Modelling Public Transport Crowding Effects in MATSim

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1 Introduction

With cities growing rapidly and becoming increasingly dense, passenger overcrowding can be routinely observed in public transport networks, leading to delays, disruptions and dissatisfaction. When cities implement new projects, it is important to account for crowding to accurately estimate demand and uptake for these projects [1]. Thus, inclusion of overcrowding impacts is substantial for public transport appraisal and management.

Crowding impacts in public transport systems can be grouped into 3 principal effects [2][3][4]:

1. Travel Discomfort – Increased in-vehicle crowding leads to higher perceived travel costs.
2. Denied Boarding and Queuing Phenomena – Passengers are unable to board full vehicles, leading to increased waiting times, queuing of left-behind passengers at stops, and a heightened risk of failing to arrive at their destination.
3. Demand-supply Variations – Longer boarding and alighting times contribute to service irregularities and bus bunching.

In this study, we aim to implement and measure these crowding effects in MATSim models. We then evaluate the reliability and accuracy with which these effects are represented, by investigating several scenarios using synthetic network and demand.

2 Scenario Setting

Travel Discomfort

To model the impact of rising passenger crowding on travel discomfort, the SwissRaptor module in MATSim as well as the useCapacityConstraints variable in the config file must be enabled. Within the Raptor module, the InVehicleCostCalculator is set to the CapacityDependentInVehicleCostCalculator (CDIVCC), which returns a cost function based on the vehicle's load factor. The minF and maxF parameters determine the cost factor at 0% and 100% occupancy respectively, while lLim and uLim define the occupancy at which the cost factor first and last reaches 1 respectively. Between these values, a linear interpolation is used.

To test the effects of crowding discomfort on route choice, a synthetic network is designed consisting of two parallel bus lines with the same headways and schedules: L1 has lower capacity while L2 has ten times the capacity of L1 (Figure 1). Agents start at the first stop of L1 and have the choice to either take L1 directly or walk a longer distance to take the less crowded L2. The default choice is to take the L1 line, but rising crowding would increase its travel discomfort and should encourage the choice of L2.

When CDIVCC is disabled, only 25% of agents choose L2, but with increasing maxF of the CDIVCC, L2's patronage rate increases substantially. This plateaus rather quickly at a route split of 80% at maxF values above 4. Decreasing the speed of L2 decreases the ratio of agents on the larger bus.

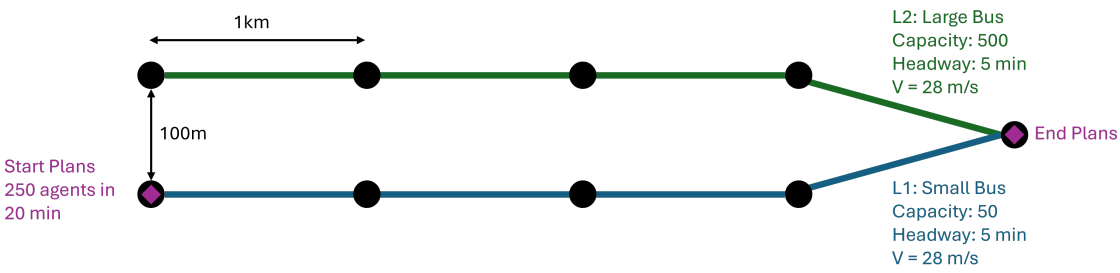

Figure 1: Synthetic Network Configuration

Denied Boarding and Queuing Phenomena
Denied boarding can emerge by default in MATSim due to the strict and explicit representation of capacity constraints. Agents will not be allowed to board if a vehicle is running at capacity. To verify the replication of denied-boarding phenomena, we simulate a similar network with two parallel bus lines with rising saturation conditions.

We increase the number of agents in the simulation and observe its effect (Figure 2). After a threshold of approximately 1000 agents, corresponding to half of the system capacity, the mean total waiting time and mean waiting time after denied boarding increase linearly. With increasing demand, the ratio of agents taking the L2 also increases.

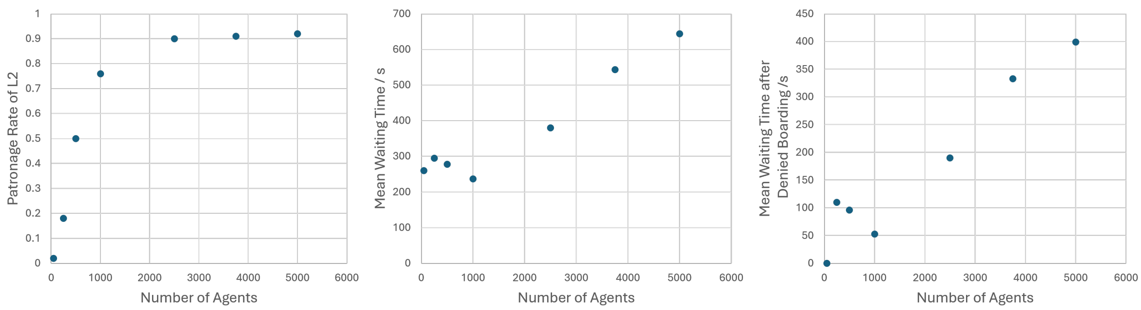

Figure 2: Effect of network demand on patronage rate, waiting time - total and waiting time - due to denied boarding

Demand-supply Variations
Variations in vehicle dwell times and service headways, and resultant bunching effects, can be reproduced by adjusting access and egress times. In MATSim, these are modelled as attributes of the vehicle type. In this study, we assume a linear dwell-time increment of 2.0 s per passenger [5].

In this synthetic network, we simulate a single bus line with 10 stops and a 1-minute headway. Agents are introduced at each of the bus stops. The trajectory plots of the buses show the emergence of bus bunching effects, where two or more buses follow shortly behind one another (Figure 3). This has substantial implications for deteriorating service quality. Effective frequency reduces from 1 min to 2-5 mins. Moreover, passenger loads are much more unevenly distributed in the network, with PT vehicles departing alternately overcrowded or underutilised.

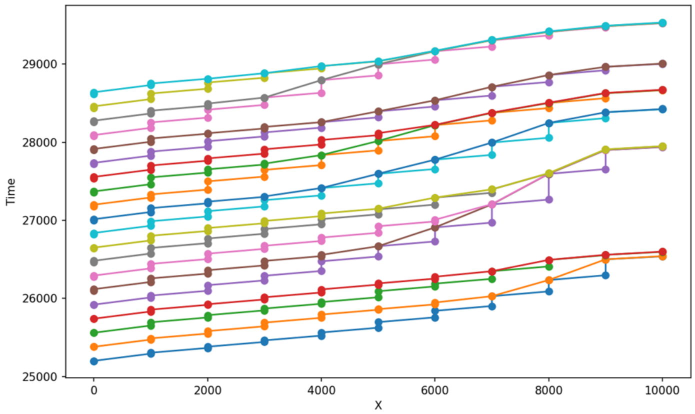

Figure 3: Space-time trajectories with visible headway variations, indicative of bus bunching

3 Outlook

Our findings demonstrate that MATSim is capable of modelling all three principal effects of public transport crowding sufficiently. One challenge encountered is that the discomfort function needs to be additionally included in the PT assignment and its parameterisation should be adjusted accordingly. Moreover, considering travel discomfort can imply that PT routes which are otherwise less popular may now become much more attractive in an overcrowded network. This calls for extending the choice set to include all the viable travel alternatives, which may be discarded under default filtering rules (e.g. plans with longer travel times but higher capacity). As a next step, we plan to apply these crowding effects in a case study of the city of Augsburg. We will explore various scenarios to assess their impact on transport planning and project appraisal.

References

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