PEDESTRIAN MODELLING FOR PERSONS WITH RESTRICTED MOBILITY AT TRANSPORT INTERCHANGES

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1. INTRODUCTION

The use of simulation modelling of passengers and pedestrians within stations and buildings has become commonplace and the application of capacity and safety evaluations is required by many rail and mass transit operators. As simulation software packages have developed, so has their application. In addition, operators and designers are now increasingly looking to address the needs of passengers and pedestrians with mobility restrictions.

Additionally, whilst interest groups and users will have a very positive contribution to make, decision makers often need to ensure that there is value for money or a priority order for work for accessibility investments. Developing a consistent accessibility and access review approach for major transport investments is required for this process.

The Mott MacDonald in-house pedestrian simulation model (STEPS) has included gradient impact within the simulation process, which is one of the factors that affect persons with restricted mobility. More recently STEPS has been developed further, with the inclusion of more person types within the simulation. Additionally, with the newer detailed platform train interface simulation program (ALIGHT) the wider issues of train doors, vestibule and seating arrangements are simulated.

This paper introduces the issues and concepts involved, the range of transport users to consider, the software approach and the results obtained through using the new approach. It outlines the developments within the STEPS and ALIGHT simulation programs that assess how interchange design may impact on passengers and pedestrians with reduced mobility. Furthermore, it sets out how this more detailed simulation approach will contribute to train, tram and other public transport investment decisions for greater accessibility.

2. ISSUES

As utilisation of rail stations and rail networks increases globally, railway operators and governments are applying greater focus on the capacity of railway systems. Additionally, rolling stock design and interface with the platform have become more important elements of the overall system capacity assessment.

Over the past decade regulations in the EU have been put in place to address the needs of people with reduced mobility (PRM). It is notable that such users form more than one-third of the European population. These include wheelchair users, elderly people, people travelling with young children and people with heavy luggage. They can all face barriers when using public transport. At some time in the majority of peoples' lives, they will travel as a PRM.

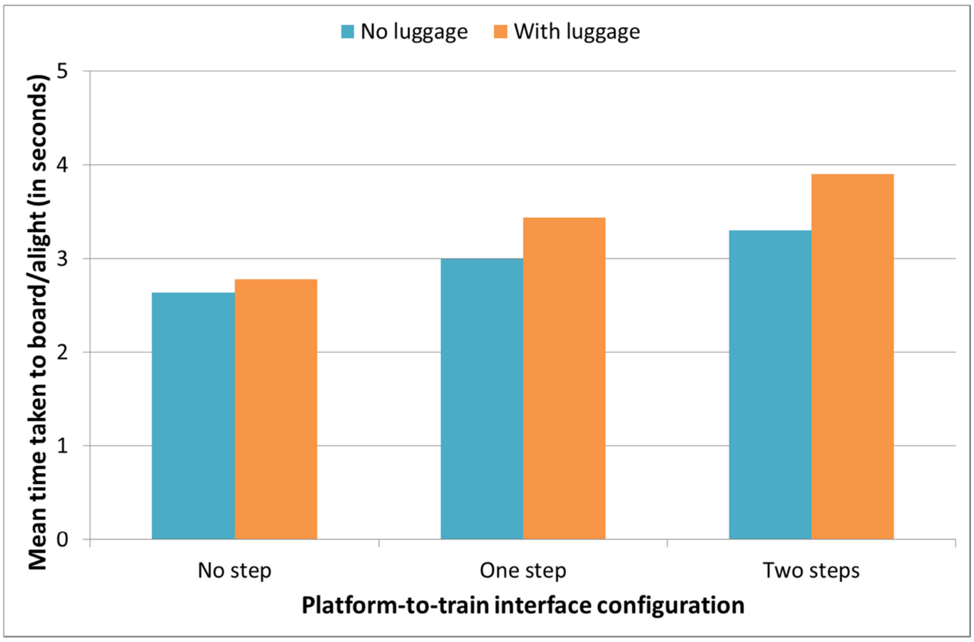
The UK Department for Transport has invested £370 million over the past decade to deliver a programme of access improvements across the network. There are currently 66 step free stations on the London Tube (or 24% of the 270 Tube stations). Further infrastructure developments, such as Crossrail and Thameslink are making provision through step-free access.

Station accessibility improvements often consist of ramps and lifts as an alternative to stairs (i.e. step-free access), the provision of seating and resting places located away from busy travel paths and appropriate wayfinding and well-lit station environments. These improvements can benefit all passengers.

Rolling stock designers have also incorporated improvements to train layouts, including step-free access and wider doors to facilitate the boarding and alighting process, dedicated spaces for wheelchair users and priority seats for other passengers with reduced mobility.

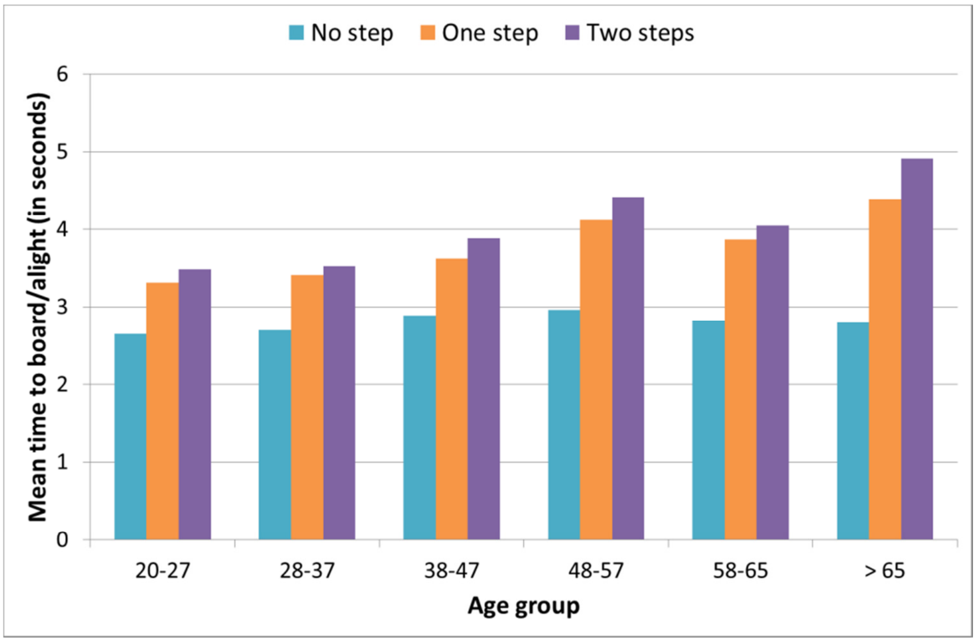
Research carried out by University College London has assessed the impact of vertical gaps and luggage on the passenger exchange times. The findings of the experimental study are summarised in Figure 1 and Figure 2.

Figure 1- Effect of luggage on mean time taken to board/alight per platform-to-train interface



Source: Effect of vertical step height on boarding and alighting time of passengers, Holloway, C. (2016)

Figure 2- Mean time to board/alight by age group



Source: Effect of vertical step height on boarding and alighting time of passengers, Holloway, C. (2016)

As would be expected, the higher the vertical gap between the platform and the train, the more time it takes per person to board/alight. Without luggage, the average time to board/alight for a two-step configuration is 25% greater when compared to a configuration with no steps. The addition of luggage increases the mean board/alight time further by 5%-18%, depending on the vertical gap.

The analysis per age group showed that the mean time to board/alight was comparable for all age groups with the no step configuration, demonstrating the benefits of a step free design for all passengers. With the introduction of one and two steps, board/alight times exceeded 4 seconds for the older groups.

3. CONCEPT

3.1. STEPS Pedestrian Modelling Software

The dynamic simulation results presented in this section have been calculated using the STEPS software. STEPS is a microsimulation tool for the prediction of pedestrian movement under both normal and emergency conditions, designed originally for modelling pedestrian flows in transportation systems though now of quite general application. The basic modelling approach was presented originally by Hoffmann and Henson and has since undergone extensive development. It has been applied to a variety of major projects including Melbourne Metro (Australia), Doha Metro (Qatar), AMTRAK station (USA), Amsterdam North/South Line (The Netherlands), Stockholm City Line (Sweden) and Kuala Lumpur Metro (Malaysia).

STEPS employs an agent-based approach which predicts the movement of discrete individuals (virtual people) through three-dimensional space. The advantages of agent-based models are that they can give a more realistic representation of pedestrian movement and they can allow the elucidation of subtle but important details of pedestrian movement, thereby giving greater insight to the designer. The individual agents are given certain characteristics, such as free walking speed, patience level and familiarity with the space, and then allowed to move through the model attempting to fulfill their individual goals. Typically, free walking speeds are set according to a statistical distribution and may be reduced to reflect congestion effects using either a speed-density or speed-distance relationship.

3.2. ALIGHT Train-Platform Interface Software

Existing pedestrian modelling software, such as STEPS, have generally been developed for the simulation of crowd movement in the built environment. As a result, there are a number of limitations when these are applied to the modelling of the train and platform interface.

The ALIGHT software enables the detailed simulation of the interior space of vehicles, with built-in passenger behaviours defining their interaction with the vehicle layout. It provides an effective modelling tool for the analysis of the vehicle capacity, as well as the boarding and alighting process.

Additionally, the software is set up so that the computer interface enables the user to test a number of timetable, demand and layout scenarios in an efficient manner.

ALIGHT is designed to respond directly to the increased demand from major transport investment projects for the computer assessment of rolling stock capacity and performance, particularly with respect to dwell times and passenger exchange.

4. APPLICATIONS CONSIDERED

In the present study, two station layouts are considered and for each, a pedestrian model has been constructed.

The first application reviews the proposed station layout and the impact on journey times based on the type of passenger, using the STEPS software.

The second application investigates the rolling stock layout and the impact on the passenger exchange time, using the ALIGHT software.

5. APPLICATION 1 – REVIEW OF STATION LAYOUT AND IMPACT ON JOURNEY TIMES

For this application, the following elements of the station layout have been modelled and assessed in the STEPS software:

- Locations of lifts
- Route choices

For each element assessed, data has been extracted from the modelling, which can assist in the assessment of the accessibility of the designs for different types of persons with restricted mobility (PRM).

5.1 Location of Lifts – Modelling Assumptions

5.1.1 Station Layout

Two station layouts have been assessed in this study, which are identical aside from the location of the lift:

- Layout 1 – the lift is located next to the escalators, near to the station entrance
- Layout 2 – the lift is located halfway along the length of the concourse and platform, approximately 100m from the station gate-line

Layout 1 and layout 2 are illustrated in Figure 3 and Figure 4, respectively, with measurements to vertical transport from the gate-line provided in Figure 5 and Figure 6.

Figure 3 - Layout 1

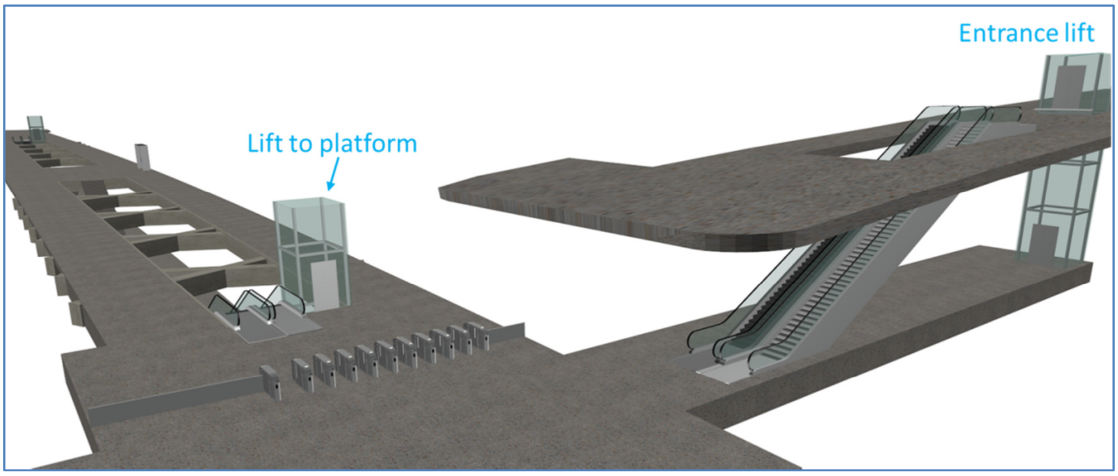


Figure 4 - Layout 2

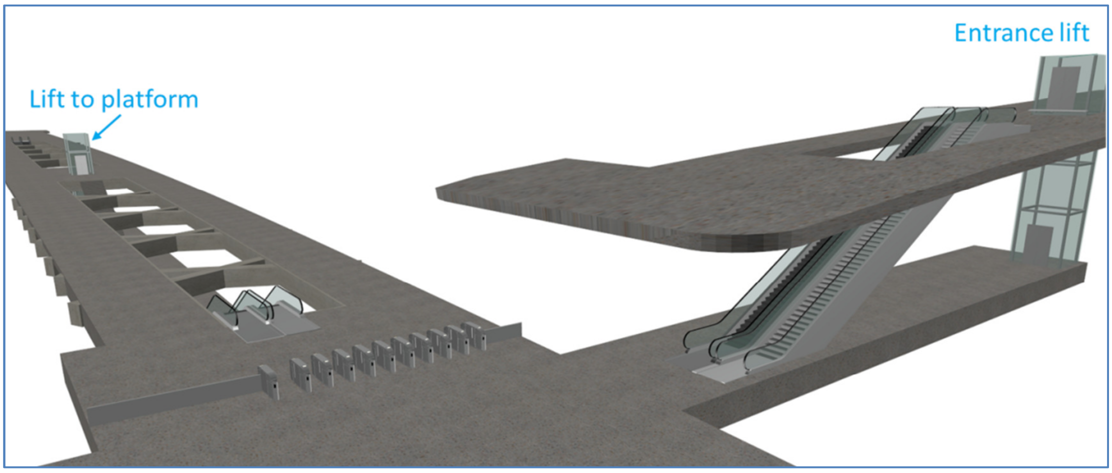


Figure 5 - Layout 1 – Top-down View

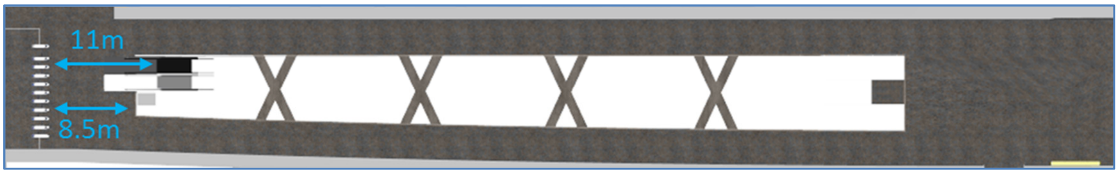
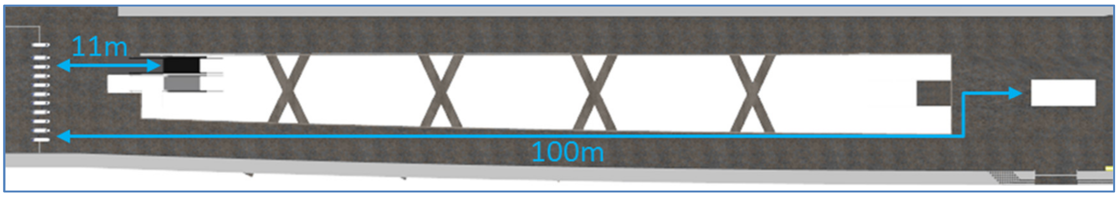


Figure 6 - Layout 2 – Top-down View



5.1.2 Passenger Demand Assumptions

The types of PRM used for the modelling, and associated attributes and walking speeds are taken from the London Underground Best Practice Guide and described in Table 5-1.

Table 5-1 – Passenger Types

Passenger Type	Attributes	Walking Speed
Standard	Non-PRM	Distribution: Min 1.1m/s, Mean 1.53m/s, Max 1.9m/s
PRM A	Wheelchair user	Fixed, 0.58 m/s
PRM B	Passengers with permanent or temporary physical mobility impairments	Fixed, 0.8 m/s
PRM C	Non-disabled passengers with heavy luggage	Distribution: Min 1.1m/s, Mean 1.53m/s, Max 1.9m/s
PRM D	Non-disabled passengers with heavy luggage	Distribution: Min 0.9m/s, Mean 1.32m/s, Max 1.7m/s
PRM E	Adults with young children (including with pushchairs)	Distribution: Min 1.0m/s, Mean 1.37m/s, Max 1.8m/s

5.1.3 Routing Assumptions

For the purposes of demonstration, only boarding passengers have been considered in this application. All passengers use the lifts from entrance to platform.

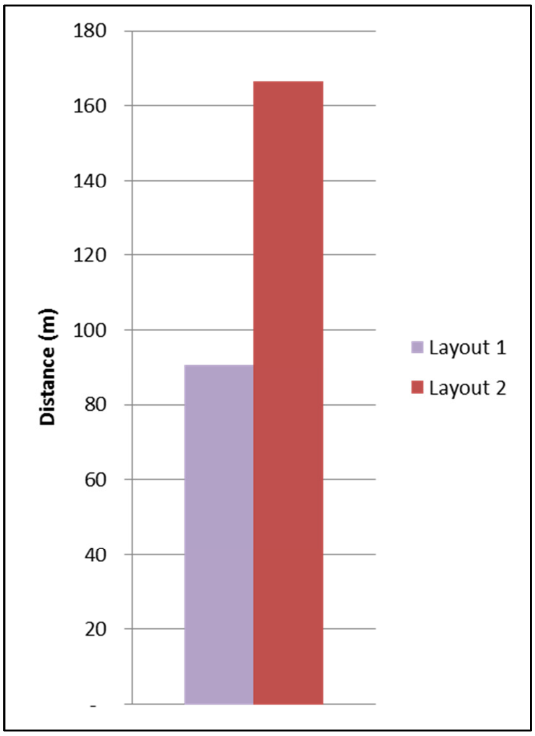
5.2 Results and Discussion

Figure 7- STEPS Simulation of Different PRM Types

Measuring dimensions on CAD is straightforward, however, measuring likely walking distances is more difficult as people may follow different routes depending on obstacles and levels of congestion. The STEPS software can automatically extract actual journey distances walked by people, highlighting differences between designs.

Figure 8 provides a graph created from STEPS data, showing the increased journey distance for lift users in Layout 2 when compared to Layout 1.

Figure 8- Total Journey Distances for Lift Users



As well as providing an indicator of the favourability of a design, the journey distance also highlights where distances may be so great that the provision of resting areas at regular intervals would be recommended for passengers with restricted mobility. The University of Leeds undertook research on walk speeds for disabled people and found that participant's required breaks when walking distances as short as 180m. This of course varies depends on the individual, including their age and extent of disability. Berrett (1988) described minimum seat spacing for maximum walking distances, based on peoples' age and level of walking impairment, as summarised in Table 5-2.

Table 5-2 - Proposals for minimum seat spacing

	Restricted Mobility				More able-bodied		
Age	90	85	80	75	90	85	80
Distance (metres)							
Maximum horizontal walking distance	30	45	60	110	110	220	280
Minimum rest area seat spacing	20	25	32	75	65	130	200

However, these results are not verified and there are multiple factors affecting the results, including health, tiredness, weather, congestion levels. More research needs to be done to provide better and more recent guidelines. The following is recommended for seating at stations:

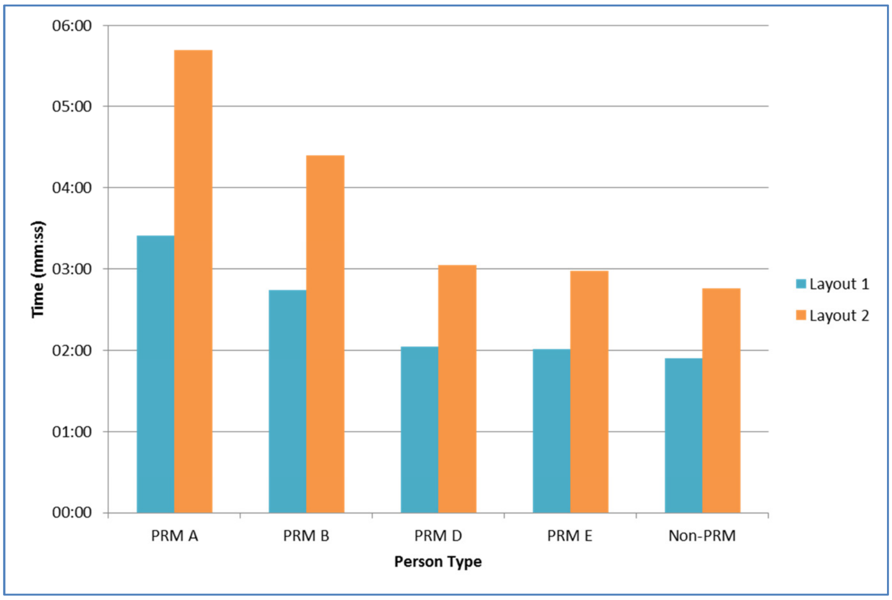
- Transport for London (2011) guidelines recommend that "seats shall only be installed along the platform wall within the 0.5m allowed for Edge Effects and not within 5m of platform entrances or exits."
- Adequate lift waiting areas with seating and wheelchair space should be provided, removed from circulation spaces.

Additionally, the Design Standards for Accessible Railway Stations, a joint Code of Practice by the Department for Transport and Transport Scotland, states:

- "on each platform where passengers are allowed to wait for trains and at every waiting area, there shall be a minimum of one area fitted with seating facilities and a space for a wheelchair."
- "where there is minimal seating, it should be clearly marked as being priority seating for disabled people, older people, pregnant women and those carrying young children."
- "Seating layouts should allow a wheelchair user and a companion to sit next to each other."

Naturally, journey time increases as journey distances increases. The journey times for each layout based on the modelling assumptions presented in Section 5.1.2, for the different types of PRM, are summarised in Figure 9.

Figure 9- Journey Time for Lift Users



In layout 1, the expected journey time for PRM A is about 80% higher than the journey time for standard passengers. With a longer travel distance from entrance to lift, the impact on journey times is even greater: in layout 2, the journey time for PRM A is over double that of standard passengers.

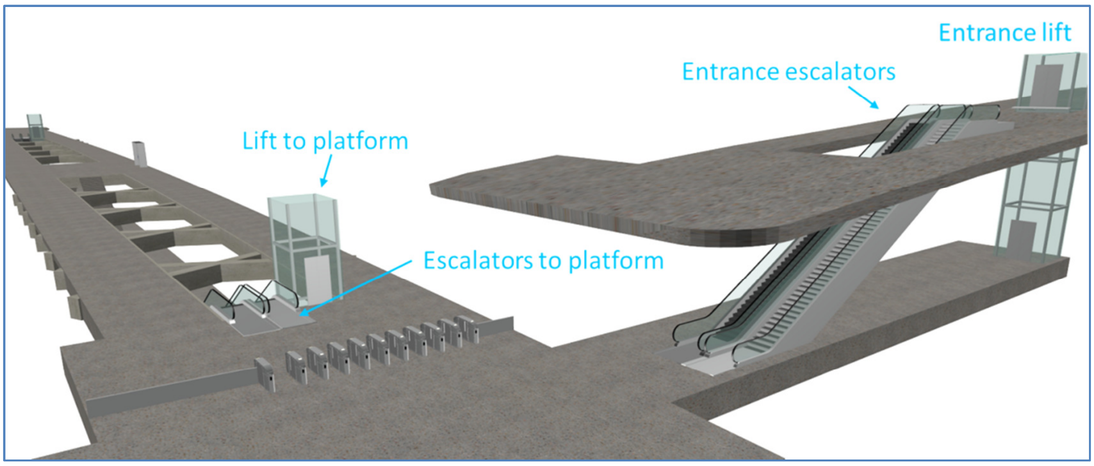
Considering that PRM A need to use the lifts, but standard passengers may have alternate route options, it is important to consider the location of lifts not only in what works for a design, but in how the user experience will be affected.

5.3 Route Choices – Modelling Assumptions

5.3.1 Station Layout

Figure 10 illustrates layout 2, with the addition of the use of escalators for all types of PRM, except PRM A who are wheelchair users.

Figure 10- Station Layout



5.3.2 Routing Assumptions

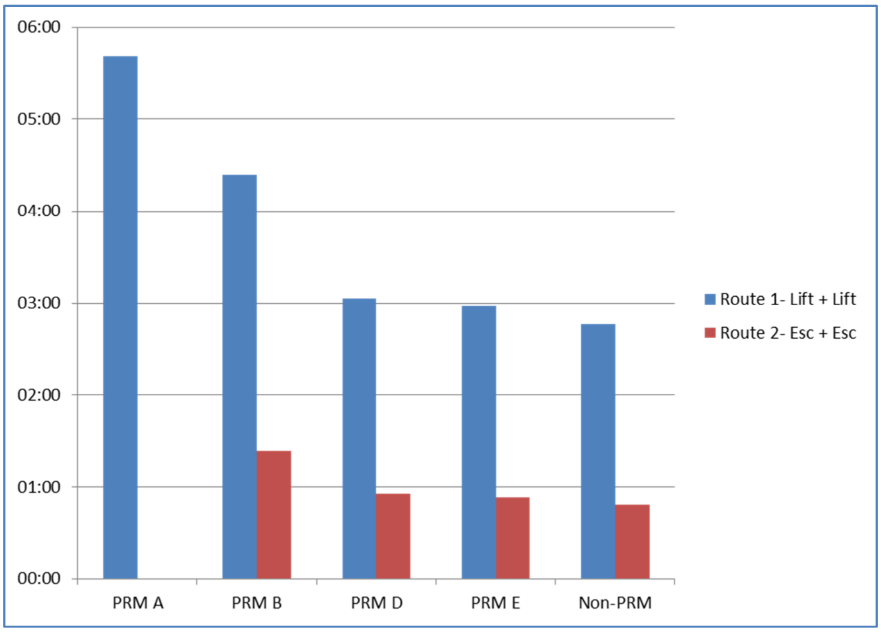
For the purposes of demonstration, only boarding passengers have been considered in this application. Two routes have been considered:

- Route 1 – via lifts
- Route 2 – via escalators

5.4 Results and Discussion

Journey times of different routes can be compared using the STEPS software, and is provided for Routes 1 and 2, in relation to the PRM type, in Figure 11.

Figure 11- Journey times for different routes



Using the escalators, rather than lifts, is shown to greatly improve journey time in this example. Journey time is one consideration when looking to create a positive user-experience. The software can also extract delay times, for when people are unable to walk at their preferred speed, queuing times, and time spent in lifts. All of these are useful to assess performances of different designs and, particularly with PRM types programmed into the model, user-experience.

London Underground takes this method further and applies a weighting to different stages of a journey, for example, walking, waiting or riding on transport. These are derived from the level of comfort experienced and level of effort required during the different stages of a journey. The time spent on each activity is multiplied by the weighting factor to give a social cost, measured in UK pounds (£). An extract of these weighting factors is given in Table 5-3.

Table 5-3- Weights for Elements of LUL Journey Time (extract)

Journey Characteristic	Weighting
Riding • on escalators • on lifts	 1.5 2.0
Waiting • for trains or lifts in acceptable uncongested conditions	2.5
Walking • unimpeded	2.0

Table 5-4 gives the LU calculations with weightings for Route 1, with lifts, and Route 2, with escalators, for layout 2.

Table 5-4- LU Journey Time Calculation for Layout 2

	Time (minutes)	Weighting	Total
Route 1			
Riding in lifts	0.62	2.0	5.6
Waiting for lift	0.30	2.5	1.23
Walking unimpeded	2.80	2.0	0.75
		Total	**7.58**
Route 2			
Riding on escalators	0.42	1.5	0.63
Walking unimpeded	0.40	2.0	0.8
		Total	**1.43**

The table shows that a higher social cost is associated with Route 1 (using lifts) than Route 2 (using the escalators). This is a conservative result for PRM A, as the weighting factors do not account for the type of user, and wheelchair users may be expected to find different stages of trips more difficult. This highlights the importance of considering all users when creating a design.

6. APPLICATION 2 – REVIEW OF ROLLING STOCK LAYOUT AND IMPACT ON PASSENGER EXCHANGE TIMES

For this application, an ALIGHT model has been built based on the existing Platform 3 layout of Vauxhall Station, London, UK, with the peak passenger survey counts provided by Network Rail. It considers the following scenarios to evaluate the impact of the train-platform interface design on passenger exchange times:

- Step-free access between train and platform
- 1 step between train and platform
- 2 steps between train and platform

6.1 Modelling Assumptions

6.1.1 Station Layout

The assessment focusses on the busiest carriage (carriage number 4) located on the middle section of the platform, next to the stair platform access. The Vauxhall station platform layout is presented in Figure 12 while a 3D view of carriages 3 & 4 are shown in Figure 13.

Figure 12- Vauxhall Station – Platform Layout (top view)

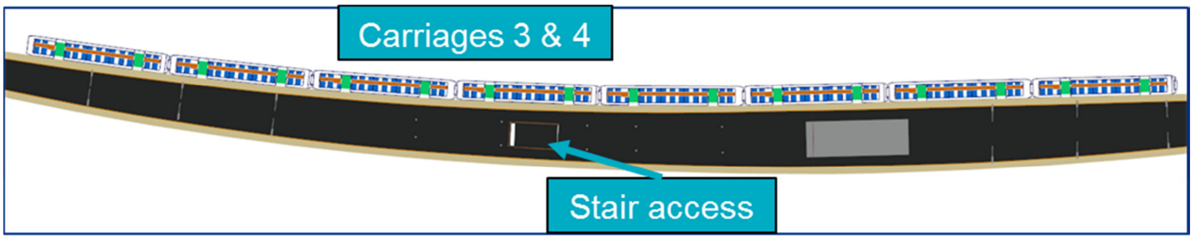


Figure 13- Vauxhall Station – Carriages 3 and 4 (3D view)

6.1.2 Passenger Demand and Timetable Data

The passenger demand and train timetable modelled in ALIGHT is based on Network Rail survey data (May 2013), summarised for the busiest carriage (i.e. carriage number 4) and busiest two trains during the AM peak 15 minutes, in Table 6-1.

Table 6-1- Passenger demand and timetable information

Train Number	Train Arrival Time (hh:mm)	Number of Boarders (Carriage 4)	Number of Alighters (Carriage 4)
Train 1	8:06	32	3
Train 2	8:18	34	4

An image from the CCTV footage illustrating the Vauxhall station platform layout is presented in Figure 14.

Figure 14- Comparison of CCTV footage and ALIGHT simulation prior to train arrival

6.1.3 Boarding and Alighting Times

The modelled boarding and alighting times per passenger are based on observed mean boarding/alighting time by step condition recorded by Watts. These are presented below in Table 6-2.

Table 6-2- Modelled boarding and alighting times

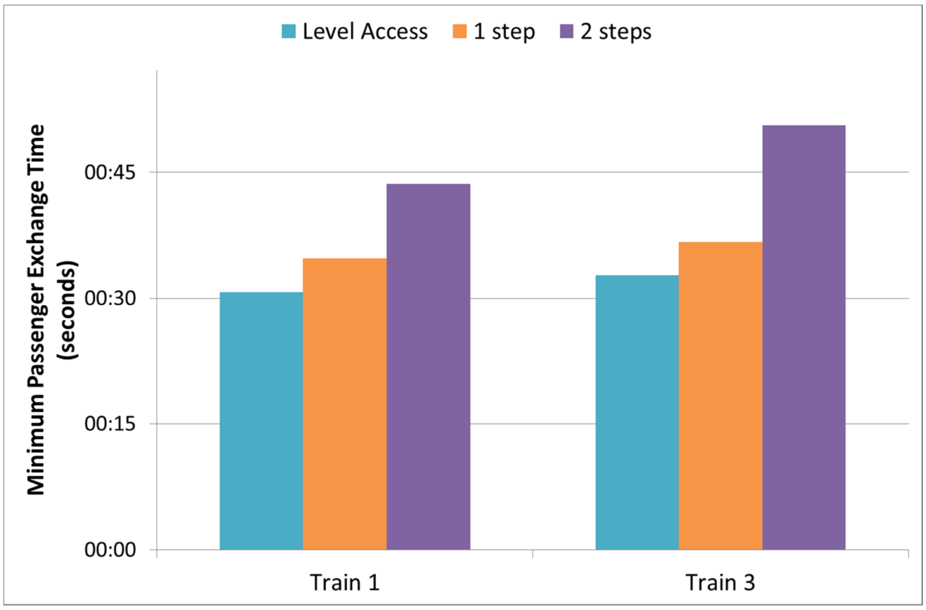
Scenario	Average Boarding/Alighting time (seconds)
Level Access	2.0
1 step	2.5
2 steps	5.5

Source: *Passenger Boarding Time, Mobility and Dwell Time for High Speed 2,* Watts, D. (2015)

6.2 Results and Discussion

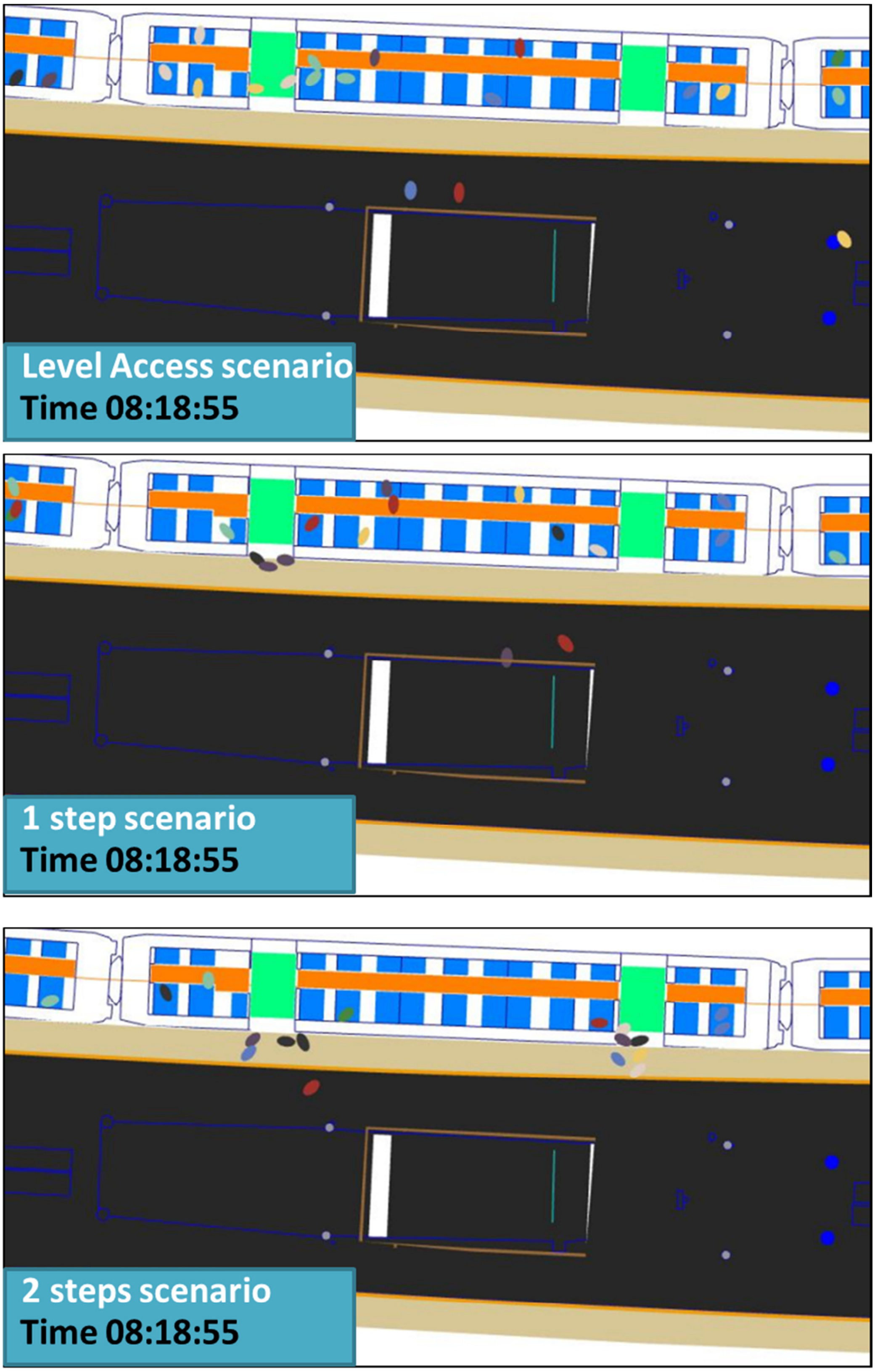
For each scenario assessed, five simulations runs were completed. The average results are presented in Figure 15.

Figure 15- Minimum passenger exchange time results



The higher the vertical distance between the platform and train, the greater the minimum exchange time. This increases the dwell time required for all passengers to alight and board each train. Snapshots from the three scenarios at 08:18:55 hrs, which corresponds to the end of the passenger exchange time for the Level Access scenario, are presented in Figure 16, illustrating the number of boarding passengers remaining on the platform for the 1 and 2 steps scenarios, when compared to the Level Access scenario.

Figure 16- Snapshots from ALIGHT simulations, taken at 08:18:55



For Vauxhall station, there is currently one small step between platform 3 and the train.

Compared to the one step scenario, the results for two steps indicate that the expected passenger exchange time is likely to increase by over 30%. In this example, this corresponds to an increase of 10 to 15 seconds per train, which would significantly reduce the maximum train frequency possible on a line, and therefore, reduce the capacity of the system.

In the level access scenario, a gain of 12% (i.e. 4 seconds in this example) in the passenger exchange time would be expected. While this time gain appears to be relatively small, it is important to note that the benefit for passengers with reduced mobility would be significant.

Based on EU rules for assistance at railway stations, passengers requiring assistance for a train journey need to plan their trip well in advance to ensure that station staff are available to help them board and alight from train on their journey. In addition, they are required to arrive at the train station at least 30 minutes before the scheduled train arrival to allow sufficient time for boarding. This results in a non-negligible increase in journey times for these mobility restricted passengers. One more factor to consider is the increase in passenger exchange time due to passengers with restricted mobility boarding and alighting from trains with the help of station staff. According to Transport for London, there may be a delay of up to five minutes at terminating stations. This extends the journey times of all passengers on the train and may also delay the following train on the same line.

For stations with step-free access route between the entrance and the platform levels, a level access design for the train-platform interface would enable wheelchair users to travel without any assistance. It would significantly reduce their journey times, as well as the journey times of all other passengers, demonstrating the benefits of a step-free access train-platform interface.

7. CONCLUSIONS AND RECOMMENDATIONS

This paper has presented the approach and potential benefits for simulating the impact of station layouts on persons with restricted mobility. The scenarios assessed have indicated how interchange time differences and other factors can be an indicator for accessibility and thus for the assessment of options for different mobility needs. Further integration of simulation results with accessibility requirements for persons with restricted mobility is recommended for all pedestrian simulation modelling to ensure an equitable assessment of transport interchanges.

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