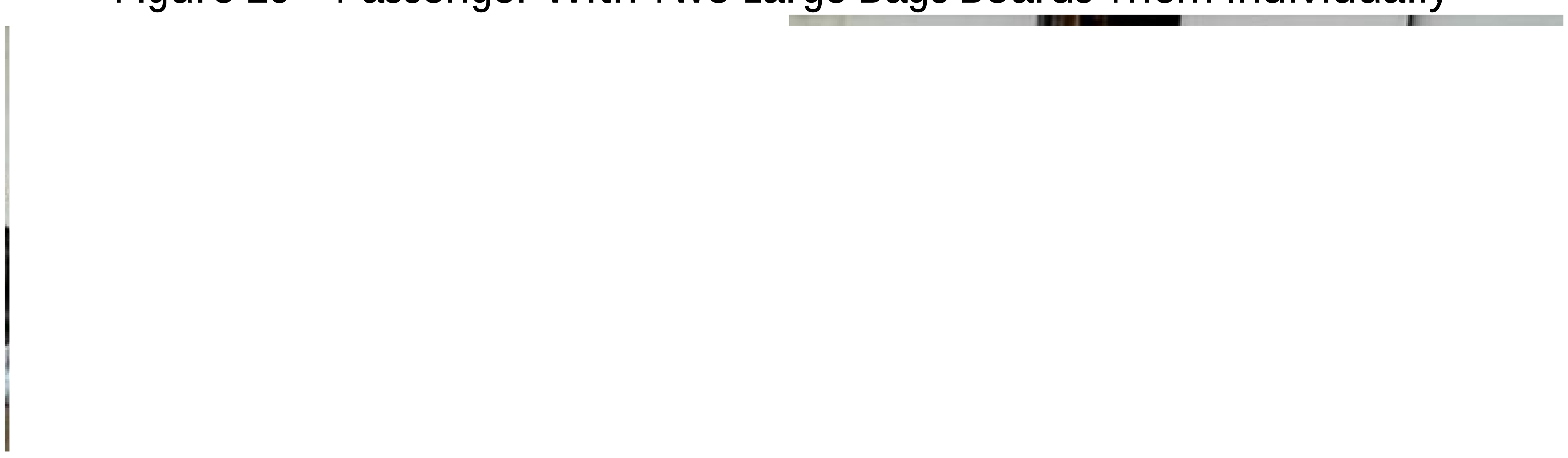
9.3.4 The observational study also highlighted how, in reality, passengers are often travelling with multiple pieces of luggage. The observations showed how, especially with steps, this made boarding significantly more difficult – see Figure

18.

9.3.5 The observations also showed that with steps, it is often too hard for passengers to carry all of their luggage on at once. Instead the luggage is put down on the platform and each piece taken on individually – see Figure 19. This can substantially increase the boarding time. It will also have an impact on the passenger experience is it is potentially stressful for passengers to leave their luggage unattended on the platform even for a moment.

Figure 18 – Passenger Boarding Eurostar with Large Suitcase and Hand Luggage

Figure 19 – Passenger With Two Large Bags Boards Them Individually



9.4 Accessibility & PRMs

9.4.1 It is an objective of HS2 to provide a step-change in the accessibility of the railway for Passengers of Reduced Mobility. The experimental study only addressed PRMs in terms of the elderly and passengers with children; it did not include wheelchair users for example. The observational study saw a limited number of PRMs boarding & alighting the trains.

9.4.2 In the case of passengers with young children and pushchairs, the observations showed how the boarding time in particular can increase. The example of the passenger at St Pancras showed how it can be very time consuming if a young child has to be removed from a pushchair and then the pushchair and luggage boarded as individual items – see Figure 20 below. This kind of situation is highly stressful for the passenger and child and is not the experience HS2 should be providing for passengers. Level access would remove this scenario from occurring.

Figure 20: Passenger Boarding at St Pancras with Pushchair & Luggage

9.4.3 The study concludes that the presence of steps into the train does not represent the "step change" in accessibility that the project is aiming for. Access with steps for all PRMs is complicated, difficult and time consuming. For many it will require external assistance from station staff.

9.4.4 To provide a genuine improvement for PRMs, it should be possible for them all to access and use the railway system without the need for assistance. This is likely to require level access to the train.

9.5 Door Handles

9.5.1 The experimental study suggested that the presence of grab handles at the door could support reducing boarding/alighting times when there are two steps.

9.5.2 The observations showed a number of people, especially older or mobility impaired passengers, using the handles although it was not possible to identify if there was any performance improvement.

Figure 21: Mobility Impaired Passengers Using Grab Handle to Board

9.5.3 The observations combined with the experimental data suggest that the presence of door handles enhances the usability of the train but does not have a significant impact in boarding or alighting time. It may offer some mitigation to performance of boarding/alighting but it would not alter the findings of the study.

9.6 Door Width

9.6.1 It was noted from the observational data that the times observed for level access and single step trains were faster than the experimental results. One suggested factor was the door widths for these trains (see Section 5.3) was wider than both the 900mm door width used in the experiment and the single door width on the 2-step trains.

9.6.2 In Figure 22, the comparison can be seen between the difficulty of carrying large luggage up steps and through a single door (Eurostar) versus the simplicity of alighting at level access through a wide door.

Figure 22: Effect of Door Width with Luggage

9.6.3 Door width was also observed to enable a faster flow with passengers moving through the door almost side-by-side – see Figure 23. The rate of flow was not part of this project and would require further study to assess its impact.

Figure 23: Side-by-Side Boarding/Alighting with Wider Doors

9.7 Train Interior Design

9.7.1 The observational study highlighted how the time for boarding is impacted by both the time it takes for the passenger to get onto the train, which has been the focus of the study, and then further by the time it takes for luggage to be stowed and the passenger to find their seat.

9.7.2 It was observed on a number of busy services that a queue quickly formed as passengers boarding were forced to wait whilst passengers on-board the train got to their seats – see Figure 24.

9.7.3 These observations highlight that whilst the platform-train interface is a key factor in dwell time it is only one part of the system for boarding & alighting.

9.7.4 The interior design for the train must consider new and innovative ways for passengers to be able to quickly and easily stow their luggage.

9.7.5 The design of the vestibule area must support passengers moving through and into the seating area.

Figure 24: Queue Forming at Derby

9.7.6 It is assumed that the HS2 services will be operated with a full seat reservation system. Therefore on boarding, passengers will have to find their allocated seat.

The design for the HS2 trains should consider better and faster ways for the passenger to be guided to the right seat. This must be an improvement on the current technology of small, hard to read displays or paper tickets in the seat back (Figure 25).

Figure 25: Existing Seat Reservation Technology

9.8 Level Access & The Gap

9.8.1 The observational studies noted how passenger behaviour for both boarding & alighting are impacted by the detailed design of the platform-train interface even under "level access" conditions.

9.8.2 It was observed at Paddington with passengers using the Heathrow Express service that both the small gap from platform to train and the small lip presented by the door seal are problematic for passengers.

9.8.3 It was reported by staff that HEX does suffer from a number of passengers tripping on boarding & alighting. It is possible that passengers see it as level access and fail to recognise the small lip and gap which catches them out.

9.8.4 It is notable at Paddington that a large "Mind The Gap" sign has been painted on the platform edge in response to this

Figure 26: "Mind the Gap" at Paddington Station

9.8.5 The observations also showed how the platform gap and the door plug gap frequently catch the wheels of suitcases.

Figure 27: Suitcase Wheels Getting Stuck in Gap

9.8.6 It is recommended that if HS2 opts for level access from platform to train, the detailed design engineering should aim to provide a continuous smooth surface from platform to train and within the train.

9.9 Arriving Passengers

9.9.1 At intermediate stations, the observations highlighted the importance for dwell time of the arriving passengers alighting and moving away from the platform door as quickly as possible to allow other passengers to board.

Figure 28: Passengers Alighting into a Crowd Waiting to Board

9.9.2 The first issue noted was how the crowd of passengers waiting to board influence the behaviour of the passengers alighting. They tend to form two groups on either side of the door. The alighting passengers have to move through the gap between these two groups, which can extend deep on to the platform (see Figure 28).

9.9.3 This results in a poor use of the available platform space, limiting the space for passengers to move to the exits and it restricts the alighting passengers from clearly seeing where they should go. To optimise the alighting/boarding experience, HS2 may need to look at operational processes or artefacts on the platform that control where the boarding passengers wait.

9.9.4 It was also observed how alighting passengers often disrupt the flow off the train by stopping to orientate themselves or pausing to adjust luggage. In Figure 29, the passenger in the light top can be seen stopping to put their luggage down having carried it off the train.

Figure 29: Passengers Stopping Having Alighted

9.9.5 HS2 should consider two elements to this. Firstly how to prepare passengers better to alight from the train. This could include a countdown to arrival so that passengers are more likely to be by the door with their belongings. It could be providing information as the train arrives on which direction to head once off the train to stop people stopping to look for signage.

9.9.6 The second element is that level access would reduce the need for people carrying wheeled luggage to stop whilst the bag is put back on the ground and turned around.

9.10 Passenger Distribution

9.10.1 It was noted that in all the services observed there was a mix of reserved and unreserved seating. As described in previous sections, this was noted to have an impact on the speed at which passengers completed the boarding task. It was also seen that this resulted in a very uneven distribution of passengers boarding different carriages.

9.10.2 HS2 is likely to operate a system with all seats being reserved. It is suggested that future seat reservation technology will mean that HS2 has the opportunity to control the distribution of passengers over the length of the train. This should mean it is possible to minimise the number of passengers boarding on each carriage. Better information on each passenger will also mean HS2 can anticipate the numbers of people alighting from each carriage and adapt to that as required.

10 Summary

10.1.1 The conclusion from the experimental and observational studies is that under most normal operating conditions the dwell time targets are likely to be met irrespective of the platform-train interface.

10.1.2 However, there is a significant risk that under peak loading conditions, the dwell time targets for HS2 may not be consistently met in operation if the TSI compliant platform height is used and there are steps up into the train.

10.1.3 This risk will increase if the passengers are predominantly older than foreseen or if the proportion of large luggage carried is higher. The data gathered on the impact of passenger age and the carrying of luggage demonstrate that both have an impact on boarding and alighting time but the impact is significantly greater when there are steps into the train.

10.1.4 The impact of passenger age should also be seen in respect of the general aging of the population and therefore the likelihood of more older passengers using HS2 than currently travel by rail.

10.1.5 It was also concluded that the presence of steps into the train will also have a negative impact on the passenger experience of the train service and will significantly hinder the efforts of HS2 to provide a truly accessible service.

10.1.6 There are a number of other design challenges for HS2 around the interior design of the train and the control of passengers on the platform which will need to be addressed to optimise the boarding and alighting both in terms of speed and in delivering the right passenger experience.

10.1.7 The recommendation from this study is that level access from platform to train is significantly preferred for boarding and alighting times. It would also improve usability for those with luggage, small children and who are mobility impaired and provide support to the overall passenger experience of using HS2.