Title **An extended fluid-dynamic model for urban-scale traffic analysis**

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Fluid dynamic models are capable of describing traffic-flow along road sections. We extend these models to analyze urban traffic dynamics. In particular, we introduce various techniques to model various scenarios by a fluid-dynamic simulation approach. We will first focus on the study of a single traffic intersection with uniform arrival flows, and optimize the traffic light control with two green phases for various goal functions including the average travel times, the average queue lengths, and the cumulative waiting times.

For all considered optimizations, we derive different operation regimes of traffic signals.

Second, we investigate the existence of a macroscopic relation between the average flow and vehicle density in urban networks (Macroscopic fundamental diagram). To this aim, we introduce innovative modeling techniques, namely a macroscopic flow quantization, a memory-less traffic flow routing. Our routing

method does not require origin–destination tables and complicated routing decisions or route assignment, which are necessary in most urban micro-simulation models. In addition, by applying the flow quantization, we are able to reproduce a realistic variability of network flows even for the same average car density. Moreover, we discover the variability as a key variable of urban traffic flows, which reveals clear functional relationships rather than producing large data clouds for congested traffic.

We observe that for the same average density of vehicles in the network and the same assumptions regarding the origin– destination flows, there is a wide variation of possible average network flows, potentially even ranging from free flow to gridlock. A key component in all cases is the spatial variability of congestion at a specific time, as expressed by the standard deviation of density among all links. Although in this study, we simulated traffic flow in a Manhattan-like urban road-network, the introduced techniques can be applied to simulate traffic on any network topology and congestion scenario.