Agent-Based Modelling Could Remove an Ethical Barrier to Researching Inclusivity in Crowded Places

J. Harding

Abstract: It is widely accepted that accessible transport benefits a wide group of people. It is less well known that congestion can be a barrier to inclusivity to enabling accessible stations. This paper reviews inclusivity issues in congested spaces and transport buildings. It identifies ontological, ethical and methodological barriers to researching vulnerable groups and large groups of people. The industry recognises Agent-Based Modelling (ABM) as a valid and verifiable way to consider pedestrian congestion. However to date it has not been used to evaluate inclusivity issues. This review suggests ABM is an acceptable way to analyse inclusivity impacts within congested spaces. Such an approach may extend current pedestrian movement theory. In addition, a future case study could test the ethics of researching people in large crowded locations.

1. Congested Space in the Built Environment is a Barrier to Inclusivity

Inclusivity is at the heart of the Rail Sustainable Development Principles (RSSB, 2016).These principles are critical to ensure the UK railway contributes towards the economic, environmental and societal wealth of the country. Thinking differently about inclusivity (Boys, 2014) requires us as to consider the needs and differences of a wide range of people who use the rail network for different purposes; for example to access employment, health services, education, and leisure opportunities (Committee, 2010). While the 'Access for All' programme (NR, 2017) has led to a significant investment in station accessibility over the last decade (DfT, 2011). There is less clarity on how to meet the needs of those passengers whose abilities vary when 20% of people in the UK have a disability (RSSB, 2016). Moreover, the elderly population is growing, passengers are travelling with young children, in prams, or pushing or carrying luggage and space and resources are limited (Network-Rail, 2011).Research identifies that crowding

John Harding, WSP. Email: John.Harding@wsp.com

in trains and stations results in poor levels of comfort (Thompson et al., 2012). Train stations may be too congested and unfamiliar to allow passengers easy access owing to congested trains and platforms during peak hours (Harding et al., 2016). Research has found unimpaired passengers travelling in the busiest times on the congested underground railway in London experience unpleasant, uncomfortable, congested, confusing and insecure experiences (Harding, 2010).The relationships between circulation spaces in busy underground stations (NR, 2015), inclusivity (Boys, 2014) and congestion (Fruin, 1971) is under researched.

Within congested urban areas, it may not be possible to overcome some of these problems. It could be too costly to introduce sufficient inclusive features into transport buildings, such as additional lifts and less congested spaces. Stations are sized according to canonical pedestrian modelling theory (Fruin, 1971) and operational and emergency evacuation requirements. Escalators and stairs are the preferred means of vertical circulation between floors of a transport building owing to their high capacity. A barrier to inclusivity could be that Fruin's theory needs developing to consider that almost all passengers find lifts a benefit (Maynard, 2007) and that lift sizing and arranging is appropriate. For example, findings of an interactive research project held during the design of Terminal 5 Heathrow Airport were:

> *" If you make things clear for the disabled and old, you make things even easier for everyone else and if people find the airport easy to use, they will be willing to repeat the experience."*

<div align="right">(Turner, 2003: 279-284).</div>

Fruin (1992: 16) hypothesises that lifts need consideration both for **deep** and **less busy** stations to provide additional vertical circulation capacity. Indeed, there are good examples of less busy stations that provide multiple lifts at recently completed airports (Turner, 2003: 279-284). However modern shallow and busy stations built in urban locations typically have a single lift serving the platforms (Harding et al., 2016). **Research Aim:** To address barriers to inclusivity the next stage of this research will examine a shallower and busy station with multiple lifts that is located in a congested urban area.

2. Ontological, Ethical and Methodological Barriers to Researching Inclusivity

To achieve the research aims, we need to consider how to overcome the ontological, ethical and methodological barriers to researching inclusivity in crowds.

a)   Ontological Issues

One problem could be how different disciplines investigate the built environment and consider inclusivity. Choosing the logic for a study is an important

consideration. Choices depend upon the research aims of the project and the discipline of the researcher. The main similarities and differences are as follows.

Positivism uses inductive and deductive logics of enquiry and removes important details and differences to produce explanations (Stainton-Rogers, 2006: 81). Further problems with positivistic logics are they result in guidance and standards that produce normative solutions and design fixation issues (Crilly, 2015). Constructionist logic defines knowledge as man-made construction of meanings (Stainton-Rogers, 2006: 81). Constructionist theory raises pertinent and thought-provoking questions including: 'what does it do?', 'how can it be used and by whom', and 'to what ends?', 'whose interest does it serve?', and 'what does it make possible?' (Stainton-Rogers, 2006: 81). Analysis requires 'looking for surprising similarities between things that are very different' or 'surprising differences between very similar things' (ibid: 87). The aim is to search for inconsistencies, difficulties and challenges (ibid: 84) between different results. In consequence, explication preserves complex details and provides a way to develop meaning from observation. Asking such questions leads to new insights and paradigm shifts (Stainton-Rogers, 2006: 81). Constructionist theory overcomes the reductionist aspects of positivist epistemological and ontological assumptions (Stainton-Rogers, 2006). This type of thinking is also considered 'abductive' thinking, and is 'the process of forming an explanatory hypothesis' (Peirce, 1955: 67 quoted in ibid: 85). Abduction, constructive thinking are all types of 'design thinking' (Cross, 1982). Explication is common in the sciences and design fields.

No discussion of inclusivity would be complete without reviewing recent discourses in disability studies that raise ontological issues between the medical, social and interactional models (Riddle, 2013: 33-35). This is a brief overview. The Medical Model claims the "impaired body must be restored, adapted and cured" (Scullion (2009) quoted in Gomez et al., 2014: 272). In contrast, the Social Model of Disability claims society's actions cause a person's disability. The particular trouble with Social Model theory is that it ignores the possibilities of advances in medical technology (e.g. wearing glasses, wearable technology, prosthetics developed within the medical and technological field) that may remove the impairment, owing to its insistence that society causes disability (Corker and French, 1999). The weakness of is that:

> … *the horse before the disability studies carriage is often politics, not science.*
>
> (Vehmas, 2008: :21 Quoted in Riddle 2013:28).

Recent interactional theory focusses on removing the impairment from both the built environment and the body (Riddle, 2013). It expands the discourse to more complex socio-political contexts (not just disability) including feminist, racial, gender, ethnicity and sexual topics (Stainton, 2000); and allows us to consider questions about lack of or insufficient affordances posed by Slack (1999). Slack raises the concern that whilst our particular medical issues may be different, we all face difficulties in transport that are socio-material-economic-political problems. Similarly, socio-material-environmental thinking found in recent research takes a more holistic view (Bichard, 2014). Therefore, interactional theory considers non-

disabled concerns (Slack, 1999: 23). Many philosophers and bioethicists support the interactional approach (Riddle, 2013: 23).

In summary, interactional theory incorporates both positivistic and constructionist logics, and appears to be a pragmatic solution to the Medical vs. Social Model of Disability discourse. Moreover, it is inclusive of non-disabled concerns (Slack, 1999). Indeed, it allows us to consider how the material aspects of a station, such as spatial and vertical circulation elements interact with the movement of people. Moreover, the aims and research questions mentioned earlier have positivistic and theory-building aims. Abduction is a way to form a hypothesis; deduction is a positivistic way to disprove or falsify hypotheses. It is therefore beneficial to have an understanding of both logics. In addition, a positivistic approach aligns with current built environment research practices and is likely to be an acceptable way forward.

b) Ethical Issues

Replicating Fruin (1971) PhD research today using photographic studies of people to determine acceptable levels of service in congested buildings and pavements would be a challenge. A researcher will have to seek permission to take videos and photography (Thompson et al., 2012) owing to some transport buildings and what we think of as public spaces are privately owned and managed (Minton, 2012). Whilst it may be legal to video or photograph people in public places there may be personal risks of harm also to the participant observer (Harding et al., 2016). It may not be possible to extract data if participants include disadvantaged people or children (Oates, 2006). Even if consent is possible, gaining consent of so many parties may be impractical for a lone researcher to undertake. Moreover, Oliver (1999), one of the promoters of the Social Model of Disability with several decades of research experience in the field of disability studies, claims that taking advantage of disabled people for the purpose of research is morally wrong, even if participants give informed consent. He raises concern that even if consent is given it may be unethical for a researcher to take advantage of participants for their own researching benefit and glory (ibid). His concerns are a reminder that we have to be aware that our research could be taking advantage of others for our own benefit. Therefore, a previous pilot study may be challenged as unethical because it directly observes the behaviour of crowds in a shallow and congested underground station (Harding et al., 2016). However, there are no anticipated ethical problems with using computer simulation using agent-based modelling as a research instrument.

c)   Quantitative vs. Qualitative Research in Inclusivity

The choice for a methodology depends upon the research aims. Creswell (1994: 2) suggests explanatory research is reductionist and positivistic by reducing details and complexity (Stainton-Rogers, 2006: 84). In contrast, social inquiry researches social or human problems to construct a complex understanding, using words to report detailed views of informants within a natural setting (Creswell, 1994: 1-2). This section reviews the implications of inclusivity research using quantitative and

qualitative methodologies and processes. Studies of inclusivity within stations use both quantitative and qualitative methodologies.

While this doctoral work will draw on a quantitative methodology, because the research aims of this project are explanatory, in this section I briefly review work that has drawn also on a qualitative methodology in order to justify this decision. Apart from methodological differences, it is worth taking notice of the differences in the researcher's interaction with participants, and the location where data is collected. The first example uses an indirect method of a questionnaire completed in a completely different context of an office setting, to research passenger experiences in stations. The second case collects data directly by observing passengers moving in an underground station. The analysis presents the advantages and disadvantages of each method.

Quantitative Methods

This positivistic study of tube users' experiences provides examples of inclusivity issues when travelling in a transport building (Harding, 2010) All 47 respondents (34 men, 13 female) answered a questionnaire using a five-point Likert scale. All respondents were frequent commuters and employed as either designers or administrators developing a major new underground rail project in London. None of the respondents claimed to have a disability. The analysis produces some interesting results that reveal certain differences between the age and gender of the respondents using statistical methods and a t-test. Figure 1 indicates how the results compare against the baseline, or average response. Whilst all groups had confident experiences, the journeys were not gentle. A gentle journey affords clear announcements, low noise, lack of fear of being lost or splitting from a group, few changes of levels and easy orientation. The findings showed that older men in senior positions were generally satisfied with their experience. Women and younger men have a poorer experience of security, confidence and comfort. These findings – which provide insights, concerns and opportunities to develop inclusive stations – were presented at an international railway conference in Singapore (Harding, 2013) and published in the proceedings.

The analysis identifies known issues with using a positivistic questionnaire for research. In this case, the group of respondents were unrepresentative of the public: most were professionals, employed and held degrees. Nobody declared a disability, which contrasts with TfL's estimate that 18% of Londoners have disabilities. That percentage excludes the many more people who find it difficult to travel by themselves temporarily (TfL, 2009). TfL's definition of disability may also include 'blue badge' holders, the elderly, and those outside the narrow definitions for people who receive disability benefits. Harding (2010) suggests the negative reply to disability in the questionnaire study could be because disabled people have trouble travelling, gaining and keeping a job, and keep silent about their disability (Payling, 2003: 395). As a consequence, a negative reply in surveys is common (ibid). For the analyst, a questionnaire provides an indirect experience of travelling. This is useful where we wish to gain some understanding of the experiences of many people from a limited set of questions. Ethical concerns remain including

potential misuse of the participant by the researcher (Oliver, 1999). Benefits include generalisations that could be useful for a researcher or designer.

Legend: Good Experience= ☺		Average= ☺		Bad Experience= ☹	
	Baseline	Young <25	Middle	Aging >55	Women	Men
Comfort	☺	☹	☹	☺	☺	☺
Security	☺	☹	☺	☺	☺	☺
Gentleness	☹	☹	☹	☹	☹	☹
Confidence	☺	☺	☺	☺	☺	☺

Fig. 1 Tube experiences compared (Harding, 2013)

Qualitative Methods

This section reviews implications of researching passenger experiences directly using a participant observer using qualitative methods. Harding et al. (2016) constructionist study takes place during the evening peak-hour commute. This empirical study describes the participant observer's journey as he alights from the train and walks along the length of a busy and congested platform. Using a small lift, the researcher travels up to the concourse and waits there, observing the movement of other passengers; he then returns to the crowded platform to board a train. The influence behind that study was to get out of the design office and learn how people actually use products (Battarbee, 2004; Battarbee and Koskinen, 2005). Harding et al. (2016) review of Canary Wharf uses video to record the participant observer's experience of moving through the station. The questions they consider are in '… what ways do we find train passengers suggestible as they move through crowded underground train stations? How do passengers protect themselves against suggestions that do not help them survive or be included within the design?'

Congestion-related findings show that it is hard to reach and find a lift if it is small and located at the end of a long and congested route at platform level. In contrast, the lift at concourse level is popular owing to its location adjacent to busy escalators. However owing to its small size, there is lack of space to accommodate sufficient passengers who wish to use it. Other negative factors result from confusion, congestion, glaring lights, noisy announcements and warnings. The typical island platform configuration results in significant queuing when trains are insufficiently frequent or too crowded to board (ibid).

These observations provide useful feedback for designers, policymakers and researchers. This particular qualitative method also sensitises the participant observer to the issues passengers and himself faces as a regular commuter in London. This direct and immersive experience includes many details that are missing from the positivistic questionnaire approach. For example, the research brings our attention to issues of glare from bright lights shining into the eyes of passengers, noise from announcements and the quietness of crowds waiting

patiently for their next train. The video data and analysis could be useful to a
researcher, or designer who is not living in London who may find it too difficult to
travel and gain an insightful experience. The participant observer has no particular
impairment; however, he is sensitised to many of the factors that influence
pedestrian movement and inclusivity issues owing to 'lived experiences'.
Nevertheless, this is a unique experience. Findings are not generalizable owing to
bias. Moreover, accuracy, replicability, reliability and verifiability are concerns of
qualitative analysis.

In summary, having found a research subject and objective from studying
literature, the reasoning discussed suggests a pathway through the research
barriers. Figure 2 suggests a conceptual model to develop a theory using a
positivistic and interactional logic using 'agents' in a quantitative case study
approach. The green arrow represents the pathway chosen for the next study, and
the suggested choices are marked in **bold**. It is suggested that presenting barriers
and choices in this way could make it clearer for the inexperienced researcher to
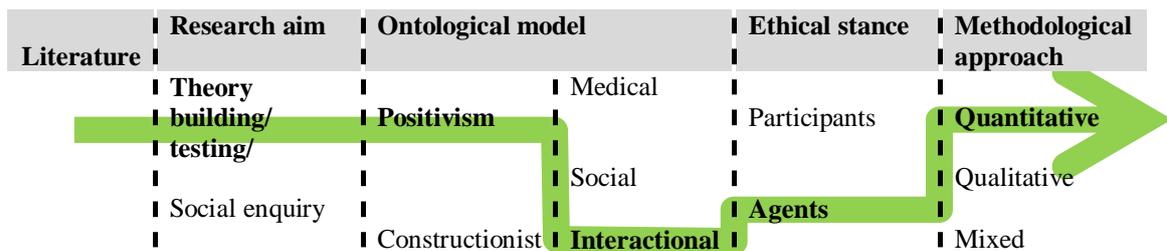find a viable pathway through these research barriers.

Fig. 2 Pathway through research barriers

3. What Next?

The need to improve inclusivity in stations is reasonably well agreed and
researched at a qualitative level (Maynard, 2007: i). Pedestrian movement in
crowded public buildings and stations is canonical theory (Fruin, 1971). However,
it is unclear whether inclusivity issues are fully considered in current pedestrian
movement theory. From an ethical viewpoint, gaining consent and ethical approval
is a concern to research. There is a need for a novel method to consider inclusivity
using indirect methods. Agent-Based Modelling (ABM) computer simulation could
be a way to investigate this matter further. ABM is a research instrument to analyse
the crowding and congestion levels within the case studies. Many transport
operators from around the world trust ABM. These include London Underground,
Network Rail, New York City Transit, and Land Transport Authority in Singapore.
ABM uses passenger demand estimates and physical data. The figures below show
examples of ABM data for the same station with the same number of 'agents'

although having two different lifts, stairs, escalators and concourse gateline arrangements.
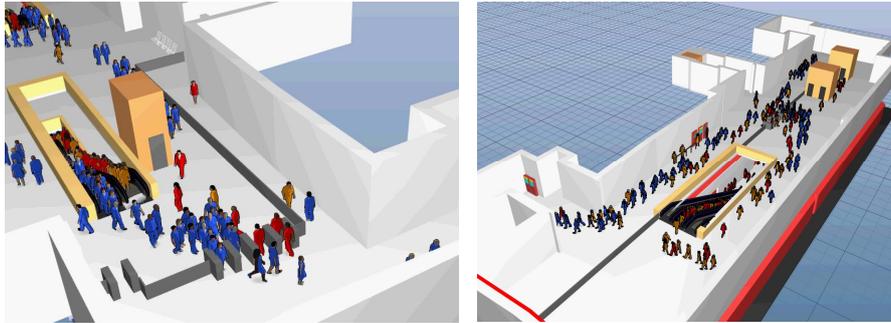

Fig. 3 Lifts serving <10% passengers   **Fig. 4** Lifts serving >25% passenger

Limitations: The level of abstraction needed to produce meaningful results requires an approach providing a limited amount of information (Crooks et al., 2008: : 421). Similarly, Wang et al. (2015) and Seriani and Fernandez (2015) confirm this is industry practice. Consequently, it is not usual to visualise pram, wheelchair or people with bags or any other physical impairment with Agent-Based Modelling data outputs. Furthermore, pedestrian movement studies consider only escalators and stairs in calculations to transfer pedestrians from concourse level to platform (Clifford, 1996). The proposed investigation of ABM data does not model 'agents' with specific mobility issues (Clifford et al., 2016). Instead it considers a higher percentage of passengers using lifts, even more than TfL (2009) estimate of Londoner's who have a disability.

The aim of the next step in this research is to develop a comparative case study (Yin, 1993). The ontological discussion above suggests there are benefits in combining a constructionist approach to developing hypotheses using abduction (Peirce, 1955:67 quoted in Stainton-Rogers, 2006: 85), and a positivistic approach using deduction to falsify results (Popper, 1972). This hypothetic-deductive logic is a common method of investigation in science and design fields.

The study will consider how ABM could:

a) reduce ontological, ethical and methodological barriers to researching inclusivity in crowded places;

b) extend pedestrian modelling theory (Fruin, 1971) by including inclusive design considerations

c) falsify the following propositions:

- increasing lifts in shallower and busy stations would increase congestion;
- the resulting station would be larger;
- and cost more.

In conclusion, the outcomes of the study may extend current pedestrian movement theories that could help provide inclusive spaces within crowded

buildings and spaces. It may also provide a way to research using ABM as a way to overcome ethical problems when researching crowd movement behaviours from an inclusivity perspective. We hope to report on the progress and discuss the outcome of the case study at future conferences.

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