Integrated trip assignment for congested rail systems: Utrecht-Amsterdam corridor

F.S. Hänseler* J.P.A. van den Heuvel† O. Cats*
W. Daamen* S.P. Hoogendoorn*

March 28, 2017

The ongoing growth in transit demand increasingly affects the quality of both rail services and rail access facilities. Traditionally, these two aspects are considered separately, namely by means of transit assignment models and at-station pedestrian models. Such an approach has various limitations as it typically ignores the interdependencies between passenger behavior at the level of transit networks, and that of pedestrians at the level of train stations. For instance, the choice of a waiting position along a platform depends on the expected loading of the vehicle serving that platform sector, which in turn depends on the necessary walking at the destination.

To overcome this intrinsic limitation of traditional approaches, we propose an integrated trip assignment model that is applicable to congested rail systems. Travelers are considered as individual decision-makers, whose moving along a transit trip is described in a macroscopic manner. The pedestrian environment in stations is modeled as a queueing network process, where walking speeds result from the interaction between pedestrians and infrastructure and are described by empirical density-speed relationships. Specifically, walkable space is represented by a network, whose links carry the pedestrian flow and mutually interact in case of congestion. Other pedestrian activities, such as waiting or level changes, are modeled in a similar way. Transit operations are described explicitly, including a detailed representation of transit schedules, delays and passenger service times. Trains are represented by their vehicles, whose capacity and seat

*Delft University of Technology, The Netherlands.
†NS Stations, The Netherlands.

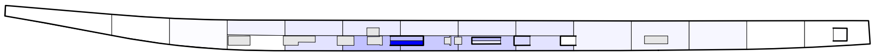
availability, as well as boarding and alighting processes are described individually.

Route choice across the rail network is approached from a behavioral point of view. Travelers base their travel decisions on the accumulated experience gathered from repetitively traveling through the network. Multiple dimensions of the choice problem are considered, ranging from the local path choice within a station, to the choice of a waiting position along a platform, to the choice of boarding and alighting itself. The learning process is concerned with the specification of different trip components, such as in-vehicle time, walking time or waiting delays, as well as comfort measures related to crowding. For instance, low levels of service in terms of pedestrian density or vehicle loading are penalized by 'crowding multipliers.'

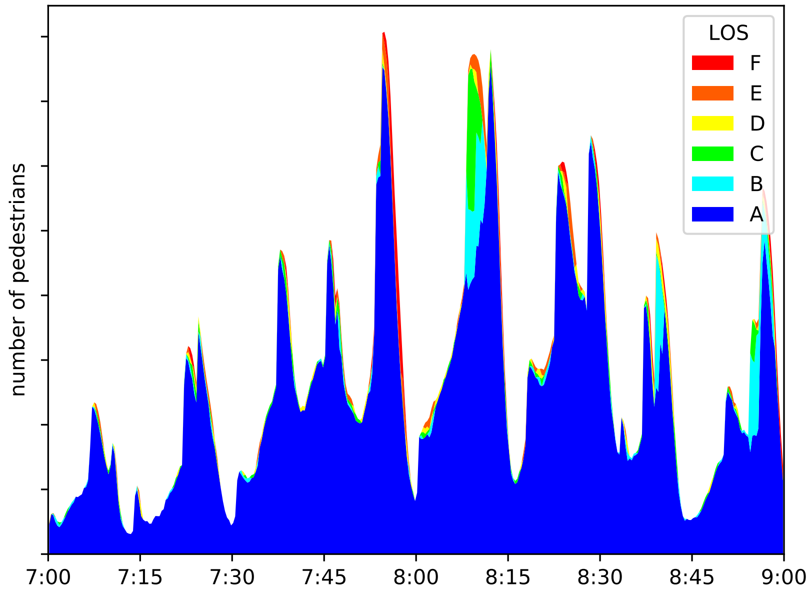
To assess the practical applicability of the proposed framework, a case study of the Utrecht-Amsterdam corridor is considered, representing one of the busiest train lines in Europe. Namely the train stations of Utrecht Centraal, Amsterdam Bijlmer-Arena and Amsterdam Zuid, together with the corresponding rail services, are considered. These train stations are characterized by distinct usage profiles: *Utrecht Centraal* is the Netherland's largest train station, and during peak periods platform safety due to insufficient availability of space is of major concern. *Amsterdam Bijlmer-Arena* is a suburban train station with a low load, except during events that regularly take place in an adjacent football stadium. *Amsterdam Zuid* finally serves a major business district, and platform egress during peak hours regularly yields precarious passenger queues upstream of escalators and stairways.

For calibration of the case study, tap-in/tap-out smart card data is available for the entire corridor. Detailed information on the rolling stock, arrival and departure times, and stop positions of each train are known. Moreover, CAD-based station maps have been implemented in the proposed assignment model, providing detailed information on capacities of pedestrian facilities. For further model parameters, mostly needed to specify the travel cost functions or density-speed relationships, standard values found in the literature are assumed.

Preliminary results obtained with a 2015-dataset are promising. Fig. 1a shows a density map of platform #5/7 of Utrecht Central Station, representing average conditions during the 5-min peak period with the highest platform occupancy. The pattern found resembles closely empirical observations, in particular regarding the high densities on the narrow side of the platform.



(a) Density map. Darker color means higher density.



(b) Level-of-service distribution according to Fruin's scale.

Figure 1: Platform #5/7 of Utrecht Centraal. Actual scales not shown due to pending confidentiality clearance.

Fig. 1b shows the evolution of the level-of-service distribution over time on the same platform. Strong fluctuations in platform occupancy can be seen, which are in the order of magnitude of a few thousand pedestrians (see confidentiality note). Even during less busy times, a small fraction of low service levels is perceivable, typically due to platform egress ways reaching capacity. This also explains the delayed recovery of low service conditions during peak periods (see for instance the persistent fraction of LOS E/F that still exists shortly before 8:00, well after the platform occupancy has reached a global maximum at around 7:53).

To validate the model, comprehensive pedestrian data is collected using a pedestrian monitoring system in Utrecht Centraal and Amsterdam

Zuid. Specifically, automated pedestrian count and density observations are available that allow for a quantitative and independent validation. A preliminary assessment of predictions of platform densities and access/egress flows on selected platform access ways shows a good agreement; a more detailed analysis is currently being carried out and will be included in the proposed conference contribution.