The MFD trip-based approach applied to multi-reservoir systems

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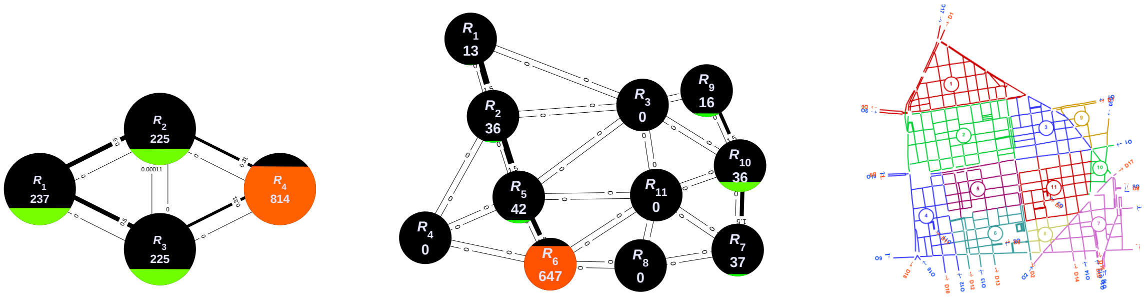
Extended abstract

Over the past decade, the Macroscopic Fundamental Diagram (MFD) has appeared to be a powerful tool to describe traffic states at the network level with few implementation and computational efforts. Many studies (e.g. Knoop & Hoogendoorn, 2014, Yildirimoglu & Geroliminis, 2014, Yildirimoglu *et al.*, 2015, Haddad, 2015) have notably used MFD-based traffic simulators for several applications, like traffic state estimation, perimeter control or assessing routing strategies at a large scale. Their modeling approaches take advantage of the multi-reservoir representation of a city, where the dynamics of each urban subregion is described by the single reservoir model of Daganzo (2007). This framework, also referred as the accumulation-based model, assumes that the reservoir outflow is for the simplest model proportional to the total circulating flow inside the zone or that partial outflows are proportional to fractions of the circulating flow for more advanced models. However, while being acceptable in slow-varying conditions, this hypothesis may be too restrictive when the demand evolves too fast as shown by Mariotte *et al.* (2017). An idea, initially proposed in Arnott (2013), has been exploited in Daganzo & Lehe (2015) and then Lamotte & Geroliminis (2016) to design a "trip-based" formulation of the MFD model. This approach considers that all users travel at the same speed at a given time, and exit the zone once they have completed their individually assigned trip length. As shown in a thorough comparison with the accumulation-based model by Mariotte *et al.* (2017), the trip-based approach gives more accurate results during transient phases, and proves to be more flexible to integrate various trip lengths inside the same reservoir. However, despite an attempt provided by these authors, using this framework to model congestion propagation inside the reservoir is still a challenge.

In this study, we propose to extend the trip-based formulation to multi-reservoir systems. Our resolution scheme uses the event-based method proposed in Mariotte *et al.* (2017). The main challenge is to properly account for congestion spillbacks in upstream reservoirs when trip lengths are different. Simulation results are investigated for two different multi-reservoir systems. The first one has four reservoirs with one regional Origin-Destination (OD) pair and three routes. Its configuration is inspired by the Braess network in choice modeling studies, see figure 1(a). The second one has more than ten reservoirs and is based on a real network: an artificial partitioning of the 6th district in Lyon (France), see figures 1(b) and 1(c). This second case aims to study a more realistic and complex multi-reservoir system with different OD pairs. In that case, network partitioning is made depending on the demand description, and not based on homogeneity constraint like in Saeedmanesh & Geroliminis (2016). The results are then compared with the accumulation-based modeling of these multi-reservoir systems. The corresponding simulator we use is adapted from the study of Yildirimoglu & Geroliminis (2014). In both accumulation- and trip-based approaches, particular attention is paid on how to model congestion propagation inside and between reservoirs. The influence of internal inflow generation within the reservoirs is also explored. The congestion inside a zone is usually modeled with a restriction on the global entrance flow from outside the zone. As there may have a lot of interactions between the reservoirs, this inflow reduction must be performed during the simulation in case of congestion, which is not necessarily trivial due to the event-based structure of the numerical scheme. While this is already well integrated in the accumulation-based framework with fix time step, to our best knowledge, inflow regulation at reservoir perimeter has never been implemented in the trip-based model. In this study, several ways to simulate congestion propagation within this framework are explored: the method of Newell (2002), the upstream inflow restriction function used in the Cell Transmission Model (CTM), and the relationship between inflow and outflow exhibited in the numerical approximation proposed by Mariotte *et al.* (2017). Moreover, when congestion propagates through adjacent regions, different flow merging functions can be used to determine the inflow allocation between all upstream reservoirs. The influence of such merging functions is investigated in both the accumulation- and the trip-based models.

Our first results show a good concordance between the two modeling approaches in steady state for simple network loading cases with the same travel distance for all users. In case of different trip lengths however, the accumulation-based model fails to reproduce reliable evolution of congestion in the reservoirs, the whole system being sometimes very unstable. On the other hand, because the trip-based model keeps the variety of user trip lengths, corrections methods can be implemented to better represent congestion propagation and ensure the system stability. Moreover, for more complicated loading tests involving several OD pairs (especially in the network of Lyon 6), very different steady states may be reached depending on the merge function used in both simulators. As for transient phases, important discrepancies are noticed between the accumulation-based and the trip-based models. This corroborates the observations in Mariotte *et al.* (2017) about the difference in travel time evolution between the two approaches. All these concerns are of great importance for further studies which would include traffic assignment in multi-reservoir systems. All results are not presented here as this study is still an ongoing work.

Keywords: Large network modeling, Macroscopic Fundamental Diagram, multi-reservoir systems



(a) (b) (c)

FIG. 1 – *Two multi-reservoir systems.* (a) *Braess network. Lyon 6 network,* (b) *schematic and* (c) *link-level representation*

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