Traffic Network Guidance using Area Accumulation and Spatial Variation in Density

Victor L. Knoop * **Hans van Lint**
Serge P. Hoogendoorn
Transport & Planning,
Delft University of Technology, Delft, The Netherlands
Email: v.l.knoop@tudelft.nl

1 Routing with the Macroscopic Fundamental Diagram

Network management has become more relevant in recent years. Urban areas have become larger, and the road traffic more intense, such that local disruptions can have effects which stretch to different locations. Road authorities have to manage the traffic accordingly, meaning it is required that they take network effects into account in their management actions. Large traffic models can be built, allowing to study the effects of all combinations of measurements. However, running these models in real time is not feasible. This paper investigates whether it is possible to have control based on a more aggregate level, requiring less calculations.

1.1 Background

Over the last few years, the Macroscopic Fundamental Diagram, or Network Fundamental Diagram (NFD) has been introduced Geroliminis and Daganzo (2008). This describes the traffic flow phenomena as function of one parameter, being the accumulation A, i.e. the number of vehicles in an area. For a fixed area, this can be related to the amount of available roadway length in that area, and hence can be translated into the average density. The NFD relates this accumulation to the network production, P, i.e. the average flow in the area. It has been shown that network variability also affects the production. Last year, we therefore proposed a generalized macroscopic fundamental diagram (Knoop and

Hoogendoorn, in print) which gives the production in an area as function of the variation of the density in the area (σ) and the accumulation

$$P = P(A, \sigma) \tag{1}$$

1.2 General idea

The idea described in this paper exploits the fact that not many data are needed to get this average flow. It would be time consuming, costly and computationally hard to collecting traffic data at all locations, transmitting these, and processing these in a traffic state estimation procedure which gives the detailed state at each point in the network. Instead, we will split the network into different parts, *areas*, for which we only use the accumulation and the inhomogeneity in the area to estimate the traffic state. We do so by estimating the accumulation and spatial inhomogeneity which gives, using the NFD, the production. The accumulation and production together give the average speed in the area, v:

$$v = \frac{P}{A} \tag{2}$$

This speed, different for all areas in the network, can be used to guide traffic through the network. This way, we separate the routing strategies on the network level, the *high level* routing strategies, from the detailed routing within an area, which can be optimized separately.

1.3 Goal

The aim of this paper is to study the effectiveness of high-level routing algorithms, using only these aggregate data, production and accumulation. These routing algorithms can be used in large networks, in which it is difficult to collect all detailed data, and even more difficult to get a state estimation (let alone prediction) of the network on link level. The advantage of the high-level routing strategies we propose in this paper is that the inputs can be estimated on an aggregate level, and the state estimate can be relatively coarse. Data-wise, accumulation can be estimated directly and the variation of density can be estimated by the spread in density over some detection points. In particular, we are interested in the added value of the variation of densities on the performance. In this study, the total delay is chosen as measure of performance.

2 Experimental Setup

To test the effectiveness of the routing strategies, we implement several routing strategies in a simulation model. This section describes the experimental setup, in terms of the traffic flow model (section 2.1), the network and origin-destination matrix (section 2.2), and the considered routing strategies (section 2.3). The full paper will provide more detail in each of these sections.

2.1 Traffic flow model

For this study we use a cell transmission model Daganzo (1994) to generate the ground truth data. In this simulation we guide the traffic according to different routing schemes (see section 2.3). The nodes are modeled according to the model of Tampère et al. (2011). This means that in congestion, the supply will be divided over the inlinks proportionally to the capacity.

2.2 Network and OD

For the network we use a regular grid network with periodic boundary conditions, similar to the setup in Knoop et al. (in print). We have 19 randomly chosen nodes in the network which act as origin and destination. From the origins is prioritized over flow from other links at the (origin) nodes. This resembles the fact that there is a very high inflow capacity to the network from parking spaces at the sides of the roads.

2.3 Routing strategies

For the routing strategies, we split the network into subnetworks of blocks of size nxn. We compare the routing strategies as summarized in table 1.

Briefly, there are 4 strategies. In the first one, routes are fixed to the (stochastically determined) shortest path in distance. This will lead to congestion. In all other routing strategies, drivers will adapt their routes en-route based on congestion. In the second routing alternative, traffic will use speed information on all links to find the fastest route. The third routing strategy, the same strategy as described in Knoop et al. (in print), uses the accumulation in an areas and from this accumulation, using the NFD, speed is calculated. This is assumed to be the average speed for all links in the area. Drivers are

Table 1: The compared routing strategies

Type	Dynamic	Shortest...	Aggregation	type of info
Fixed	No	...distance	None	Distances
Speed	Yes	...time	None	Distances and speeds at all locations
Accumulation	Yes	...time	Subnetwork	Accumulation in an area
Area state	Yes	...time	Subnetwork	Accumulation and variation in density in an area

routed over the fastest route in time. Finally, the fourth routing strategy estimates the speed in an area based on the accumulation and the spatial variation in density. This is of particular interest since it will show the added value of estimating the inhomogeneity in the area. Also in this routing strategy, the same speed is assumed for all links in the area.

3 Expected results and outlook

It can be expected that the routing strategy with full information will give the least delays. However, an early application of a routing scheme using only aggregated data and getting the area speed from the NFD already showed promising results. Including the spatial variability of the density in the area as explanatory variable as well can potentially lead to a major improvement on the network performance, because this spatial variability has a very large effect on the production, and thus speed. The full paper will show to which extent this additional data will improve the routing strategies. It will also comment on the feasibility to collect the data.

References

C. F. Daganzo. The Cell Transmission Model: a Dynamic Representation of Highway Traffic Consistent With the Hydrodynamic Theory. *Transportation research part B*, 28B(4):269–287, 1994.

N. Geroliminis and C. F. Daganzo. Existence of urban-scale macroscopic fundamental diagrams: Some experimental findings. *Transportation Research Part B: Methodological*, 42(9):759–770, 2008.

V.L. Knoop and S.P. Hoogendoorn. *Proceedings of Traffic and Grannular Flow 2011*, chapter Two-Variable Macropscopic Fundamental Diagrams for Traffic Networks. in print.

V.L. Knoop, J.W.C. Van Lint, and S.P. Hoogendoorn. Route advice and its effect on the marcoscopic fundamental diagram. *Transportation Research Records*, in print.

C.M.J. Tampère, R. Corthout, D. Cattrysse, and L.H. Immers. A generic class of first order node models for dynamic macroscopic simulation of traffic flows. *Transportation Research Part B*, 45:289–309, 2011.