Kling David R, Marinov M. Age-Friendly Rail Station: Software package application for designing and evaluating rail stations. ***In: RailLille2017, the 7th International Conference on Railway Operations Modeling and Analysis*****. 2016, Lille, France.**

DOI link to Conference:

https://raillille2017.sciencesconf.org/

Date deposited:

10/04/2017

Age-Friendly Rail Station Simulation: Software package application for designing and performance evaluating of railway stations

Raphael Kling David, Marin Marinov
NewRail - Newcastle Centre for Railway Research Newcastle University,
Newcastle upon Tyne United Kingdom.
r.kling-david@ncl.ac.uk, Phone: +44 (0) 191268864533

Abstract

The study of railway station design, considering new technologies, operational measures, and operational solutions, has become an important aspect of rail planning. Railway stations have been extensively studied in recent years looking at understanding the movement of different individuals in urban environments to improve customer experience and passenger flow. The effect of an ageing population in Europe seriously increases the importance of the transport system design including stations. Developing age-friendly transport systems requires a significant improvement in sympathetic and realistic transportation design. Although considerable research has been devoted to the design of accessible railway stations, less attention has been paid to identifying the specific mobility and safety needs of older people. The purpose of this investigation is to study problems which may inhibit elderly mobility and to support flow modelling of older people within railway stations. This study uses an exploratory case-study approach to investigate the level of accessibility performance of the age-friendly railway station.

Keywords
Older people flow simulation, VR simulation, Age-Friendly Rail Station, Elderly simulation

1 Introduction

The fast-growing and ageing population is one of the most important societal challenges Europe is facing. The demographic trends projected show a dramatic change in age structure of the EU population due to multiple factors such as the dynamics of fertility, greater life expectancy and migration rates.
The integration of the older and disabled people into the society presents important challenges for public transport leading many European countries to rethink transport infrastructure and vehicle design to recognise these developments by developing a more inclusive and understanding approach.
People Flow modelling and transport layout simulation technology have led to many intuitive advances in recent years improving the layout planning at railway stations to allow easier circulation.

1.1. Objectives
The objectives of this work are to evaluate the existing simulation tools for designing age-friendly railway stations suggesting an alternative methodology for estimating, analyzing and evaluating the railway stations performance capabilities at the concept and early

design stages.

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Although considerable research has been devoted to the design of accessible railway stations, less attention has been paid to identifying the specific mobility and safety needs of older people. The purpose of this investigation is also to study problems which may inhibit elderly mobility and to support flow modelling of older people within rail stations. This study uses an exploratory case-study approach to investigate the level of accessibility performance of the age-friendly rail station for Newcastle Central Station.

1.2. Paper outline

This paper is addressed at "Age-Friendly Railway Station Simulation: Software package application for designing and performance evaluating of railway stations" and is presented in a cumulative way. Each section presented is dependent to the preceding sections.

The paper is organized as follows. It begins with the motivation for age-friendly transport and inclusive design, including a brief overview of the key literature on inclusive design and demographic trends that will have a profound impact on the future passenger transport system in the European area.

In Section 3 short definitions of People Flow modelling are provided followed by a brief literature review of people flow simulation focusing on agent-based models and the main differences related to age. An overview of simulation tools is presented in Section 4.

Next, a simulation modelling methodology for evaluating age-friendly station is proposed in Section 5, followed by a detailed case study demonstrating its application in Section 6. Finally, in Section 7 synthesis and conclusions are presented

2 Age-Friendly and Inclusive Design

Looking at the economic impact of demographic trends the European Commission's 2015 Ageing Report (EC, 2015) forecasts that the EU will move from having four working-age (15-64) people for a person aged over 65 years in 2013 to two by 2060. Demographic changes in the form of an increasing longevity and low birth rates have forced the international community to consider improvements to meet the needs of an increasingly ageing society, bringing more economic growth and jobs and also reducing the health care costs. Figure 1 illustrates the life expectancy for men. The increasing longevity will affect the average age of Europe and increase significantly the number of people aged over 65 with special characteristics that require alternative infrastructure and vehicle designs.

Life expectancy at birth, men (in years)

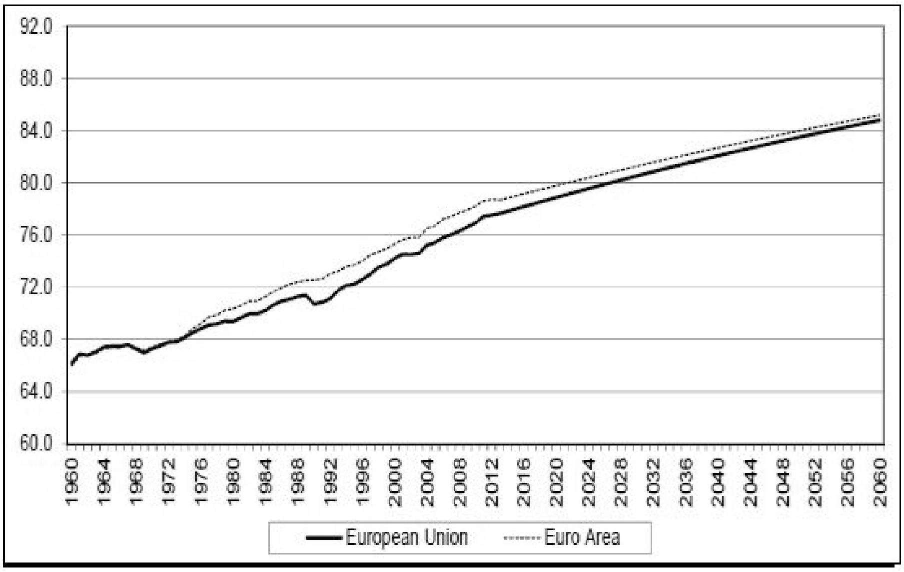

Fig 1 – Trends toward life expectancy European Union Euro area (men)

The transport system as an enabler of economic activities such as access to economic activities, entertainments, and health, plays a crucial role in regards to the life quality of older people. According to with Holley-Moore and Creighton (2015) in the United Kingdom 1.45 million of those 65 and over find it difficult to travel to hospital, whilst 630,000 of those 65 and over find it difficult or very difficult to travel to their GP. Considering analysis from the English Longitudinal Study of Ageing (ELSA) the authors have identified that the current transport system is failing to meet the needs of older people due to significant design limitations.

The importance of including disabled individuals in the process to build public spaces toward a more inclusive society is not recent. In 1985 the Disabled Persons Transport Advisory Committee (DPTAC) was established in the UK as an independent advisory group offering advice and challenges to the government to help the transport sector to meet the transport needs of disabled people. A legal framework was implemented in the 90s in the US with the Disabilities Act 1990 and Disability Discrimination Act 1985 in the UK, now part of the Equality Act 2010, requires transport operators to ensure that customers can board transport vehicles with relative ease. The UK legal framework for the passenger transport sector also includes the Transport Act 2000 and the Active Travel Act 2013 proposed by Welsh Government to encourage the use of public transport by reducing the use of the cars for short journeys.

However, to understand the transport design process for an ageing society it is important to recognise the evolution of the concept of disabled people that in the past was characterized by a medical model of disability (born or acquired) to one of social disability in which people experience disability by inadequate design, inconsiderate and inappropriate services, environments and cultural stereotypes (Clarkson and Coleman, 2015). A more detailed analysis of the evolution of the inclusive design concept has been carried out on [Coleman at al. 2003, Waller et al 2015. Clarkson and Coleman 2015)

The modern concept of inclusive design has grown in importance recently with several publications addressing the need to make rail accessible including DfTS 2015,TRB 2012 and NetworkRail 2011. Despite the fact that previous solutions to station design improvements are promising, none have taken the focus specifically on age challenges and demographic trends impacts on the railway station infrastructure that we propose here.

2.1 UK Age characteristics

According to the Office for National Statistics (2013) in England and Wales in 2011 more than 10 million people were limited in daily activities, with the North East region with the highest percentage of activity limitations (21.6 per cent). Figure 2 illustrates the activity limitations around the country

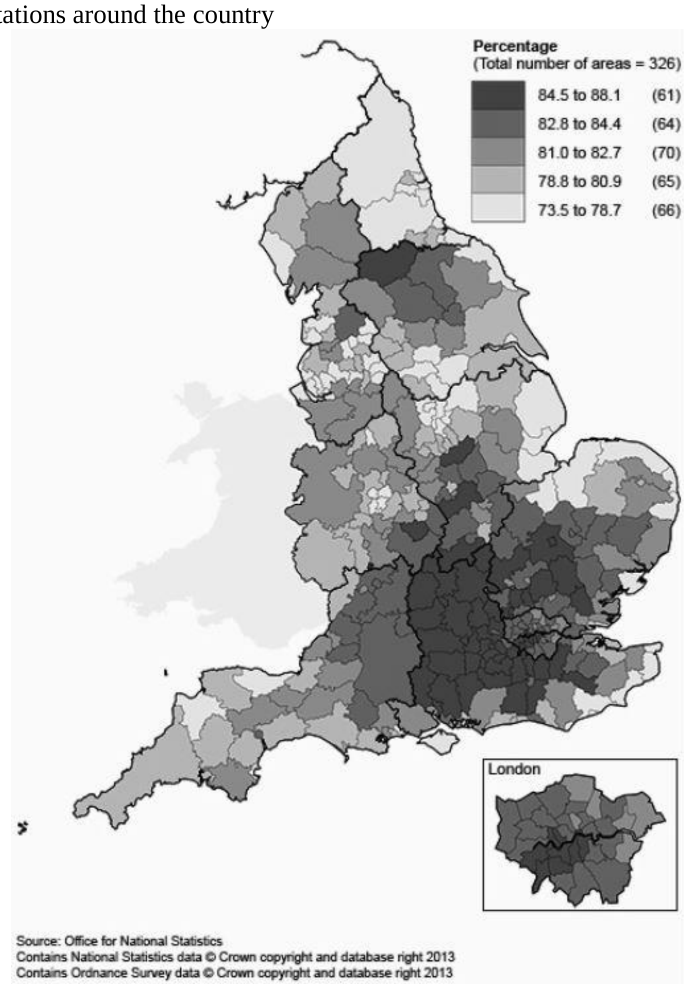

Fig 2 - Percentage of individuals with activity limitations

There are a large number of published studies (Lollar and Horner-Johnson 2016, Pagan et al 2016 and Wahrendorf et. al 2013) that describe the link between disability and age. The NHS statistics (Department of Health, 2012) of the people with long term conditions (defined by a condition that cannot, at present, be cured but is controlled by medication and/or other treatment/therapies NHS) confirm the strong correlation between age and disability.

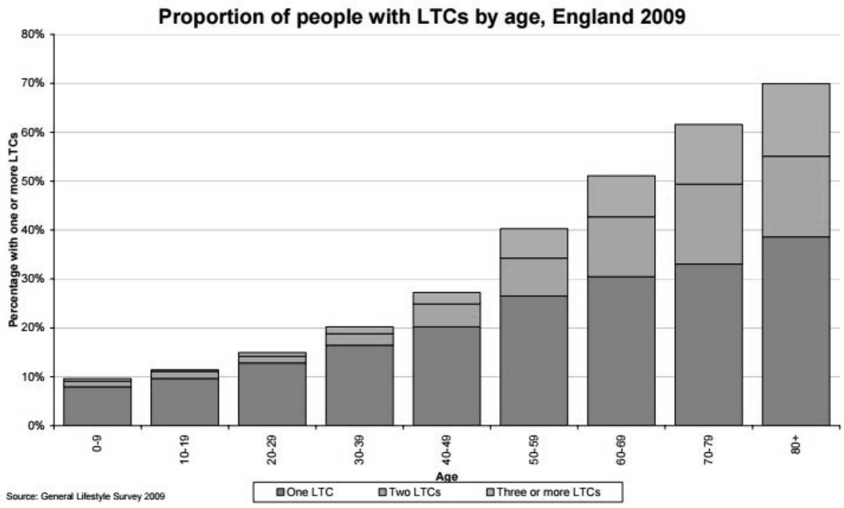

Fig 3. Graph with proportion of people with long term conditions by age group.

Therefore the increase in the life expectation is directly associated not only with the healthcare costs but also to the need for improvements in the accessibility of the transport system, both public and private.

2.2 Specific disabilities and assessable design

The Office for Disability Issues and the Department for Work and Pensions estimate of the number of people with a long-standing illness or disability shows a significant unbalance between different regions and the nature of the disability. Table 1 illustrates the specific type of disabilities for Great Britain

Table 1 - Disability prevalence disaggregated by impairment for Great Britain (millions)

	2002 2003	2003 2004	2004 2005	2005/ 2006	2006 20/07	2007/ 2008	2008 2009	2009/ 2010	2010 2011	2011 2012
Mobility	6.3	6.2	6.0	6.2	6.2	6.3	6.4	6.3	6.4	6.5
Difficulty with Lifting, carrying	5.8	5.9	6.0	6.1	6.0	6.0	6.1	6.0	6.1	6.3
Manual dexterity	2.4	2.6	2.5	2.5	2.6	2.6	2.7	2.6	2.7	2.8
Continence	1.2	1.3	1.2	1.6	1.5	1.5	1.5	1.5	1.7	1.8
Communication	1.3	1.7	1.9	2.0	1.9	2.0	2.0	2.1	2.0	2.2

Memory/ concentration/ learning	1.7	2.0	2.0	2.0	1.9	2.0	2.2	2.2	2.3	2.5
Recognising when in danger	0.4	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8
Physical coordination	N/A	N/A	2.2	2.2	2.4	2.4	2.4	2.4	2.6	2.7
Other	1.4	1.9	2.5	3.2	3.2	3.4	3.5	3.8	3.9	4.1
At least one impairment	10.4	10.1	10.1	10.8	10.4	10.6	10.9	11.0	11.2	11.6

As can been seen the limits to mobility and difficulty of lifting and carrying are the major disability concerns. . Since the Discrimination Act (1985) the concern about accessibility on the rail stations has grown with the publications of Accessible Train Station Design for Disabled People (DfTS 2011) and Design Standards for Accessible Railway Stations (DfTS 2015) establishing the framework for an accessible station with parking requirements, unobstructed circulation routes and accessible toilets

3 People Flow Modelling

The main disabilities identified in the previous chapter are influenced by ageing factors (mobility and carrying lifting) and directly impact on the average speed of movements and the use of some station elements, such as lifts and automatic stairs. Traditionally the people flow modelling theory considered a number of equations of motions and also pedestrian behaviours with multiple pedestrian types. The concept of people flows simulation has been harnessed before in the literature. Simulations for pedestrian walkways standards, sports stadium design, and evacuation plans was extensivly investigated by Fruin, (1987) looking the relationship between the crowd speed and density ; Older, (1968); Hankin and Wright, (1958). Most of the studies published in the field consider gender groups to compare movement speed differences. Henderson (1971), Polus (1983) Ando et al (1988), Navin and Wheeler (1969). The influence of the age on people's walking pace has been analyzed by Ando et al (1988), Peschel(1957), Fruin (1987) and Gates et al (2006). Table 3 illustrate comparative of speeds and gender influence toward mean speed in people flow literature.

Table 2 Mean free speed in Literature

Author	Gender	Age	Mean Free speed (m/s)
Hankin and Wright(1958)	Mix	unknown age	1.6
Peschel (1957)	Mix Mix Men	(6-10) (13-19) (>55)	1.1 1.8 1.5
Henderson (1971)	Men Woman	unknown age unknown age	1.6 1.5
Fruin (1987)	Men Woman	unknown age unknown age	1.5 1.3
Older (1968)	Mix	unknown age	1.4

Polus (1983)	Men Woman	unknown age	1.3 1.1
Still 2000	Mix	unknown age	1.2
Ando et al (1988)	mix	unknown age	1.4
Gates et al 2006	Men Men Woman	Adult older adult older	1.44 1.16 1.4 1.1

As can be seen, a number of factors that influence the mean speed can be found in the literature such as topography/design, age, gender, density and even the cultural and anthropomorphic characteristics. Different behaviours also play a crucial role in crowd modelling. A comprehensive overview of different models and capabilities achievements in the last two decades models has been carried out by Duives et al. (2013).
The choice of adapting similar multi-agent methodology adopted by Still (2000) helps understand how the design can impact and interact on asset utilization. In the following section, the characteristics used for different age groups, gender and disabilities probability will be explained in detail.

4 Simulation Tools Overview

The technical characteristics of 4 simulation models have been analyzed briefly to support the creation of the age-friendly simulation. The 4 simulations tools are described below:

4.1 Legion
Legion was developed by Still (2000) to analyze the dynamics of crowds using the least effort algorithm. With fine grid geometry Legion aims to enable model different entity (person) and behaviours in the crowd and calculating their positions in order to choose an appropriate action. The software is a property of Crowd Dynamics which acts as a specialist consultancy to analyze safety and efficient environments modelling the complex movement of people. As the agent based behaviour strategy is not detailed in Still (2000) the replication of similar behaviour strategy is not a viable solution.

4.2 Exodus
Exodus (Galea et al. 1993), developed by Galea was designed mainly to simulate the crowd under evacuation scenarios modelling a large numbers of individuals from large multi-floor buildings by adopting fluid dynamical models and with discrete virtual reality simulations to recreate hazards. The behaviours use a rule-based strategy which is adequate for our model, however, the movements of the agents are limited to eight directions.

4.3 STEPS
Developed by the consultancy company Mott MacDonald, STEPS is an agent-based microsimulation tool for pedestrian movement under both emergency conditions and normal movement. It has been used on multiple transport planning projects for example UK's Heathrow Terminal 5, Australia's Adelaide Oval and Hong Kong's MTR Sha Tin to

Central Link. The agent behaviour principles enable each agent moving through the domain to operate under some basic attributes which include the unobstructed walking speed attained when walking in a clear path, environment awareness by the agents and group association;

4.4 Pedestrian Dynamics

Pedestrian Dynamics® is designed to simulate large pedestrian movements in complex infrastructures to evaluate the performance of these and environmental safety. The main advantages are the simplicity of model creation and its' flexibility. It also enables the user to create evacuation simulation to optimize evacuation plans and response plans evaluation. The object import tool enables loading on the simulation 3D models to generate on to external tools such as CityGML, CAD/DXF, XML, ADO, ActiveX, 3DS. The multi-agent based modelling contains unique properties for each agent or group profile

5 Age-Friendly Tool Simulation

Although some commercial tools such as those described in the previous chapter allow the use of different velocity bands for different actors, some aspects related to the characteristics of the disabilities can alter speeds in a specific way in different parts due to the agent's difficulties for example in detecting signs due to visual deficiencies such as macular degeneration, diabetic retinopathy, glaucoma, colour blindness, cataracts and sightedness (short and long). Similarly because of the lack of visual support some station elements may not be accessible to all subjects because of mobility-related disabilities such as wheelchairs and use of walkers on conventional stairs and escalators. In this way, the simulation system must establish not only different speeds but a credible accessible path for each subject.

Traditionally the commercial flow simulation tools are designed to simulate a wide range of flow situations, therefore the individual entering in the system uses statistical distributions for arrival patterns. Our model uses different approach. As link between the interrelation between the users/agents and their intention (boarding/ alighting) can be established, we consider the passenger arrival and departure patterns are a direct result of scheduled train times.

The difficulties of simulating the age-related characteristics reliably suggest the need for a specific tool for simulation of the elderly population in order to evaluate the characteristics of the design that impact the flow of people circulating in the station.

5.1 Geometry and multi-agent simulation

Like other simulation programs the workflow of the age-friendly station simulator includes the modelling of the station geometry as a first step, characterizing the elements in which the agents interact with for instance the system of acquisition of tickets, access control, lifts, and escalators. The modelling also includes public toilets, commercial establishments for the supply of services and products such as newspapers, magazines, service stations, and spaces for the individuals/agents to wait for the train departure.

Future research is needed for a deeper analysis of the interrelationship between the probability of using commercial establishments and the use of public restrooms. In addition, a statistical analysis of the variability of the time of use according to sex and age would be an important indicator for the modelling of patterns of agent's behaviours. In the current stage of development of the tool, empirical data of user time by each age /sex are used.

The variability of the use of the railway throughout the day also has a direct impact on the intensity of the use of the stations and the pedestrian flow in the stations.

5.2 Station planning

The Network Rail Station Capacity Assessment Guidance (NetworkRail 2011) describes the capacity analysis process and the importance of modelling and assessment of the rail stations in the planning process and stations designs guidelines. The Stations are categorized into 6 groups:

Category A: National Hubs – the largest stations in the UK, serving the most important cities. They provide the highest number of facilities

Category B: Regional Hubs – stations generally serving important cities and towns

Category C: Important Feeder – provide regional connectivity or service significant commuter areas

Category D: Medium Sized Staffed – stations serving local populations or commuter pick up points

Category E: Small Staffed – stations serving smaller local populations or commuter pick up points

Category F: Small Unstaffed – stations with infrequent services serving mainly rural or low density areas

Traditionally future demand forecasts are used to produce a predictable plan for growth considering observed station data and forecasts for station entry/exit and for flows and origin-destination matrix. When determining the need for design improvements or application of an assessment, the process illustrated in figure 4 should be adopted:

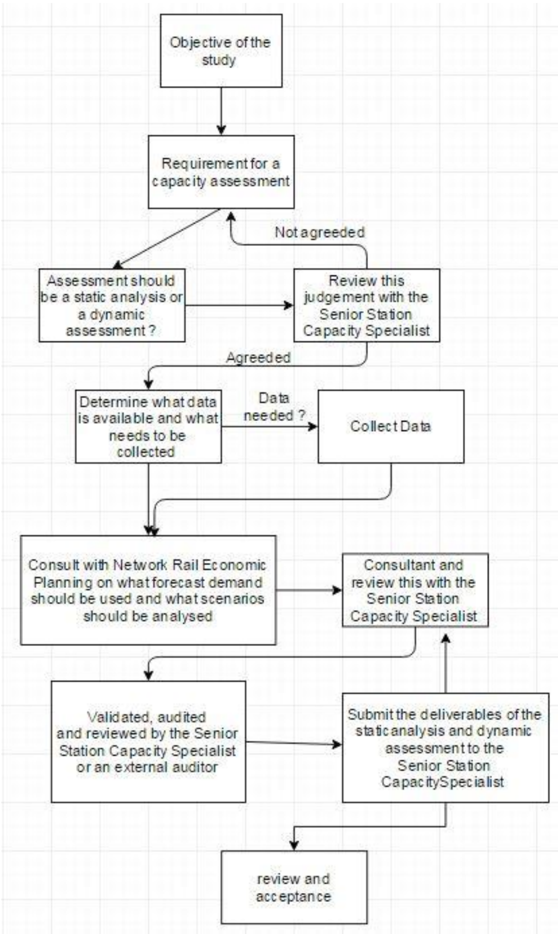

Fig 4. Station assessment modelling strategy

The resulting assessment provides potential for data analysis to meet user's needs. This has to be done by carefully considering design characteristics and users behaviour. In order to illustrate the proposed tool the Newcastle Central Station will be analyzed in next chapter

6 Software Implementation: Newcastle Central Station

According to the ORR in 2014/15, 8.053.112 passengers have been ending or originating journis at Newcastle Central Station (estimated passenger usage based on sales of tickets ORR 2014). The customer satisfaction of Newcastle Central Station using holistic method suggested that station needed some infrastructure improvements. (Marinov et al 2014)

6.1 Station Modeling

To recreate the virtual model of the station blueprints a 3d a blueprint of the Central Station and Station plan with the location of accessible WC; ATM/Cash Machine; Bar; Cycle Rack/Storage; Drop Off Point have been used. Figure 5 illustrate the original plans from 1851 and Figure 6 illustrates the 3D model of the station and the wheelchair agent.

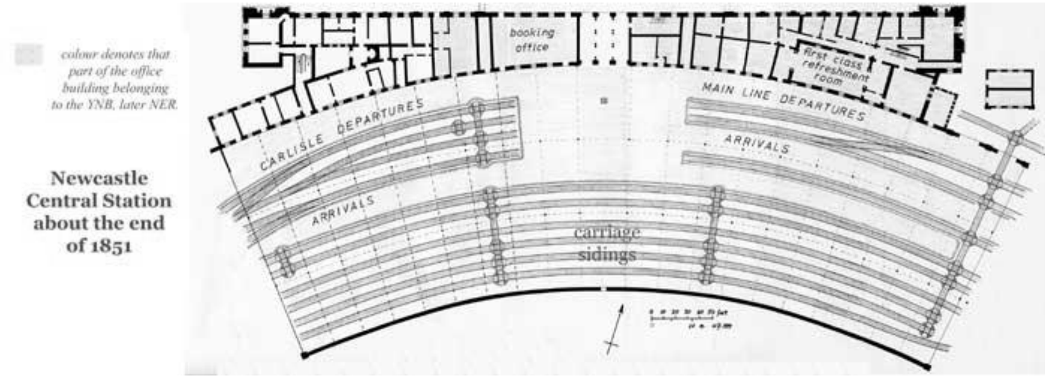

Figure 5: Newcastle Central Station plan

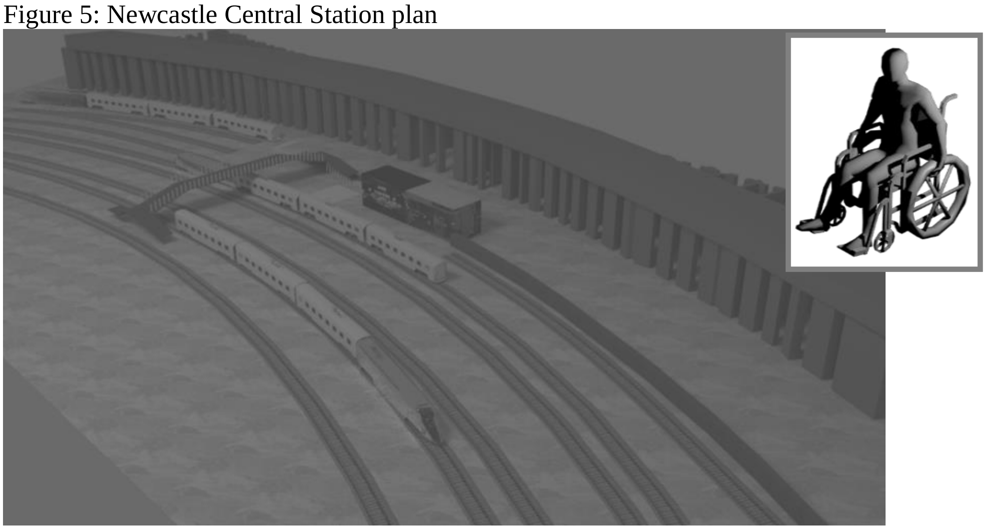

Figure 6:3D model of the Newcastle Central Station and wheelchair agent modelled

6.2 Actors intention

The modelling strategy uses the train arrival /departure times and real time arrivals and departures as objective points for the actors. The actors start to arrive at station 30 min before the train departure time times in a normal distribution. The table shows the trains arriving departing between 17:00 to 18:00. In absence of real demand data and for testing the concept of the alternative flow modelling we adopted the total number of passengers with origin/destination Newcatsle Central Station divided by the total hours in operation (17) which gave us a 1289 passenger hour, for 14 trains hour we can assume 92 passenger/train

Table 3- Trains stopping Newcastle Central Station

Time	Destination	Plataform
17:03	Liverpool Lime Street	9
17:15	Morpeth	4
17:16	Barrhead	10
17:24	Hexham	7
17:26	London Kings Cross	3
17:30	Nunthorpe via Hartlepool	5
17:32	Southampton Central via Doncaster	11
17:37	Glasgow Central	2
17:38	Chathill	5
17:41	Bristol Temple Meads via Leeds	4
17:44	Metrocentre	1
17:53	Stirling	2
17:54	Carlisle	6
17:59	London Kings Cross	4

Therefore for each train in the table 92 passengers have been generated arriving at the station between 0 to 30 minutes before train departure. The Microsoft Excel module (Data Analysis) for Random Number Generation was used using a normal distribution with mean 15 min and standard deviation of 5. (Figure 7)

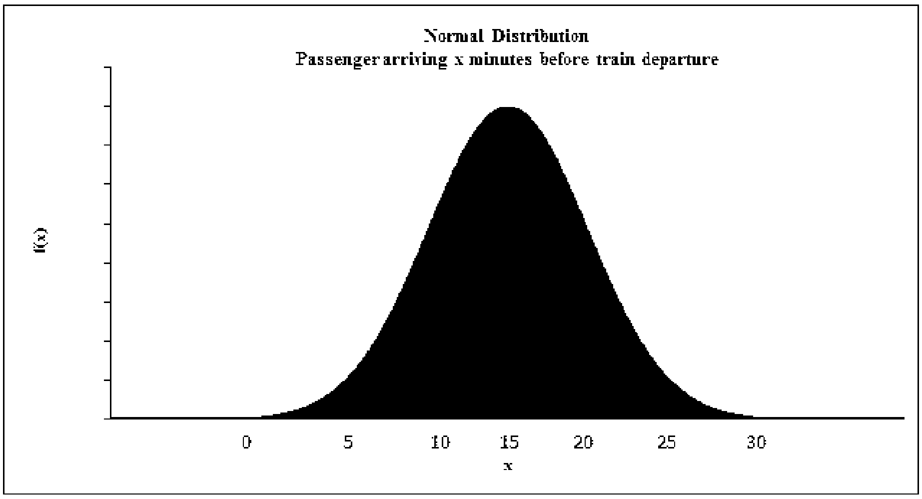

Figure 7: Arriving time before train departure

The passengers next have been animated according to with the intention (platform destination) using different speed parameters age and gender, we follow Gates et al. average speed (1.44 young men, 1.16 older man, 1.4 young women and 1.1 older women). We also introduced the wheelchair simulation on the station and visual disabilities reducing the average speed by 20% for the disabling agent.

Research on the subject of wheelchair speeds has been mostly restricted to limited comparisons to quantify the use of a wheelchair in nursing homes, however, the work of Karmarkar team provide a useful indicator of mean speed on the wheelchair. The suggested speeds of 0.48 m/s for individuals using arms only and 0.58 m/s for a combination of arms and legs (Karmarkar et al.2010). The simulation has been produced using 0.53m/s speed. Futures versions of the model will incorporate multi variable speed and behaviours. Based on the how many minutes before the train departure the passengers may have to consider and act upon different decisions.

7 Evaluation and Performance Results

No considerable design limitations for aged/diseabled have been found on the Newcastle Central Station, all the disabled agents are able to access all points of the station according to with their particular objectives. However as the number of the disable/older agents increases, the infrastructure required to meet disabled peoples' needs shows inefficiency increasing the time required to the perform the activities (e.g.lifts, toilets). The number of the disable/old agent modelled (2 per train) is very small compared to the 21.6 per cent North East persons with activity limitations. Further research using higher percentage of disabled agents and older will help the understand the age-friendly performance of the station based on the number of disabled agents the station are able to serve without performance constraints

8 Synthesis and conclusions

The overall evaluation modelling strategy for age-friendly station seeks to prove three hypotheses: (1) That mean speed of different agents have a significant impact on the crowd and infrastruture requirements. Considering demographic trends some improvements are required to increase the accessibility for elderly and disabled people (2) That a heuristic's agent based is even more important than the simple behaviour model when numerous age groups and different range of disabilities are introduced. (3) That disabled peoples' behavior framework have been limited to local surveys and requires further investigation. The notable lack of research around age factors and the impact on the transport suggest that further work is required to address the challenges Europe will face on next decades.

Note that we have decided to develop an experimental simulation software architecture to understand the viability of the agent-based simulation to model age behaviour.

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