HIGH DENSITY BOARDING AND ALIGHTING – HOW DO PEOPLE REALLY BEHAVE? - A PSYCHO-PHYSICAL EXPERIMENT: 3RD INTERNATIONAL RAIL HUMAN FACTORS CONFERENCE

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Abstract

This paper contains details of a full scale psycho-physical experiment jointly designed by Arup and UCL and conducted at the UCL Pedestrian Access Laboratory. The experiment was developed to assist in the design of the Thameslink project (on behalf of the Department for Transport) where high densities of commuter traffic is expected and where the performance of users in boarding and alighting tasks is critical to overall system performance. The experiment involved 125 participants each performing boarding and alighting tasks for a 5 day period and the physical parameters and psychological stimuli being adjusted throughout to test the effect on their performance. The experiment utilised video technology to capture the boarding and alighting sessions and these were analysed in detail using behavioural observation software. The experiment data was then compared and validated with real life video data acquired from one of the stations on the Thameslink route. The outcomes from the experiment were then used inform computer models and to enable accurate modelling of pedestrian performance. The results also highlighted the need to consider the system in an holistic way and to give adequate consideration to factors such way finding, customer information and other behavioural influencers.

The findings from the research are summarised as follows:

- Computer simulation models can benefit from this kind of experiment ensuring that the nuances of behaviour, especially in high density

environments, are adequately taken in consideration in the model.

- The flow rates for alighting when a step down is involved is less than for boarding (Counter to intuition)
- Crowd density has are far greater effect on performance than was expected.

This research provides valuable insight into practical design and modelling for passenger boarding and alighting and has special relevance in high density environments. The presentation supporting this paper will contain full details of experiment development, execution and results/analysis and use example video footage.

Keywords: Behaviour, experiment, boarding/alighting

1. Introduction

The railway that links Bedford (in the South East) with Brighton (in the South) via London in the UK is known as Thames Link. This is an existing railway that currently carries significant volumes of passengers in and out of London on a daily basis. As with most railways serving capital cities, the passenger profiles differ between peak and non-peak times with a.m. and p.m. weekday peaks being mainly commuter passengers and leisure/non-business passengers being the main users at weekends and off peak times.

This railway is currently undergoing a major upgrade in order to accommodate the volume of demand predicted for the future. The upgrade includes permanent way, signaling and rolling stock as well as improvements to stations and facilities.

Arup were appointed by the UK Government's Department for Transport (DfT) in 2007 to provide technical assistance for the specification, design and procurement of the new rolling stock for this major infrastructure project.

Studies into demand have been conducted and high level demand modeling implemented for all stations along the route. The information obtained was then used to perform calculations on service level requirements and the overall system performance specification developed accordingly.

The outcome of this work is that, although the railway is categorised as 'heavy rail', the required service provision through the London section of the route will be similar to that of a metro style operation with trains arriving at stations every two minutes. Further study on the operation of the railway shows that the maintenance of reliable and fast dwell times is critical for the delivery of the performance required and that dwell times are one of the most important factors.

Feasibility studies for the permanent way and signaling options concluded that two minute head ways are achievable. This then gave rise to the question about the performance of users and in particular how the design of rolling stock and train/platform interface can affect the performance of these users.

2. Train platform interface challenges

Whilst the upgrade programme planned is extensive, the cost and feasibility of making changes to some of the existing infrastructure is prohibitive. For example, the positioning and alignment of platforms throughout the London section would need to remain as is.

Some of these platforms are built on a curve and this results in a horizontal gap that varies, throughout the length of the platform, between the train and the platform.

From a rolling stock perspective the design of the bogeys and suspension would have an effect on the height of the carriage floor with respect to the platform and the potential implication of any vertical gap on boarding and alighting performance would need to be understood.

2.1 Approach to the challenge

Arup were commissioned to perform a study on boarding and alighting performance at one of the London stations in order to obtain performance data and the effect that horizontal and vertical train/platform gap may have on the boarding and alighting performance of users.

The station selected was Farringdon where there are significant volumes of user traffic and where the platform is built on a curve, therefore providing some indication of the effect of gap size on user performance.

3. The Farringdon study

In order to ascertain the effect of gap size on user performance two video cameras were installed at vantage points on the platform. One camera was focused on a door at the front of the train, where the train/platform gap was small. The other was focused on a door half way down the length of the platform where the train/platform gap was large due to the curvature of the platform.

Video footage of all boarding and alighting at both doors over a twelve hour period was taken. This included a.m. and p.m. peak periods.

The video footage was then analysed using behavioural analysis software to an accuracy of 40ms.

The analysis methods included capture of exact timing of doors opening and closing, the number of users boarding and lighting within that time and the crowding density on both the train and on the platform. The analysis software allows the accurate capture of events such as when the user enters the door, when the user ‘lands’ on the platform etc and as such we were able to analyse the boarding/alighting performance dynamically and observe behaviour as well as record events within the timeframe.

3.1 Results from the Farringdon study

It is important to note that the vertical gap was the same at both doors.

The analysis from the Farringdon study showed that there was no significant differences in performance of users at either door. To this end we were not able to provide any insight into the effect of the size of the horizontal gap on performance of users.

There could be many explanations as to why the gap size in this particular instance did not affect performance. One hypothesis is that there may be ‘tipping points’ where step distance will have significant affects on performance. In the case of Farringdon, the delta in the horizontal gap distance at the two doors may not have been large enough to make a difference.

The study did, however enable us to ascertain the flow rate for boarding and alighting in a real environment and the results from the behavioural observations concluded that various train and platform parameters may have an effect on user performance.

Subsequent to a review of the Farringdon results the DfT took the decision that further research into user performance was required and Arup was commissioned, along with University College London (UCL), to design and execute a large scale psycho-physical experiment.

4. The experiment exam question

In order to ensure that any further research delivered value to the project, an approach was taken based on an ‘exam question’. This approach enables the focusing of research by clearly articulating the requirements by using a question.

The question was derived using the known system performance required to deliver the required service level. In this case station dwell time was used to derive a maximum door open time and the demand forecast was used to ascertain the number of boarding and alighting passengers required.

The exam question was arrived at during a number of workshops involving all stakeholders and was agreed as follows:

- ‘Can we board/alight 50 persons in 27 seconds?’ And
- ‘Which variables have what effect on the performance of passengers?’

5. The Psycho-physical experiment

5.1 Background to PAMELA.

In order to research the effect that various parameters could have on user performance, the UCL designed and operated Pedestrian Access and Movement Environment Laboratory (P.A.M.E.L.A.) was used to conduct a comprehensive psycho-physical experiment. PAMELA is a purpose built pedestrian laboratory situated in North London. The laboratory includes a fully configurable computer controlled platform which enables creation of slopes and steps with different surface materials, fully configurable lighting conditions, video camera gantry’s and a state of the art audio system that enables realistic production of the audio environment.

6. Summary of the experiment

Using the facilities in the PAMELA laboratory, Professor Nick Tyler of UCL and Ian Rowe of Arup designed an experiment which is understood to be one of the largest of its kind ever conducted.

This involved building a full size mock up of half a standard train carriage (10 metres) with windows, seating, luggage racks and opening door then using a representative sample of users to perform boarding and alighting tasks. Various parameters were then changed and the experiment repeated. The behaviours of all participants during all runs were recorded using video camera and these were then analysed to determine the effect that the various parameters had on performance.

6.1 Variables

The experiment was set up to enable physical and non-physical variables to be altered during the five days of experiments.

The variables were:

- Vertical gap between train and platform
- Door width (when fully open)
- Vestibule set back distance
- Seat configuration
- Passenger density on train

- Passenger density on platform
- Level of encumbrance (luggage carrying)
- Platform queuing rules

6.2 Participants

The participants for the experiment were recruited using various techniques and were financially compensated for their time in participation.

For each of the five days of experiments there were around 125 participants and these included a representative profile including age, gender, size, physical fitness and abilities etc. All participants were treated in accordance with UCLs ethics policies and practices.

6.3 Method

Each participant was allocated a unique number which was used throughout the day of the experiment. The starting condition was then set by instructing the participants by their unique identified whether to stand on the platform or board the train. Once this start condition was achieved then the train door was closed and the experiment could begin.

For each run of the experiment the following sequence was used:

- The participants on both the train and the platform were informed of their required task (By unique identified number, participants were informed if they were to board the train, alight the train or remaining in position.)
- An audio sequence of a train arriving at a station was then played back over the PA system in order to provide an increased feeling of reality and provide audio cues enabling participants to prepare for the task.
- The door alarm sounder was activated.
- The door was opened to allow the boarding/alighting task to begin
- After 24 seconds the door close alarm was then activated to warn of door closing.
- 3 seconds later the door was then closed regardless of the boarding/alighting situation
- The participants were then instructed to complete their required to task once the door were re-opened
- The doors were then re-opened
- Individuals completed their boarding/alighting task

For each physical configuration condition there were 3 runs of the experiment. This enabled reliable results to be obtained by decreasing the effect of variation in performance associated with any individual.

The proportion of participants instructed to board and alight during the experiment was as follows:

- 5 Boarding/45 Alighting – p.m. peak conditions (mainly boarding)
- 45 Boarding/5 alighting – a.m. peak conditions (mainly alighting
- 25 Boarding/25 alighting - worst case performance conditions (50% contra-flow)

After 3 runs of the experiment for each boarding/alighting proportion, the whole area was cleared of participants and the physical train/platform parameters were adjusted one at a time.

The physical parameters used throughout the 5 day experiment were as follows:

- Platform/Train step height: 50mm, 165mm, 250mm
- Maximum door open width: 1300mm, 1500mm, 1800mm
- Vestibule set back (Position of draft screen relative to the door position when fully open): 0 mm, 400mm, 800mm

Other factors intended to influence behaviour were also implemented including:

- Platform 'keep clear' zones
- Platform 'queuing' zones

For each run of the experiment all participant behaviour was captured by overhead video cameras covering Train left, Train right, Train vestibule, Platform left, Platform right and Platform door area.

After completion of the five days of experiments, all video footage was analysed using behavioural analysis software and results published.

6.4 Experiment results and analysis

This section contains a summary of results from the experiment.

A common metric of flow rate measured in Persons per Second (PS) was used to quantify performance.

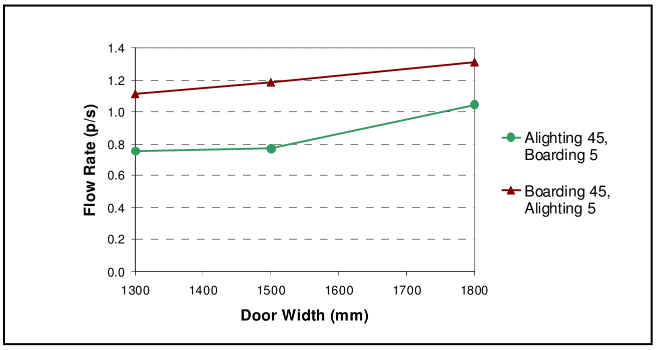

Fig. 1 Effect of door width

Conclusion: Flow rate increases with increase of door width.

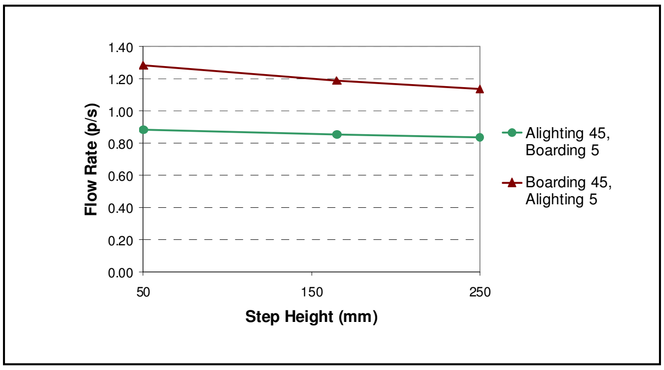

Fig. 2 Effect of vertical step distance

Conclusion: The lower the stepping distance the higher the flow rate

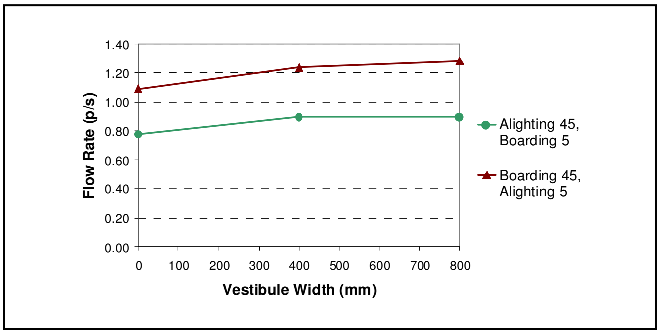

Fig 3. Effect of Vestibule set back
Conclusion: The larger the ‘set back’ the greater the flow rate

6.5 Comments on findings

With regard to the findings the following observations are made:

6.5.1 Physical variables

Perhaps un-surprisingly, maximum flow rate is achieved with the largest door size, lowest step height and maximum vestibule set back distance.

Flow rate for alighting is lower than for boarding. This may seem counter-intuitive but is aligned to other research conducted by UCL on stair usage. It is believed to be due to lack of visual information, there is a momentary delay for each participant at the position of the step whilst a plan for the landing is derived. i.e. people pause at the threshold to determine the distance down, prepare for how they should land etc. Conversely, for stepping up participants can generally see or better perceive the distance to climb etc. before reaching the threshold and therefore less delay is required.

Whilst there is a slight improvement in flow when using the larger vestibule set back, the improvement is not linear and between 400mm and 800mm there would seem to be a diminishing return on the trade off between increasing vestibule set back (therefore decreasing available seating room in the carriage) and performance. From observations it would appear that this is due to the behaviour of participants in the vestibule area. A 400mm set back enables one person per side to stand without obstructing the flow at the door. Flow rate is increased due to a slight decrease in density in the vestibule. However, when 800mm is used participants chose not to close themselves into a corner and be tightly blocked in by the person using the vestibule set back space. Therefore, although the actual space available in the vestibule increases, the behaviour of the participants resulted in the same crowd density in the vestibule as the extra 400mm became effectively ‘dead’ space. The slight increase in flow is likely to be due to the ability of participants that were staying in the vestibule to move to enable ‘movers’ to pass.

6.5.2 Non physical variables

After all physical parameters were adjusted, behavioural influencers were introduced to establish effects on participant task performance.

A clear zone on the platform directly in front of the door was introduced and participants instructed not to wait in this zone. Further, participants were also instructed to allow alighting participants off the train before boarding. The analysis from experiment runs showed that there was no significant improvement in overall performance. However, it was noted that density in the train could be a major influencing factor as the ‘crush load’ conditions used during the experiment meant that participants were not able to pass each other quickly and therefore flow was impeded. i.e. the bottleneck for alighting participants on the platform was removed by the platform marshalling but the bottleneck in the train remained.

Introduction of platform queuing lines had a similar effect as that of clear zones. This is also probably due to density of participants in the vestibule area of the train.

6.5.3 Behaviour of participants

During the experiment observations of behaviour of participants was observed and the following noted:

Participants quickly learnt the cues provided by the audio sound track and were observed preparing for movement prior to the event of door opening. This is similar to the behaviour exhibited by regular commuters who are familiar with visual cues associated with their destination.

Despite the lack of penalty for not achieving the task within the 27 second time scale, participants were observed making a genuine effort to perform the tasks required.

The participants had learnt the experiment process within a short time and behaved accordingly. E.g. were observed reading newspapers and books within the train etc. There was a concern during the design of the experiment that participants would start to socialise during the experiment and this may have affected behaviour. It was noted however that during observations, participants behaved very similarly to those during the a.m. and p.m. commute i.e. little verbal communication.

The results from the psycho-physical experiment were then used to provide inputs for a pedestrian model that is being used to assist in the selection of rolling stock design options.

7. Pedestrian modelling

The performance information obtained from the experiment with respect to flow rate across the train/platform interface and other behavioural information such as how participants preferred to use spaces within the train on boarding was used to inform a pedestrian simulation model. Legion software was used to provide base data on flows and behaviour and configured to allow organisations, bidding for the rolling stock tender, to test their designs for performance against the required specification. The testing and submissions of design against the requirement using the Legion model now forms part of the tender evaluation process.

Credits:

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