Assessing the Design of Urban Transit Vehicles using Microscopic Simulations

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The design of vehicles in urban transit is a key component that determines the overall capacity of a line of public transport. Main determining factors for the capacity of transit lines is the process of boarding and alighting as well as passenger flows inside a vehicle.

Designers of urban transit vehicles need to assess and compare their design choices by predicting the passenger flows in typical situations. Here, field tests with real vehicles or mock-up models can be conducted in order to collect empirical data that provides insight into pedestrian behavior under different conditions. Experimental research into boarding and alighting behavior has been conducted [1] and alighting and boarding rates in different subways around the world have been compared previously, see e.g. [2]. However, these studies are expensive in terms of costs and time due to the need of many participants for a large-scale experimental research.

Alternatively, microscopic simulations can be used which take into account the geometry of the vehicles as well as the user behavior. In [3] a cellular automaton is used for this purpose, reproducing certain behavior recorded in the Beijing subway and [4] describes the calibration process and results for the commercial Legion simulation model. In [5] it was demonstrated that the social force paradigm can be used in order to calibrate models to predict boarding and alighting processes.

The main contribution of this paper is the demonstration of simulation methods that allow for investigating passenger flows in different designs of urban transit vehicles. We applied our simulation methods in a project with BOMBARDIER Transportation, Business Unit Light Rail Vehicles LRV, on three different vehicle layouts each comprising an overall door width equal to seven double wing doors. Our simulation results have been validated against measurements of crowd flows and we discuss which information can be gathered from different graphical representations.

As a starting point for the simulations, eight different scenarios have been defined which vary in passenger load, distribution of passengers on the platform and the process of boarding or alighting. We defined two passenger loads according to [6]:

- Low Load: occupation of all available seats plus standing area with 2 persons / m²
- High Load: occupation of all available seats plus standing area with 6,67 persons / m²

For the different scenarios we distributed the passengers on the platform either uniformly or split the number of passengers into two equally sized groups and placed them along the platform next to the front and rear third of the vehicle. Furthermore, one scenario included individuals with handicaps, i.e. a person with a wheelchair and a person with a baby stroller.

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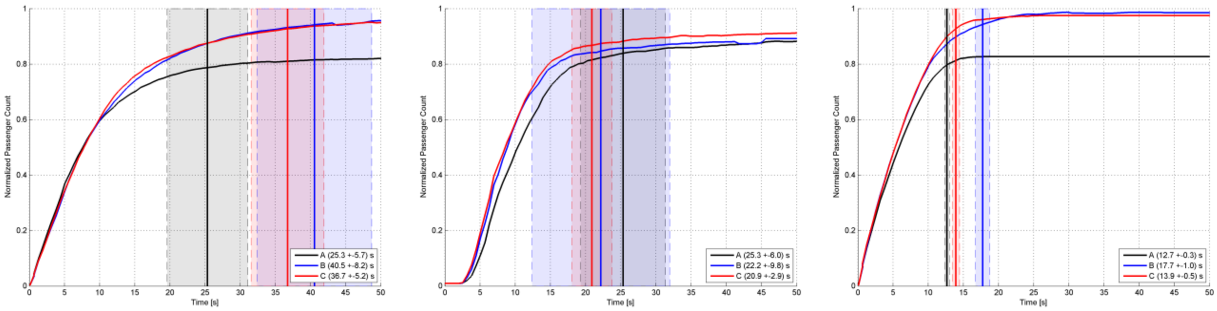
In this paper the social force paradigm based on the definition of the repulsive force from [7] is used to model the passenger movement. The calibration of the social force model was performed according to [8]. We validated our simulation results using crowd flow measurements which have been observed during multiple experiments [5], in real world and provided from scientific literature [9]. The measured average passenger flow rates strongly depend on the observed period since during the beginning and end of the boarding respectively alighting process the rates are significantly lower than in between. Thus, we considered only the period between 25% and 75% of all passengers have entered respectively left the train leaving us with nearly constant flow rates. The resulting flow rates from our simulations comply well with the observations which were confirmed by a sum of squared error in the range of 0.004 to 0.018.

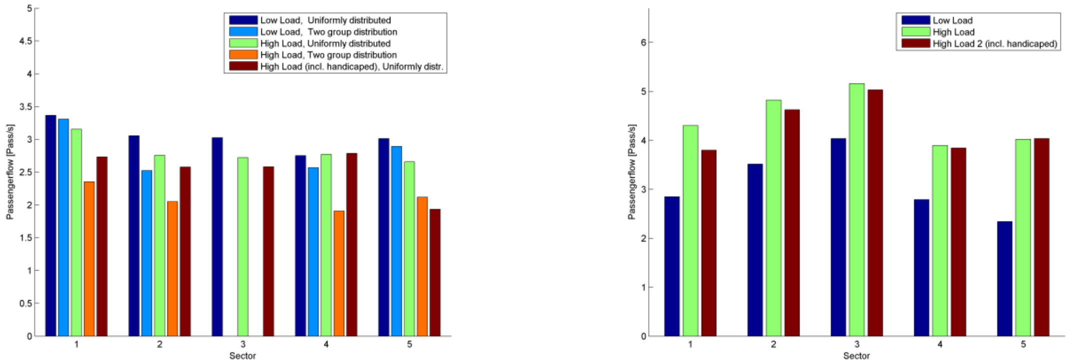
For each vehicle layout a total of eight scenarios have been simulated providing us with trajectories for each individual. As depicted in Figure 1, we determined the time when 95% of all passengers have boarded the train (Figure 1a), taken a seat (Figure 1b) and alighted the train (Figure 1c). Differences in vehicle designs and the impact on boarding, alighting and seating times were identified and documented.



(a) (b) (c)

Figure 1: Time when 95% of all passengers have (a) boarded the train, (b) taken a seat and (c) alighted the train.

Furthermore, we investigated the flow rates in the period between 25% and 75% of all passengers have entered respectively left the train. We clustered the available space on the platform into five sectors in order to control the distribution of passengers to individual doors. This allowed us to efficiently define the two different distributions of passengers on the platform. We investigated sector specific flow rates. Obstacles in specific sectors have been identified and their impact on the boarding and alighting process examined (see Figure 2a for the boarding process of a vehicle and Figure 2b for the alighting process).



(a) (b)

Figure 2: Flow rates per sector during (a) boarding and (b) alighting.

As a result we clearly identify and quantify differences between the three investigated vehicle designs. We highlight the differences according to different door types used, the interior design and space available in the vehicles, passenger loads and passenger distributions on the platform. This provides important information for the design of the vehicles which can be used to further improve boarding and alighting times by eliminating obstacles or bottlenecks.

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