Accounting for capacity constraints and online information in a frequency based transit assignment model

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The transit assignment problem is defined as the mapping of passenger demand on a given transit network. Transit assignment is commonly used to estimate travel times and line use and thus by enables to evaluate network design; therefore, it plays a key role in transit network planning.

Approaches to transit assignment are broadly divided into schedule and frequency based modeling. Schedule based models are commonly used for simulation of detailed time-dependent transit assignment. Frequency based models are commonly used for planning purposes, yielding the average distribution of passengers over time and enables the handle of large scale networks.

In the last decade Information and communication technologies (ICT) have become widely used. Platforms such as electronic panels in boarding stops and mobile apps inform the passenger of predicted arrival times. Such information may include the arrival times of vehicles to a boarding stop, and in some cases the expected waiting times at the transfer stops. When available to passenger, this information is likely to influence route selection.

Another central theme that influences route choice is the capacity of the service. If the capacity of an arriving vehicle is lower than the demand, passengers may miss a boarding. Capacity constraints are essential to realistically describe the distribution of passengers in a transit network. Frequency based transit assignment models that consider capacity constraints commonly apply equilibrium procedure by attribute longer travel time to over-crowded transit lines (Cepeda et al., 2006). Extending the travel time of the crowded line reduce its attractiveness and thereby the number of passenger assigned to it. The equilibrium problem is commonly solved using the Method of Successive Averages (MSA) procedure, which has slow convergence properties.

The objective of this study is to develop an efficient heuristic to consider capacity constraints and online information and integrate them in an assignment model. A frequency based transit assignment model that considers online information of predicted arrival times that is available to passengers was developed by the authors (Oliker and Bekhor, 2018). The presented study extends the developed transit assignment model to account for capacity constraints.

The capacity constraints are considered for two types of information cases: (1) passengers are informed of the carrier occupancy in real-time and may change their route selection accordingly, (2) passengers do not have prior knowledge of the carrier occupancy, and in such cases, will necessarily choose an inferior alternative which departs later than the desired over-crowded vehicle.

The main idea of the suggested model is to reallocate the surplus to the next attractive path in the O-D path set. The idea is to re-calculate the probability of choosing a path under different conditions of predicted arrival times and occupancy. The model scheme is presented in Fig. 1 and is composed of the following steps:

1. The transit assignment model (Oliker and Bekhor, 2018) is run with no capacity constraints. The O-D identity of all assigned passengers is saved.

2. Transit links with assignment that exceeds the maximal capacity of the carriers are traced and a list of O-D demand with surplus assignment is created.

3. The list is sorted with respect to the surplus quantity of each O-D.

4. The elements in the list are dealt iteratively until the list is empty and there is no surplus in the network.

5. In each iteration, the O-D with the maximal surplus assignment is handled.

6. The links with surplus passengers are assigned to their upper bound as described below in equation 1 and 2.

7. Surplus passengers are routed to different paths in the attractive path set. In case the passengers are assumed to be informed of the carrier occupancy they are routed to all other alternatives in their attractive path set. In case the passengers have no a-priory

knowledge on the occupancy they are routed only to alternatives that are inferior to their desired, full carrier (i.e., vehicles that arrive later than the fully occupied one).

8. After the O-D is re-assigned, it is removed from the list. If new surplus were generated due to the re-assignment surplus, they are traced and added to the list.

9. This procedure is repeated for each O-D with surplus until the list is empty.

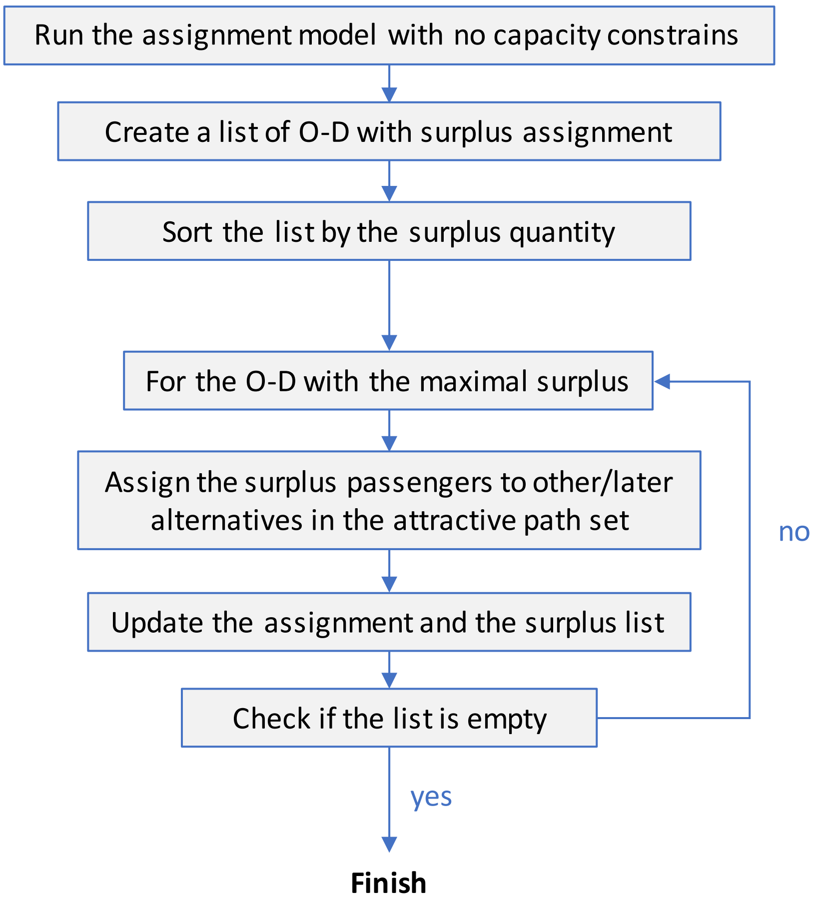

Fig. 1 Model scheme

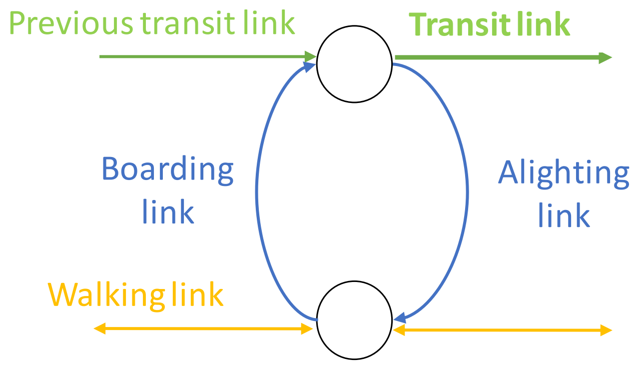

Fig. 2 Transit link example

The free capacity in a transit link, shown in Fig. 2 and the corresponding updated link assignment for a certain O-D pair, denoted as $UL_{O\text{-}D}$, are defined by the following expressions:

$$\text{Free capacity} = \text{Full capacity} - \text{Previous transit link} + \text{Alighting link} \qquad (1)$$

$$\begin{aligned} &\text{If Free capacity} \leq 0 \qquad\qquad (2)\\ &\quad UL_{O-D} = 0\\ &\text{else}\\ &\quad UL_{O-D} = \text{Free Capacity} \cdot P_{O\text{-}D} \end{aligned}$$

where $P_{O\text{-}D}$ is the proportional share of the O-D pair in the previous assignment of the transit link from origin O.

The selection probability of each path in the path set is calculated analytically as described in Oliker and Bekhor (2018). If a path becomes invalid due to over-crowding its probability of selection is reduced to 0. The probabilities of all other paths in the set increase according to their independent relations (i.e., the probability ratio of the remaining paths, while eliminating the over-crowded alternative). Since the probabilities have an analytic expression, their update is very fast.

The model was successfully applied on a small network and is currently being implemented on a real-size network.

References

Cepeda, M., Cominetti, R. and Florian, M., 2006. A frequency-based assignment model for congested transit networks with strict capacity constraints: characterization and computation of equilibria. Transportation research part B: Methodological,40(6), pp.437-459.

Oliker, N. and Bekhor, S., 2018. A frequency based transit assignment model that considers online information. Transportation Research Part C: Emerging Technologies, 88, pp.17-30.