

# The Anisotropic Mesoscopic Simulation Model on the Interrupted Highway Facilities

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In the recent years, the mesoscopic traffic simulation models have received increasing attention due to their applications in the areas of simulation-based dynamic traffic assignment (DTA) as well as large-scale mass evacuation simulation modeling. The literature about mesoscopic traffic model is however relatively limited comparing with traffic models with different temporal resolution or modeling characteristics (e.g. continuum hydrodynamic model or microscopic traffic simulation models). The definition of mesoscopic modeling also differs widely in modeling concepts and techniques in literature.

One of the discussed mesoscopic modeling paradigm is the link-based queue-server models that explicitly represent individual vehicles on a link. During each simulation interval, vehicles are moved according to a user-defined macroscopic speed-density ( $v-k$ ) relationship, with a queue-server at the nodes accounting for delays caused by traffic signals, downstream capacity limits and interaction with additional traffic. Examples of such models are the traffic flow models in DYNASMART (Jayakrishnan, Mahmassani et al., 1994), DynaMIT (Ben-Akvia, Bierlaire et al., 1998), FASTLANE (Gawron, 1998), DYNAMEQ (Mahut, Florian et al., 2002) and MEZZO (Burghout, 2004; Burghout, 2005). Explicit representation of individual vehicles allows various decision rules vis-à-vis route, departure time and mode choices to be applied to individual motorists/vehicles.

Some of these models move vehicles according to the density of the entire or vehicle moving part of the link, implying the violation of the fundamental anisotropic property of traffic flows (Daganzo, 1995; Zhang, 2001). This violation could be of particular concern under situations when vehicles are simulated on a long link, particularly due to vehicles entering a link, as they create an infinite-speed forward-moving shockwave which influence the vehicles in front/ahead. Not preserving the anisotropic property can create prolonged delays when traffic in front/ahead needs to be discharged from fully queued links caused by a signal or a temporary roadway blockage. In effect, leading vehicles move at unrealistically slow speeds after the capacity restoration, due to increased link density triggered by the increased net link influx.

A new mesoscopic modeling concept that departs from the typical link-based queue-server model, called the Anisotropic Mesoscopic Simulation (AMS) model, was previously proposed (Chiu and Zhou, 2006; Chiu, 2007; Chiu, 2007; Chiu and Song, 2007). The AMS model is built upon an intuitive

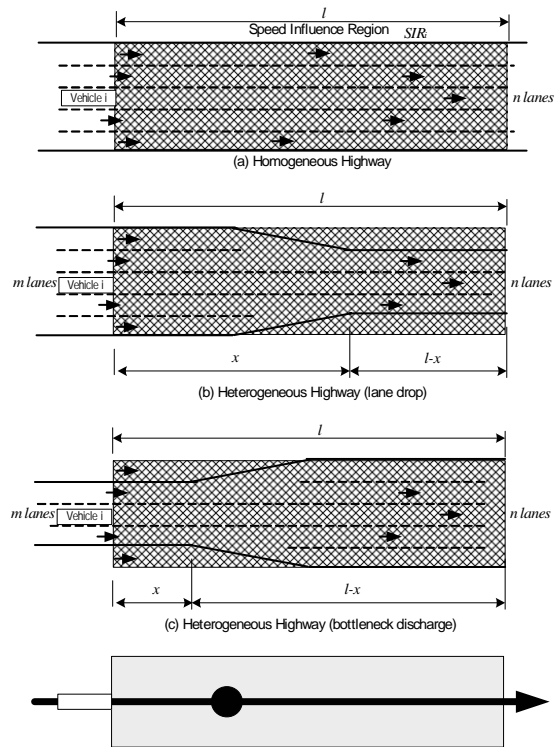


Figure 1

concept that at any time, a vehicle's prevailing speed is affected only by vehicles in front/ahead of it, including those in the (immediate) adjacent lanes. In other words, for any vehicle  $i$ , only those leading vehicles (in the same lane or in the adjacent lanes) present in vehicle  $i$ 's immediate downstream and within a certain distance are considered to be influential to vehicle  $i$ 's speed response. This is of similar concept to stimulus-response type of car-following models with the difference that the stimulus of a vehicle's speed response is represented in a macroscopic form. As shown in Figure 1, for the modeling purpose, the *Speed Influencing Region* for vehicle  $i$  ( $SIR_i$ ) is defined as vehicle  $i$ 's immediate downstream roadway section in which the stimulus is significant enough to influence vehicle  $i$ 's speed response. The prevailing speed of vehicle  $i$  is determined by using a macroscopic  $v$ - $k$  relationship based on the density in  $SIR_i$ . Every vehicle retains its own speed according to traffic conditions in front/ahead.

In the previously reported publication (Chiu, 2007; Chiu, 2007), the analytical (e.g. compliance of LWR models and shockwaves) and numerical properties of AMS as applied on the uninterrupted flow facilities (e.g. mainly freeway or highways without signals) have been discussed in details. Figure 2 depicts the space-time trajectories of AMS simulated vehicles on a freeway segment with bottleneck and temporarily closure. The trajectory information clearly illustrates that AMS exhibits important fundamental traffic flow properties in characteristics, shockwaves and merging flows. Field collected data (e.g. NGSIM) were also used to calibrate the model. Satisfactory calibration results have been obtained in these studies (Chiu, 2007; Chiu and Song, 2007).

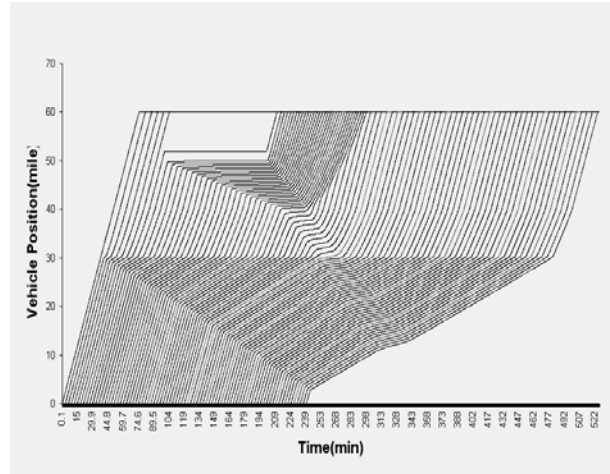


Figure 2 AMS vehicle trajectories

This submitted abstract briefly discusses a research focusing on extending the AMS modeling to the interrupted flow facilities (e.g. signalized intersections). Denoted as AMS-I, the AMS-I model addresses the driver's acceleration and deceleration dynamic upon approaching the intersection based on the signal indication, intended turning movements and geometric configuration such as turn bays. The lane groups are structured in a manner that left turning vehicles are on the left lane group, through turning vehicles are in the middle lane group and finally right turning vehicles are in the right lane group. There is also a notion of on/off ramps which are associated with each of the lane groups. This differentiation allows for flexibility in the model to account for spillback from left/right turning bays, freeway off/on ramps as well as ensuring that vehicles located in turning bays do not artificially impede through traffic as typical link-based queue-server models would.

The general modeling Equation for the AMS-I model is shown in Equations (1) and (2). For vehicles receiving the right-of-way to traverse through the intersection during the simulation interval, the vehicle will travel at a turning movement based target minimal speed  $v_{tg}$ . The corresponding target maximum density is then adjusted to  $k_{tg} = \phi^{-1} : \rightarrow \phi = v_{tg}$  to ensure that vehicles are reducing to the target speed when traversing the intersection. For vehicles to be stopped at the intersection, the target speed is set to zero and the same Equations (1) and (2) apply.

$$k_i^{t-1} = \min \left[ k_{tg}, \frac{N_i^{t-1}}{mx + 0(l-x)} \right] \quad (1)$$

$$k_{tg} = \wp^{-1} \Rightarrow \wp = v_{tg} \quad (2)$$

Furthermore, the temporal scalability of the model is discussed in this paper. The temporal scalability of AMS-I is derived by allowing flexibility in the temporal resolution by allowing time step size to range from 0.1 to 10 seconds. This is feasible because of the unique SIR length-density concept of the model. This is accomplished by utilizing a SIR length-density function which is dependent on time and vehicle speed. This overcomes issues associated with constant SIR lengths in which vehicles can jump over signals (flow interruptions) at larger time-step resolutions since a constant SIR length may not be long enough to capture the interaction of the vehicle and the signal when the vehicle speed is high and the time-step is relatively long. Further, since this flexibility can be controlled by vehicle, it is feasible to model different sections of the model at varying resolutions. One can control the time-step resolution by link in order to have higher fidelity of traffic flow, emulating a microscopic model, in certain areas of a large-scale model. Other challenges that are addressed are the definition of dilemma zone and the how events are handled within the simulation logic as vehicles approach the flow-interrupters.

In conclusion, the AMS-I models offers a technically sound, computationally efficient traffic flow model. Its flexibility in assigning varying time-step sizes, its handling of spatial generalization of the network as well as its foundation on proven traffic flow models makes this a viable and attractive alternative. A description of the AMS-I implementation into the MALTA simulation assignment system, results and discussion will be also included in the paper.

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