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A new node model based on CTM-UT with capacity determination

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Abstract

Despite the results obtained in literature to improve the macroscopic node model it is necessary to consider a general node model approach. A general node approach could take into account different aspects about conflicts at intersections. In this paper, we present a new node model based on CTM to represent traffic flows that crosses signalized and unsignalized intersections. It allows to model complex intersections for urban contest. In particular, to represent different turn movements of the inflow at intersection and belonging at the same lane, the model introduces a new variable. It is utilized to represent the percentages of different turns. The model takes into account also the estimation of the merge flows at the intersection. We present a new model to compute the minor streams that are limited by major stream on unsignalized intersections. This model reduces the problems and the complexities of the capacity determination (based on gap acceptance) and it could be used for dynamic traffic assignment. Our model could be used also for complex signalized intersection, where many conflicts among through flows are presented.

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Keywords: Intersection modeling, Cell transmission model, Urban traffic, Macroscopic simulation

1. Introduction and State of Art

In the last years the complexity of the urban network and the randomness of the traffic demand has made reliable prediction of travel time on urban networks, a research area that still requires significant development. Research

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studies have confirmed that the traffic simulation techniques are among the few ones able to predict urban traffic travel time at the network level. The macroscopic model, one of principal models among those existing, permits to apply a large number of mathematical programming algorithms, but on the other hand, the accuracy in the representation of traffic, its most important benefit, comes to be sacrificed.

In the study by Kang (2000) there is a categorization of traffic flows. The author defines the traffic flow as uninterrupted and interrupted. The first one defines the flow category where the only interaction is among vehicles belonging to the same flow (e.g. highway and freeway flows). Interrupted flow defines a category of traffic facilities having traffic signals, 'stop' signs and other types of control devices which influence the progression of vehicles along the section. The flow can be obstructed by interaction among vehicles belonging to the same flow, interactions among flows or by traffic control. The travel time for interrupted flow is primarily influenced by the waiting time at the intersections. The interrupted flow provides for two different types of intersections, non-signalized and signalized, depending on the type of traffic regulation. The through time of non-signalized intersection depends on the probability for a driver to have enough space between vehicles on the conflicting streams to pass the intersection safely. Instead, the through time for the second type is determined by the traffic light cycle time.

The urban traffic is strongly conditioned by signalized intersections. For this reason, intersection modeling can improve the representation of traffic on the road network. In order to provide a correct model of traffic when crossing an intersection, it is necessary to prevent the mistakes of representing various movements that occupy the same physical space and to consider the complex interactions among movements in the intersection model. In literature there are several methods to improve the macroscopic node model. The models of Elloumi et al. (1994) , Buisson et al.(1996), Lebacque et al.(2002) , Hilliges and Weidlich (1995) present different approaches to model urban intersection (overlapping cells, exchange zones or pointwise model), but they don't take into account the interaction of traffic flows, consequently overestimating the value of inflow and outflow at intersections. Van Hinsbergen (2008) proposes an adapted Godunov scheme to model intersection delays. The model defines a turn capacity at the intersections in function of the conflicting demands. To represent the reduction of traffic flow from signaling and conflicts at intersection Rouphail et al. (1989) and Troutbeck and Brilon (1999) have presented node models with supply constraints, for signalized and unsignalized intersections, respectively.

To model the traffic on multi-lane intersections it is important to take into account the queue propagation and the delay. In Ngoduy (2006), to improve the accuracy of the macroscopic model, the author defines a discontinuity modeling for multiclass multilane traffic flow operations. In particular, in this study is proposed a model intersection where the inflows and outflows are determined based on a gap-acceptance model.

In this article we present a new node model able to represent, different turn movements of the inflow at intersection and belonging at the same lane, respecting supply and demand constraints of the node. We also propose a new formulation to estimate the flow capacity at intersection. It is based on gap-acceptance model and it is included as an eventual flow constraint in node model of the CTM-UT. Our idea is based on the following papers.

The paper by Troutbeck and Kako (1999) presents a gap acceptance model based on limited priority for the major stream. It models the traffic on unsignalized intersections under congested conditions. The case of study in Troutbeck and Kako (1999) shows that for congested traffic condition, is not appropriate to define a distribution of the available downstream supply (over the incoming links) based only on priority rules.

Brilon and Wu (2001) present an approach to the determination of capacities at unsignalized intersections based on the additive conflict flow (ACF) method (originate from conflict theory). The method can be used to define node supply constraints, for conflict point of crossing flows or merging flows, Brilon and Wu (2001) present a simplified model respect to the theoretical method of gap acceptance, that is unrealistic for some conditions Jin and Zhang (2003) and Ni and Leonard (2005) propose an extension of the merge model by Daganzo (1994-1995). The first paper presents a simple distribution scheme that satisfies the "fairness" condition, in which the distribution of upstream flow is proportional to its demand, while, the second one, proposes a distribution of upstream flow proportional to its capacity. Tampere et al. (2011) present a generic class of first order macroscopic node models (GNM), satisfying the dynamic macroscopic requirements to realistically represent flow at signalized and unsignalized intersections. The GNM can define supply constraints for interaction rule and node, the first defines up- and downstream link boundary constraints (i.e. how limiting supply is distributed over the competing flows and how supply constraints interact with each other and with the flows over the node), while the second defines internal node constraints (as different flows that use some shared part of the internal node infrastructure with limited capacity). Relying on GNM, Flötteröd and Rohde (2011) formulate an incremental node model for general road intersections to represent the flow conflicts adequately. The classic continuity equation for flow conservation plays a