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Investigating commuter train boarding and alighting dispersal by contemporary agent based modelling techniques

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Abstract

This paper concerns research into the use of a contemporary computer simulation to replicate the passenger dynamics of boarding and alighting suburban trains. Advances in computational methods have enabled researchers to model and animate imagined scenes in more visually compelling ways. The implications of these improvements in crowd modelling can be seen in decision-making processes concerning the design of carriage interiors and the impediments of platform furniture. While agent based modelling has been in the professional milieu for many years it has tended to be applied to macro scale problems, presented in plan view with agents represented as dots all moving at similar speeds.

This paper describes work which models small numbers of passengers and variable behaviours therein allowing a more detailed analysis of the effect of individual behaviours on for example dwell time. The inclusion of 3D human models with animated behaviours into these spaces remains comparatively rare. The reasons for the absence of human models can be attributed to the unique challenges involved in animating 3D figures, but also to the absence of animators and computer game researchers involved in the simulation design process. Recent advances in game engine technology and processing power has enabled sophisticated representational human models with walk cycles, idle cycles and a range of recognisably human gestures.

The Authors believe that there is a compelling case for increasing the visual sophistication of simulations so that they enable more accurate and nuanced responses in the development of station infrastructure, train carriage design and their implications on timetabling and network planning.

1. Introduction

The most significant variable in the journey of a train is the time it will take paused at each station. This ‘dwell’ time is at the mercy of how long it takes passengers to board, alight and disperse within the train carriage or across the platform. At peak periods dwell times can become extended as passengers jostle to board or alight. With increased patronage the predictability of dwell times becomes more difficult. Delayed trains create a number of implications beyond poor punctuality, including the extension of headways. Extended dwell times reduce network capacity leading to less services and more late services, ultimately impacting upon an operator’s revenue and contributing to poor passenger perceptions of the mode. Building mathematical models to aid dwell time prediction mask the intricate composition of the causes of extended dwells. Studies show (Daamen et al 2008) that there is a range of qualitative variables that impact upon passenger behaviour while boarding and alighting. These human factor variables are difficult to determine quantitatively, but they do relate strongly to the interface between the passenger and carriage. Figure 1 shows where the predictable and unpredictable variation in dwell is located. Figure 2 encapsulates, as a flow chart, each of the ‘factors’ that affect the efficacy of the passenger to board or alight from a train and by implication impact upon the dwell time variability of the service.

Figure 1. A linear diagrammatic depiction of time subdivisions as a train pulls into a station. Reading left to right most subdivisions can be accurately predicted and determined, while passenger boarding is variable.

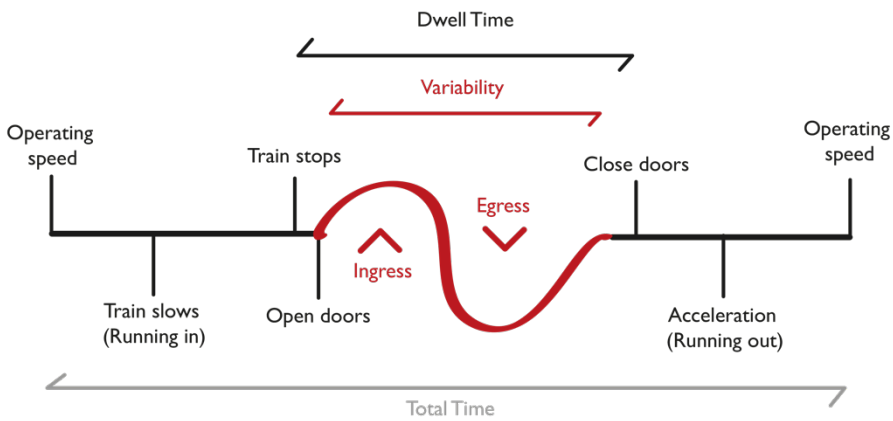
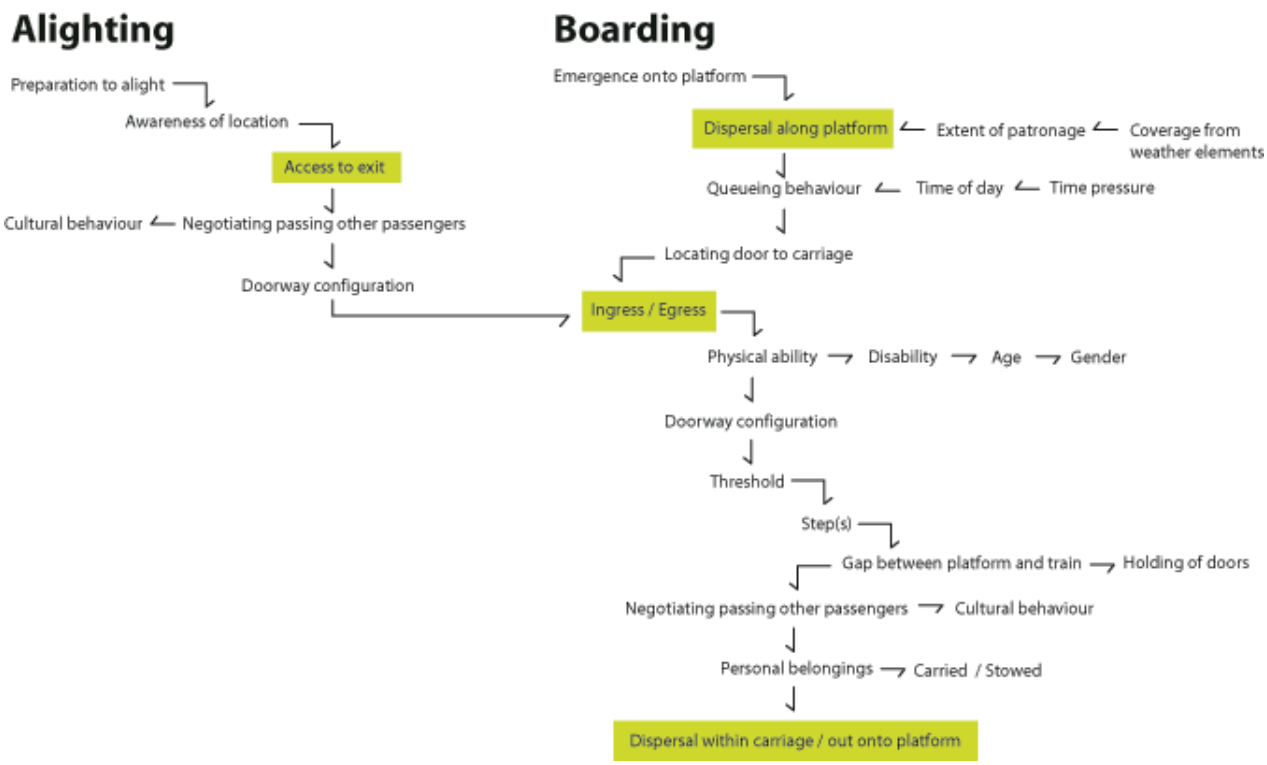


Figure 2: Flow chart depicting the influential factors brought to bear on passenger boarding and alighting behaviour.



Extended dwell times imply difficulty in passenger boarding and alighting at any one or more of the stages outlined above. With significant increases in patronage, particularly during peak time, crowding itself is the significant determinant of extended dwell times.

2.Measurement and evaluation methods – the role of computational modelling.

Agent Based Modeling seeks to direct digitally animated 'agents' by way of a series of algorithms originally derived empirically. ABM interactions exhibit the following two properties:

(1) The interactions are composed of individuals (agents) with a designated set of characteristics

(2) The system in which these interactions take place exhibits emergent properties, that is, new properties arising from the interactions of the agents that cannot be deduced simply by aggregating the combined properties of the agents.

The primary benefit of these methods of evaluation is that they take away the expense and lack of realism present in physical experiments with full-size mock-ups. In computer simulation animated passengers are programmed to undertake simple tasks with directed goals, e.g. board and find nearest free seat. This is done irrespective of any sense of urgency that might be present at a real boarding or lack of urgency at a static mock-up.

ABM begins with assumptions about the agents (passengers) and their interactions and then uses computer simulation to reveal the dynamic consequences of these assumptions. ABM researchers can investigate how large-scale effects arise from the micro-processes of interactions among many agents. Large-scale effects of interacting agents can be surprising because it can be hard to anticipate the full consequences of even simple forms of interaction. For problems such as determining the ebb and flow of large groups of train passengers where predicting the effects of individuals on each other is difficult, ABM techniques have great potential. What is difficult to determine is how accurate and representative the salient aspects of the agents are of the travelling public. In highly sophisticated simulations, it is possible to equip the agents with the ability to learn and develop over time. The key issue here is the extent to which the resulting outcomes are orderly within the environment where they have been placed.

While the simulation of 3D environments is a long established practice in the computer aided design and engineering disciplines, the inclusion of 3D human models with animated behaviours into crowd modelling spaces remains comparatively rare. Some of the reasons for the absence of human models can be attributed to the unique challenges involved in animating 3D figures, but also to the absence of animators and computer game researchers involved in the simulation design process. Recent advances in game engine technology and computer processing power have enabled human 'agents' to be realistically graphically depicted in simulations, walk cycles, idle cycles and a range of poses and animated behaviours that can enhance the interpretability of the simulation.

3.Creating the 3D characters.

Fundamental to the authenticity of animated passengers is their walk cycle. For the 3D characters designed for the simulation discussed here, different animated walk cycles were designed to communicate whether an agent was male or female, young or old. Moving into a run, a walk cycle can also convey the urgency of the agent's objectives. When at rest, such as waiting for a train or as a passenger on board the animated characters function in an idle cycle, which is an animated loop of small and almost imperceptible movements that characters make when they are sitting or standing. Characters may, for example, shift their balance slowly from one foot to another or turn their head slightly in each direction to look about. The 3D characters in this research were modelled as Melbourne city commuters; they were realistic enough that their facial features could be discerned and attire to indicate gender or replicate the dominant dress styles of commuters during peak periods. Their clothes were to some degree interchangeable and appropriate for Melbourne's temperate

climate, though not for any particular season. The male and female figures ranged in age from high school students to retirees and accommodated a number of body shapes and ethnicities.

Figure 3. Selection of 3D commuter characters: the visual and animated embodiments of the agents in the simulation. Created by Chandara Ung.

As the simulation was developed, the interplay of character typologies, attire and idle cycles presented challenges. For example the sitting posture in the idle cycle differs for women and men reflecting their physiology. Creating a stance that could be perceived as relaxed and not tense required subtleties in the building of each iteration of character model. The building in of commonplace distractions such as the inspecting of mobile phones and the shifting of body weight all added to the appearance of a realistic environment (Figure 4).

Figure 4. A 3D character in 'walk cycle' and an idle loop for standing and sitting. Created by Chandara Ung.

4. Outline of simulation logic and rendering

The *Unity* game engine was created in 2005 by Unity Technologies. The software allows for the creation of interactive 3D content with minimal technical effort. Though mostly used in video game production, it has also become a popular visualisation and scientific research tool in a number of varied disciplines. In this project the Authors' used *Unity* as the platform to develop and test the efficacy of carriage interior seat and impediment arrangements. *Unity* has a path finding engine built-in which allows the author of the simulation to define which areas of the scene are "walkable" and the different kinds of "agents" that will move through the scene. Figure 5. Once these have been defined the author can write code that will give the agent a goal position. The agent will then calculate the shortest path towards this goal through the "walkable" area thus avoiding issues such as walking through walls and other designated solid objects. The path is updated in real time to avoid walking into or through other agents within the simulation. In order to determine this goal position each 3D character was programmed to follow a simple logic tree and make decisions depending on their current situation. For example, an agent who has walked into the train carriage will 'look' for a free seat (deciding on the closest free seat near them) and then walk towards that seat. As it's walking the agent is constantly rechecking if the seat is still free (another agent could have taken it). If it the seat is free and they are close enough to sit in it, they will sit down. Once the agent is seated the simulation considers them 'complete' and no further action is required. A flowchart outlining the decisions that each agent makes can be seen below in Figure 6. The interaction between agents is managed in the same way as other physical impediments such as walls and seats. However, in this instance they are moving and so each agent is continually recalculating their position relative to other agents and how they might impede their goal. This creates a collision avoidance loop that can be set to varying distances.

Figure 5. Plan view of the mapping of agent movement in Unity. Areas permissible for agents to walk in are outlined in blue.

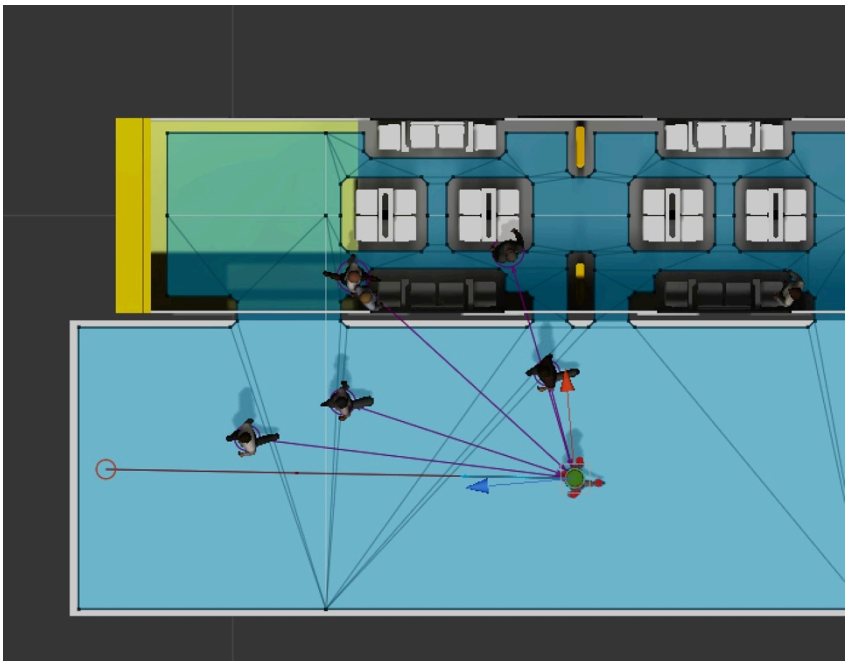
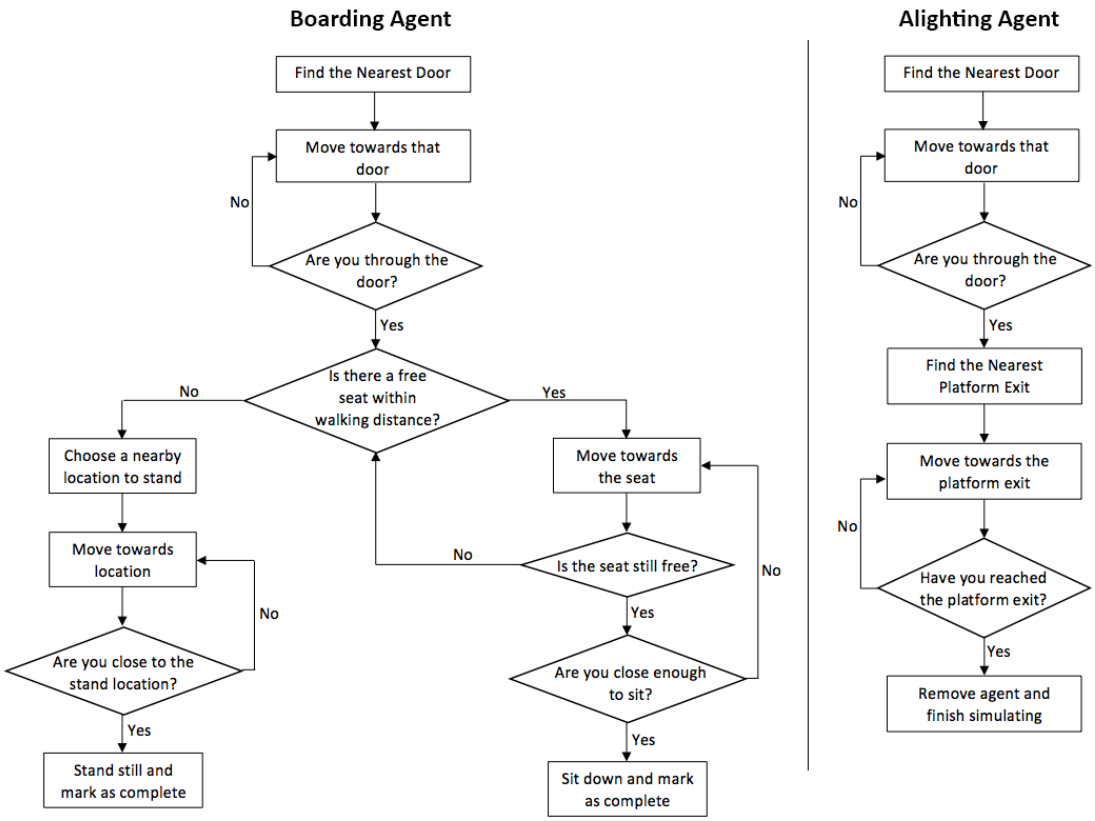


Figure 6. Flowchart decision tree for agents moving through the simulation.



6. Application of this technique.

To test the efficacy of the modelling simulation a simplified model of an existing rolling stock type, Hitachi, was modelled. The animated agents would interact into and through the carriage in accordance with the motion motivations prescribed to them. Figure 7 shows the simulation screen appearance. Firstly the basic carriage in a default three quarter view unpopulated. A user interface in the form of a series of sliders is located in the top left hand corner of the screen, seen in Figure 8. The sliders determine the magnitude of the crowding one seeks to test. Beginning with the number of alighting passengers then boarding passengers through to seated passengers. The total number of passengers for each simulation is also displayed. The interface also provides for different views of the simulation referred to as camera angles. The train layout option button is set to the type of train being tested, the Hitachi three door trains on the Melbourne network. A future aspiration of the simulation is to develop a variation of train types and this facility is also built into the interface. The human figures appear on the screen immediately one uses the slider. So the number of patrons can be dynamically increased or reduced as required. The arrangement and general disposition of the agents is entirely random. No two simulations are the same. Upon pressing start and initiating the simulation a clock appears in the left hand of the screen counting the second for which the passenger exchange is taking place. The clock stops when the doors are closed.

Figure 7. Plan view of the simulation. Top showing an unpopulated train interior and below as the simulation reflects a random spread of patrons about to board or alight.

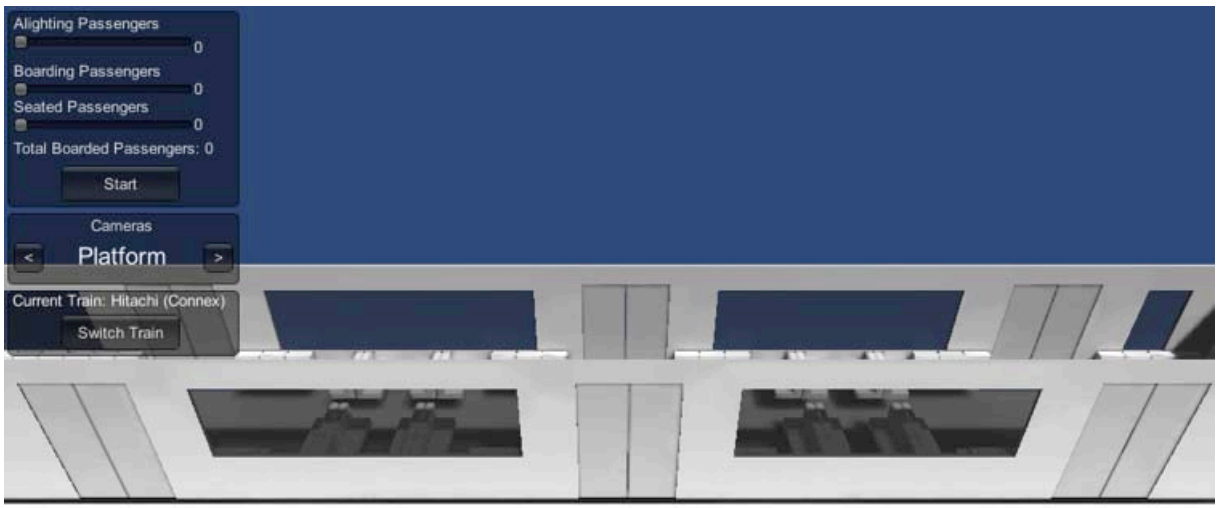
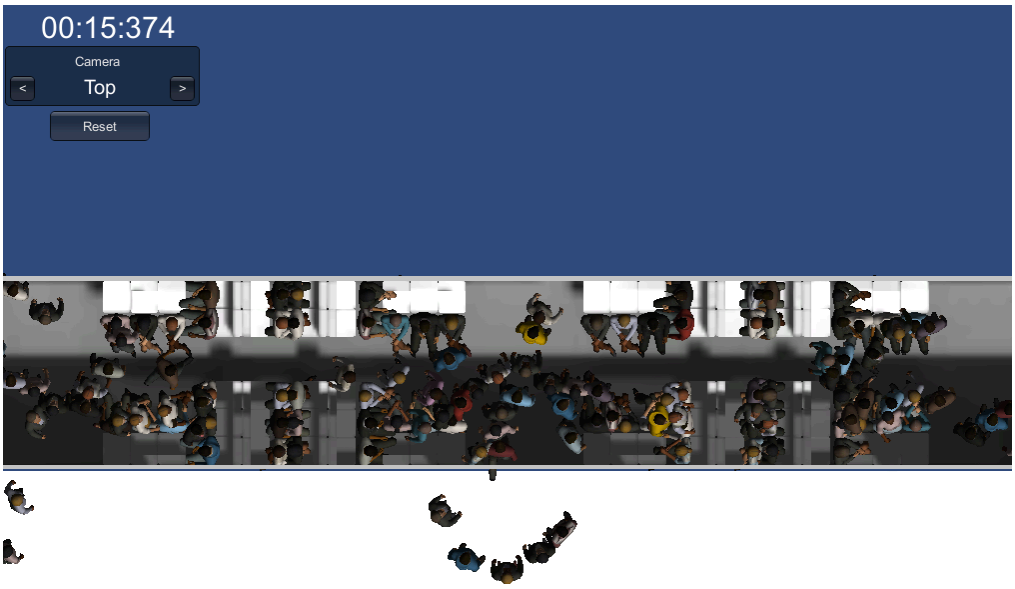


Figure 8. The user interface for the simulation.

Figure 9. A plan view of a simulation. Note that the controlling algorithm for the platform passengers determines they wait for alighting passengers to leave the train before beginning their boarding.

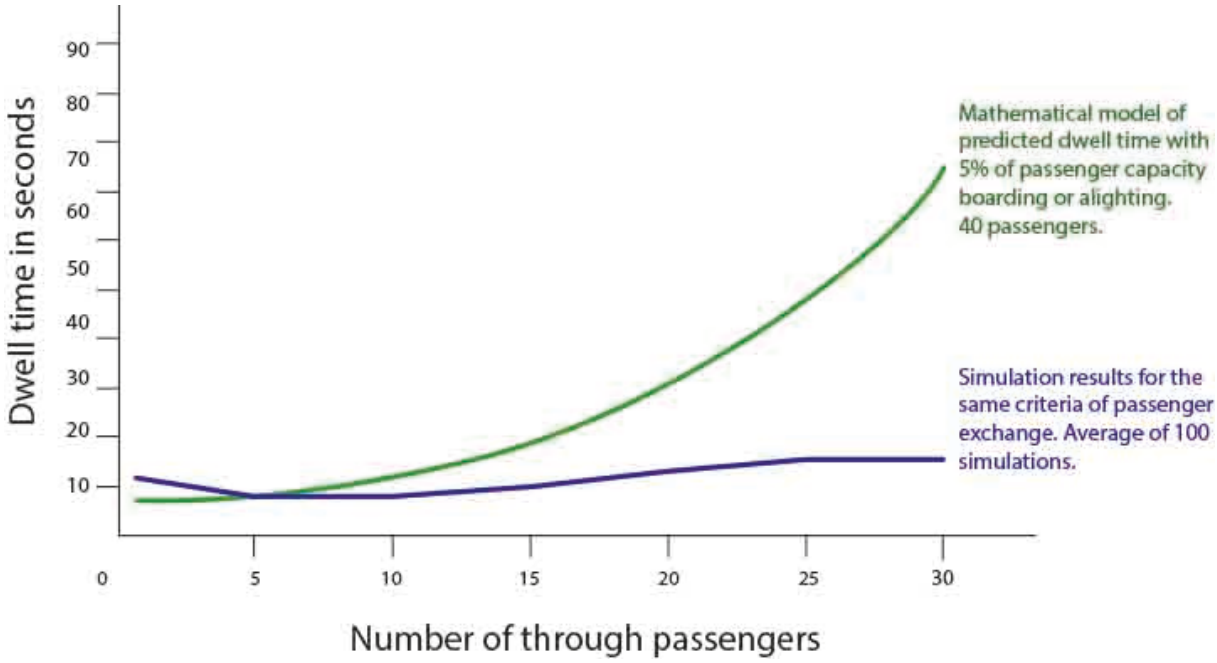


7. Results.

The simulation serves to demonstrate the possibilities of measuring and observing boarding and alighting behaviour that agent based modelling can bring. The worst case situation for dwell-time delays is caused when all the seats in the carriage are taken and the excess in capacity is beginning to build as standees cluster around the door vestibules. When such a train arrives at a significant interchange, where passengers need to alight and significant numbers need to board, then extended dwell times occur.

To test the efficacy of the simulation, experiments where carried out to load the passenger numbers in line with existing mathematically derived data where the numbers of through passengers are incrementally increased as a proportion of the carriage capacity. The number of boarding and alighting passengers remained constant at 5% of the carriage capacity i.e. 40 passengers across the length of the carriage. As Figure 10 shows there is a significant discrepancy between the mathematically anticipated dwell times and those shown through the simulation, which largely remained constant. This diversion can be accounted for by the way the simulation is populated. Using a random distribution through the length of the train carriage rather than an accumulation of standee passengers specifically in the doorway as observed by other studies. The doorway occlusion makes a significant impact on dwell time. This is something the simulation will need to address in future iterations.

Figure 10. Comparative graph showing pre-populated anticipated dwell times for specific percentage of passenger exchange compared with the simulation outcomes.



8. Future work.

These initial simulations are encouraging in terms of visualisation but need refinement tin the shaping of passenger distributions to get better authenticity and the insights gained therein to how passenger crowds might board, alight and disperse in various carriage arrangements. Extending the range of behaviours that 3D agents exhibit when reacting to other agents poses a number of interesting possibilities. If a crowd consists of passengers mostly travelling alone, the simulation could account for people's general preference in not only their spatial separation but also for seats facing forwards and next to a window. The Authors' current simulation reflects an environment most like a peak time commute, whereby most passengers are not associated with a group of other people. What if our agents were travelling in the company of friends and companions? Fine tuning the simulation to account for groups of agents gathering together near the doors or in adjacent seats would entail a consideration for how other agents navigate around these groups. A large crowd of vocal high school students boarding at a station, for example, brings about a new range of agent behaviours and movement dynamics. We discussed above the possibility of agents moving at very different speeds, but how might agents be convincingly programmed to consider other agents, for example to give up their seat or make way for elderly or disabled passengers? And finally, how might other agents react to groups of disruptive passengers or even aggressive and intoxicated ones? Refinements of agent behaviours such as these would clearly benefit from the collaboration of behavioural psychologists.

9. Conclusion.

Commuter rail is experiencing growth in patronage with higher passenger densities and the effects of crowding, accessibility and extended dwell times. Research indicates that the design of the train carriage and the impediments of platform furniture all have an influence on dwell time performance and therefore network capacity. The building of new train and platform infrastructure concepts are expensive undertaking and carry a high level of risk. The Authors' have demonstrated that contemporary high level game engine software can create authentic simulations of crowd behaviour and dispersal to the extent that designs can be tested in advance of implementation.

The *Unity* driven simulations indicate a level of authenticity not achievable by most contemporary software systems and while clearly requiring refinement also indicate potential for accurate and more realistic scenarios. Certain assumptions have been made. Motivations for agents to seek a seat and obey certain cultural norms have been assumed and while observable evidence would suggest these assumptions have validity (Hirsch 2011), this does not negate all possible behaviours that might be encountered at stations. Equally, passenger motivations discussed in the literature but not applied in these simulations due to technical difficulty include sitting next to known people or away from strangers, sitting in the direction of travel and next to windows, bunching at certain doors, as in rainy or hot sunny conditions and when some patrons circumnavigate control conventions and so work against prevailing crowd movements. Contemporary software such as the one used by the Authors' enables these refinements to be undertaken in the next iteration of this simulation tool.

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