An examination of platform and train passenger boarding, alighting and dispersal through innovative 3D agent based modeling techniques.

Dr. Selby Coxon\textsuperscript{a}, Dr. Tom Chandler\textsuperscript{b}, Mr. Elliott Wilson \textsuperscript{3b}.

\textsuperscript{a} Department of Design, Faculty of Art Design & Architecture, Monash University, Melbourne, AUSTRALIA.

\textsuperscript{b} Faculty of Information Technology, Monash University, Melbourne, AUSTRALIA.

Suburban railways around the world are experiencing a rapid increase in patronage. Higher passenger densities, particularly during peak times of the day, have implications for train punctuality, crowding, accessibility and passenger comfort. Research indicates that the design of the train carriage and the impediments of platform furniture all have an influence on accessibility and passenger dispersal, with consequences for service punctuality and network capacity.

Building new concepts in train and station design are expensive undertakings and carry with the investment a high level of risk. Computational simulation methods such as agent based modelling (ABM) can mitigate this risk at much lower cost. Many contemporary ABM modellers represent passenger flow at a macro scale often in a single plan view and with agents travelling at same speeds and represented crudely as dots on a flat plane. This research paper describes the building and the testing of a boarding and alighting simulator at a scale where a deeper and richer experience of crowd behaviour can be modelled using 3D animated figures.

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 these 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 processing power has enabled sophisticated representational human models with walk cycles, idle cycles and a range of recognisably human gestures.

Practitioner Summary

The primary benefit of these methods of evaluation is that they take away the expense and lack of realism present in experiments with full-size mock-ups. Certainly 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.

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 this does not negate all possible behaviours that might be encountered at stations. For example the implication at carriage level of passengers sitting next to known people or away from strangers, sitting in the direction of travel and next to windows, bunching at certain doors, as during inclement weather conditions, and when some patrons circumnavigate control conventions and so work against prevailing crowd flow.

The outcomes of this work has resulted in sophisticated imagery, underpinned by technical accuracy that provides a tool for the development of station infrastructure, train carriage design with implications on timetabling and network planning.

Keywords: Rail, Simulation, Passenger, Crowding.

1. Introduction

Rail is a popular means of transport as urban populations increase (Burdett, Sudjec et al 2007). Growth in city populations has fuelled increased rail patronage with the consequence that many train networks can struggle to be punctual. The most significant variable during a train trip is the time paused at each station. This 'dwell' time is at the mercy of the time taken for passengers to board, alight and disperse within the train carriage or across the platform. At peak periods dwell times can
become extended as passengers scramble to board or alight. 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.

Dwell time predictability is important in the creation of service timetables. Current timetable convention determines dwell times by mathematical means. While there are variations to the formula, they all in essence treat boarding and alighting as a linear period of time multiplied by a coefficient representative of how much passengers have been slowed down by the circumstances of other passengers, width of the doors and if they are carrying belongings. However, mathematical models of determining dwell times also mask the intricate composition of the causes of extended dwells. Studies show (Daamen et al 2008) that there is a wide range of qualitative variables that impact upon passenger behaviour while boarding and alighting. These factors include the prevailing culture of the passengers, their age, relative athleticism, the gap between the platform and the train, the level of the occlusion at the door and their motivations once within the train to finding a seat. 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 the points between predictable timing with where the unpredictable variation in dwell is located. Extended dwell times imply difficulty in passenger boarding and alighting. During peak time, crowding itself is the significant determinant of extended dwell times.

![Dwell Time Variability Diagram](image_url)

**Figure 1.** The segments making up the train dwell time. Authors’ diagram.

### 2. Methods.

Conventional methods of determining boarding and alighting performance have been confined to the building of full size mock-ups and inviting a sample group of passengers to enter and alight from the interior and a platform structure. This method is time consuming and costly and to some extent flawed by the unreal nature of the setting (Daamen et al. 2008).

In recent years advances in computational simulation have enabled planners to replicate crowd movements with some accuracy to indicate likely passenger flow dynamics. Agent Based Modelling (ABM), 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.

Typically ABM modelling has involved crude representations of human movement through the visual device of dots across a flat plane. Some of the reasons for the absence of more realistic 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 depicted in walk cycles, idle cycles and a range of poses and animated behaviours that can enhance the interpretability of the simulation.
A number of different software types were used to build the simulation from surface modeling software to animation specialised applications. To enable the mobility of the agents a software known as *Unity* was used. This product has a high penetration into the industry and is readily accessible. 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 research the Authors’ used *Unity* to develop and test the efficacy of carriage interior and the impact of various impediments. 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 since 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 2.

![Flowchart decision tree for agents moving through the simulation.](image)

Unity has a path finding engine built-in which allows the author of the simulation to map which areas of the scene are “walkable” and the different kinds of “agents” that will move through the scene, Figure 2. 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, Figure 3.

![Plan view of the mapping of agent movement in Unity.](image)
The creation of authentic looking agents in the simulation has been built up from the following layers:

1. Determining the human form, the gender, age attributes and level of build. The figures needed to be realistic enough that their facial features could be discerned and their attire indicated gender or replicate the dominant dress styles of commuters during peak periods. Level of dress would also have an impact upon their overall spatial volume.

2. Walk cycle, the speed and sense of urgency with which to imbue the agent.

3. An idle cycle to replicate a passenger at rest. This is a rest 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.

4. Building the environment into which the agents would move. In this research this environment was formed around the creation of an enclosed space, (the train carriage) complete with impediments within that carriage such as seating and the open platform space.

5. Mapping goals. The agents have, within the context of this experimental work, simple rules of conduct. Their movement is goal orientated to move from a commencing point and navigate through doors to locate a vacant seat. Or in the case of alighting move from the commencing point to locate the exit doors and out onto the platform area.

Figure 4. 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. 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 5).

Figure 5. A 3D character in ‘walk cycle’ and an idle loop for standing and sitting. Created by Chandara Ung
To test the efficacy of the modelling simulation example carriage interior designs where prepared. This was part of a long running larger project concerning dwell time and passenger dispersal behaviour. An example of existing rolling stock was modelled to create a base line performance of the system. A concept design whereby the interior was re-arranged to accommodate a different seating arrangement and an alternative set of doors was devised. The alternative test design concept attempted to manipulate passenger flow with the following strategies:

- re-arranging seating into centrally mounted clusters with dual corridors through the carriage.
- door arrangements that dictate passenger flow either by dint of their width (greater than 2 m) or by the implementation of ‘rules’ to impose passenger behaviours.
- creating the largest possible seating capacity.

There relative performances where then compared by using the simulation with variable crowding figures. The conceptual design contained a central arrangement of seating clusters with dual corridors running along the length of the carriage and high numbers of folding and perch seats. The central innovation offered here is the concept of the ‘peak door’. In essence, the authors’ are speculating that the three-door arrangement as utilized on contemporary trains remains in place and that extra boarding and alighting capacity is only required at certain times of day and at those times an extra two doors per side become operational. These peak doors would be relatively discreet during the off-peak period and indeed folding seats would be located across the temporary vestibule (Figure 6).
Figure 7. A perspective view of the simulation demonstrating a realistic three-dimensional view of the passengers boarding and alighting. Note also the user interface in the top left corner of the screen where loading patterns of passengers is determined.

3. Results.

The simulation serves to validate, via experimentation, an improved boarding and alighting time. The validity of the conceptual carriage interior as an arbiter of improved passenger exchange and stabilised dwell times is seen most keenly by applying the simulation to the highest loads. 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 delays in dwell time occur.

In these simulations, both the existing rolling stock (Comeng) and the new concept carriage are populated to the capacity of the simulation; 250 passengers seated and standing. There are no data sets indicating exact numbers of passenger exchanges, boarding, alighting and standees, so a number of simulations were created, incrementally increasing the percentage of passengers alighting and boarding. The percentage increments are based upon an existing study originally contracted by the Melbourne Transport Operating Company, in which Weston’s formula was used to calculate a graphical distribution of anticipated dwell times. In each simulation, the number of passengers either boarding or alighting is increased by 5%. The distribution of these passengers, both within the carriage and on the platform is randomly driven by the Unity software and so no two simulations can be exactly repeated. For each of the conditions, both carriages fall within the generally accepted dwell time of 20 seconds; however, the peak door two-corridor solution (Figure 7) gives consistently quicker passenger exchanges. Only for very small numbers (5% equating to 14 patrons) were exchange times roughly comparable. As the number of passengers in the boarding and alighting exchange increased, the extra door and corridor space had an observable impact on dwell time reduction.

As an example of an extreme exchange, simulations were run based on the very high passenger loads; 36% above intended carriage capacity. This figure is based on recorded loading counts at Clifton Hill, Melbourne during May 2011. In this scenario, the train was carrying an average of 182 passengers per carriage. The test aimed to determine the results if all the seats remained occupied and the remaining standing passengers all alighted from the carriage to be replaced by the same number boarding. Over 100 repeated simulations, on average the concept train carriage had a 33% shorter dwell time, although it was noted that neither the existing train design or the concept achieved the desirable standard 20 second dwell time at these very high loads.

4. Discussion.

These initial simulations are encouraging in terms of the data they are able to generate and the insights gained therein. 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. Fine tuning the simulation to account for groups 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. How also might other agents react to groups of disruptive passengers or even aggressive and intoxicated ones?

5. Conclusion.

Commuter rail is experiencing growth in patronage with higher passenger densities and the effects of crowding, accessibility and extended dwell times. 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.

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. Future work points to developing the sophistication of the simulation to include agents 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.

References.

Harris, N. 2006, “Train boarding and alighting rates at high passenger loads,” Journal of Advanced Transportation Information Vol, 40 No,3.