Traffic Smoothness for ITS

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The smooth traffic flow, which refers to the stochastically stabilized flow (ie. flow without disruption, that prevents the acceptance of a specific probability distribution of the headways), in the queuing model with moving buffer, can be described using the maximum density referring to the smooth flow.

Keywords: Expected traffic smoothness ; ITS ; Intelligent transportation systems

1. Introduction

In smooth flow vehicles ride with the speed with no additional delays (no waiting time), and with the same intensity of vehicles by all minimal distances that are components of path of the smooth flow. The density stands for the jam density and therefore is length of elementary segments of the road, as described for example in the queuing model with moving buffer. Thus is the maximal number of vehicles forming smooth flow. The gap between vehicles in smooth traffic flow — taking place on the road consisting of distances — is dependent on the expected (mean) speed of free traffic flow and shall take into consideration the safety distance (safe gap), mapped by shifting the exponential distribution of headways on the road. Such mapping is also related to the fact that in description of the traffic flows of high density the small variances of gaps are taken into account. In addition, in dense traffic flows a minimal safety distance (safe gap) is relatively small, with the result that the probability of disruption—in the form of sudden deceleration (stop) of vehicles—increases. Therefore, the probability (risk) of the formation of queues of vehicles is growing. [1]

Intelligent Transportation Systems (ITS) are interrelated systems that work together to deliver transportation ITS services [2]. An ITS architecture defines a framework within which ITS systems can be built, and the information that is exchanged between elements of ITS systems, as [3]:

- the functions that are required for ITS,
- the physical entities or subsystems where these functions reside (e.g., the field or the vehicle),
- the information flows and data flows that connect these functions and physical subsystems together into an integrated system.

Mentioning above ITS systems offer the potential to improve smoothness of traffic flows, by means of the user services grouped in service packages [4]. Therefore for modelling of expected traffic smoothness that takes into account ITS user services and services packages the specific description of ITS systems is required.

The average delays—which correspond to the traffic flow passing through the elements of transportation network—are closely dependent on the speed, density, and intensity both of the analyzed traffic flow and of other flows in the network - flows interact at each elementary node. It should also be noted that the values of these three fundamental characteristics of traffic flow for each elementary node may be different. Average delay which corresponds to the passing of the traffic flow through any elementary node by applying package of the ITS services, is dependent on traffic conditions in the node. [1]

2. Smoothness and the Intensity of Traffic Flows

Determination of the relationship between the smoothness and the intensity of traffic flows leads to the optimization problem of traffic assignment in the transportation network. According to the optimal traffic assignment in the transportation network is conditioned by optimization of traffic assignment in each elementary node of the network. Only the analysis of elementary traffic conflicts in the nodes provides an accurate assessment of the smoothness of traffic flows. Disruptions of the smoothness of the traffic flows usually occur in the critical nodes. So, on the one hand disturbed traffic flow indicates the location of the greatest potential benefits from the improvement of traffic assignment, and on the other – the structure of the queues in the complex critical nodes maps the reserve capacity in their elementary nodes. This allows for such selection of the package of the ITS services, that leads to the optimal variant of the traffic assignment.[1]

The permanent small disruptions are the results of very high density of traffic flow. They are caused by gaps between vehicles that are close to minimal distances (minimal gaps) - the variation of the gaps is equal to or close to zero. In such situation the high probability (risk) of the formation of queues is caused by delayed reaction of human-vehicle system. The probability of disruption, resulting in the queues of vehicles, increases nonlinearly with increasing of the intensity and of the density of the traffic flows. In a similar way, the waiting time in the queue of vehicles is increasing, if such disruption has occurred. In addition, the smaller the conditional capacity is—and thus the smaller optimal intensity, due to the low level of smoothness of traffic flows—the faster the waiting time in the queue due to disruption is growing. Therefore the optimal intensities for the individual network elements are not equal to their capacities - they are smaller. This follows from the fact that the intensity of the traffic flow equal capacity of the node occurs when all vehicles are moving in the states close to the saturation states with very limited levels of service, and thus the function of the expected smoothness of traffic flow reaches zero - no vehicle is moving freely.[1]

The assumptions about the smoothness of traffic flow, may be supplemented by the postulated way of describing the traffic conditions in congested transportation networks. In such networks, with dense traffic flows and a high risk of the disruption (even in the form of a short queue of vehicles) the probability of such an incident seems to be a better measure of the probabilistic description of the capacity constraints than the expected waiting time in the queue, because the probability takes into account the risk of delay in the traffic flow from the point of view of the person that plans a trip.[1]

That is particularly important in congested networks, in which a high probability of queues is most often associated with high expected value of extension of travel time - as a result of the high risk of the large number of secondary disruptions and queues because of a sequence of following forms of congestion: the single interaction -> the multiple interaction -> bottleneck -> triggerneck -> gridlock.[1]

References

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