Dynamic Route Choice Modeling with Macroscopic Fundamental Diagrams

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Travelers' decisions, such as when to make a trip (i.e. departure time) and which way to get to the destination (i.e. route choice), highly depend on the location of congestion pockets and traffic conditions in the network. For large-scale networks with a high number of route choices and multiple ODs this problem is still challenging due to the computational complexity and the uncertainty in the behavioral characteristics of drivers. In this work, we attempt to model and solve a dynamic traffic assignment problem with experienced travel time estimation at the network level by considering the sequence of regions in the trip chain, than the detailed sequence of links in a route choice framework.

A (roughly) homogeneous urban region can be modeled using macroscopic fundamental diagram (MFD), which provides a uni-modal, low-scatter, and demand-insensitive relationship between network vehicle density and space-mean flow (e.g. Geroliminis and Daganzo, 2008, Geroliminis and Sun, 2011). Recent studies have shown that route choice can affect the distribution of congestion and as a result the shape and scatter of the MFD. Dynamic traffic management strategies (e.g. perimeter control, gating) that benefit from MFD dynamics provided promising results regarding their effects on network capacity and performance. However, this raises the question of route choice behavior in case of heterogeneous urban networks, where different parts are modeled with separate MFD functions. In this study, we incorporate a route choice model into the MFD, and establish stochastic dynamic user equilibrium (SDUE) conditions. These conditions are satisfied within a dynamic traffic assignment (DTA) framework, and their effects on network capacity and performance are tested. MFD approach requires aggregate modeling of traffic flow within urban regions, and it describes traffic flow propagation within or between the regions using average trip lengths. However, average trip length is not informative enough to build a route choice framework; instead, trip length distributions (TLD) within each region and for each OD (i.e. origin and destination regions) must be considered to ensure DUE conditions in the system. This study does not explicitly calculate TLD's, but it deals with them in an iterative way within stochastic network loading procedure. The loading procedure incorporates random sampling of origin and destination points inside the regions and a logit-based traffic assignment component to account for trip length distributions and perception errors in travel time, respectively. The results taken from the iterative stochastic loading procedure are, then, processed through an averaging procedure called method of successive averages (MSA). MSA is an effective solution heuristic which is highly implemented in simulation-based DTA (Peeta and Mahmassani, 1995). Given that it does not require derivative information for the flow-cost mapping function, MSA can be easily adapted to simulation studies. MSA uses the simulator (i.e. MFD dynamics in this case) in each iteration to project future traffic information as part of the direction finding mechanism in searching for a solution. As simulators take significant amount of time, simulation-based DTA strategies are not suitable for real-time deployment (Peeta and Ziliaskopoulos, 2001). On the other hand, MFD approach, even in case of large-network modeling, can get along with a small graph network with few nodes and links. Therefore, this study does not suffer from feasibility issues in real-time deployment.

Multi-region dynamics that will be described in details in the full paper and DTA methodology to be developed within this study are first tested on a simple-network presented in **Fig. 1**. The network in **Fig. 1** presents a case with a single destination (red dot), which is modelled using MFD dynamics. The system is partitioned into three sub-networks with different MFD functions. In this simple network, travellers have alternative paths to reach their destination. For example, people who travel between region 1 to the destination point have two alternatives; staying in region 1 (denoted as 1-D) or passing through region 3 (1-3-D).

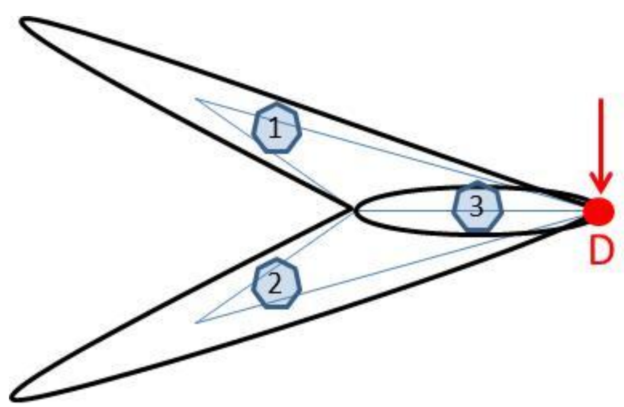

Fig. 1 Single-Destination Multi-Region Network

Fig. 2a and b display average travel times on the alternative paths for OD pairs (1D) and (2D), respectively. Note that average travel times are calculated using the time-dependent speed measurements in the regions shown in **Fig. 2**c and average trip lengths are depicted in **Fig. 2**e and f. Also, **Fig. 2**d provides route choice parameters indicating the proportion of OD demand using the paths 1→D and 2→D. As region 3 is congested at the beginning of simulation, its speed is very low. Therefore, about 90% of (1D) and (2D) demand prefer to follow 1→D and 2→D, respectively, instead of going through region 3. As the time passes, the accumulation in region 1 and 2 increases, hence, travel times on alternative paths become comparable and more travelers start to choose sequence 1→3→D. $\theta_{1\mathrm{D}}$ reaches ≅0.4 at approximately 1 h after the simulation start, which indicates that about 60% of OD demand prefer to follow 1→3→D. At the end of the simulation, where speed measurements indicate almost free flow traffic conditions, both route choice parameters converge approximately to 0.5.

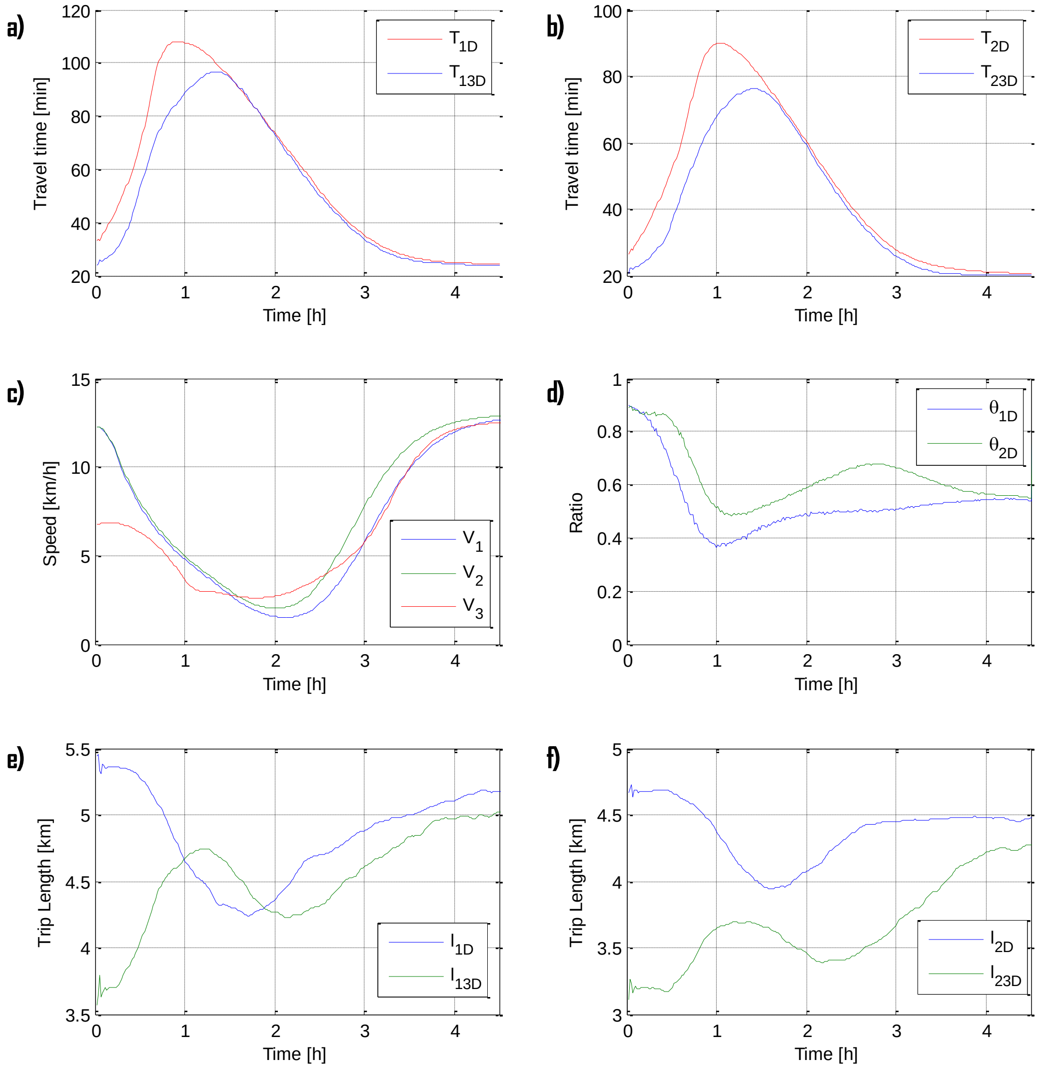

Fig. 2 a. Travel times on alternative paths for OD pair (1D), b. for OD pair (2D), c. Speed measurements in the regions, d. evolution of route choice parameters, e. evolution of average trip lengths on alternative paths for OD pair (1D), f. for OD pair (2D)

Note that travel times depicted in **Fig. 2**a and b are not conventional trip times used in discrete modeling approach. They represent average travel time experienced by the proportion of OD demand which choose the corresponding path. For instance, even though travel time on path 1→D is higher than the one on path 1→3→D at the beginning of the simulation, greater proportion of OD demand (≅ 0.9) choose the path 1→D. As **Fig. 2**e indicates, average trip length in the path 1→3→D is significantly lower than the one on the alternative path at the beginning of simulation, which implies that only travelers who depart from locations close to the destination point prefer to use this path. Thus, average travel time is lower on the path 1→3→D, while only ≅10% of OD demand prefers it. As time passes, travelers who depart from farther locations in the region start to choose 1→3→D, which increases the average trip length on this path. In addition, the approach presented in this study, as it aims for SDUE conditions rather than DUE conditions, is not expected to produce equal travel times on alternative paths. Instead, it presents equilibrium conditions in which people may perceive travel times differently and make route choice decisions based on their location inside the region.

Details of the traffic assignment methodology presented in this abstract will be included in the full paper. Extensions of this study include incorporation of a time-dependent shortest path algorithm to determine the link sequence with minimum cost among all the possible combinations in compliance with a particular region sequence definition. A future direction is the development of a routing guidance strategy based on the methodological framework of this work.

References

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