Modelling the capacity effects in a transit network: the CapTA model and selected results from the RER-A line in Paris.

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EXTENDED ABSTRACT:

In the transit network of large urban areas, it frequently occurs that the transit system is submitted to heavy congestion at the peak hours on working days, especially so at the morning peak in the central part of the urban area. Under that circumstance, the passenger experience increased discomfort and degraded conditions, while the operations of the services may be disrupted or heavily affected, leading to reductions in service frequency.

On a transit network, passengers and service vehicles interact in a number of ways. Vehicle traffic determines the in-vehicle travel times and also the waiting time on platform. Passenger traffic influences the dwelling time, hence also track occupancy and maybe even service frequency. Furthermore, the interplay of passenger flows and vehicle capacity determines the in-vehicle comfort and the residual capacity for access at a station. The CapTA model (for Capacited Transit Assignment), introduced in Leurent et al (2011), treats these effects while dealing in a specific manner with service operations by line and the local interactions of vehicles and passengers.

The objective of the paper is to offer a systemic representation of the CapTA model and the identification of the relations between its components. Furthermore, it describes the line model used for the treatment of the various capacity effects affecting the travel conditions and the system performance. An application instance is provided – derived from the Grand Paris transit network – for the illustration of the model's capabilities and behaviour on the line level.

The systematic treatment of the public transportation system makes possible to identify the system's components and establish the relations between them to facilitate the modelling process. Each modelling aspect is treated at the appropriate level: at local, at system or at network level. At local level we address the effects occurring at the platform and station. At the level of the transit line we coordinate the passenger flows of the services and establish the physical flowing and economic evaluation of the travel conditions. At the network level, the passenger flows are assigned in the transit network based on the conditions of the trip.

The systemic framework of the CapTA model benefits from a bi-layer representation of the transit network. A classic representation of the transit network is considered on the lower layer composed by particular subsystems in

the network. However, on the upper layer the representation is conditioned by the types of the trip segments used by a passenger: the in-vehicle trip, the in-station circulation and the access-egress trip. These define, respectively, the appropriate network legs: the line leg, the station leg and the access-egress leg. A network leg corresponds to a unique trip of a passenger from its origin to its destination node. Each type of leg is treated by the appropriate system sub-model – the line model, the station model and the access-egress model – acting as a specific cost-flow relationship.

A line is defined as an acyclic, connected graph in one direction of traffic. A system sub-model at the line level – the line model - developed in Leurent et al (2012) treats the line operations on the basis of specific models: a physical model of flow loading in vehicles and of service traffic – the line flow loading model -, and an economic model of cost evaluation in the setting of the individual passenger that would use the line on a given leg – the lien leg costing model.

The RER-A – the busiest line in the Greater Paris network – is provided as an application instance to serve as a showcase of the model's capabilities and as a means to test its behaviour. The results focus on the operation and the quality of service of the trips on the busier westbound service, where 30 trains/hour carry up to 60 000 passengers/hour. However, the service frequency rarely is greater than 27 trains per hour, a fact attributed to the dwelling time recurrently exceeding the scheduled dwelling time.

Considering the capacity constraints, the resulting passenger flows differ significantly from the unbounded situation. Selected results on the line level illustrate the impact of the passenger flows on the operation of the transit routes; where the frequency and the capacity offered are reduced. We observe that considering only the dwell time increases – due to the boarding and alighting flows – can explain an important part of the frequency reduction. Furthermore, the paper focuses on the degradation of the travelling conditions – linked to the in-vehicle comfort and the increased waiting time – on the service perceived by the transit users.

The CapTA model provides a framework for modelling the capacity constraints within a transit line that affect the operation of transit services and the quality of service perceived by the users. A more realistic traffic assignment model for public transportation may also be of value when linked to other models, such as trip demand models for simulating departure times or transport mode choices.