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# Conception of effective number of lanes as basis of traffic optimization

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Abstract

This article describes the methods of mathematical modeling and simulation of processes of local interaction in transport systems. Described transport flow models, developed by the author, based on extension of the microscopic Treiber's model and on the queuing theory. These models cover more details of behavior of flow participants on signal-controlled crossroads. modification. The article describes a model of traffic on the ring road.

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## 1. Microscopic model of traffic

The appearance of computers has allowed to produce complex numerical experiments using the imitating modeling of process and has become possible to consider random nature of traffic flow. Modelling is commonly used in cases where studied systems can not be analyzed by direct or formal analytical methods. In microscopic models each vehicle is considered as a separate element of the transport system. It is assumed that the acceleration of the vehicle depends on the neighboring vehicles. The greatest influence on the behavior of the driver has the vehicle situated ahead, «the leader».

The authors developed a microscopic model of traffic flow, extends existing Treiber's «Intellect Driver Model» [1] in case of multilane roads and signal-controlled road intersections. In this model each car have a desired speed in the range $0 \dots V_{max}$, value $d$ — is the distance between the current vehicle and the next vehicle in front of it, $V_n$ — speed of the current vehicle. Update rules are set by Treiber's model. Treiber's model was extended to the two-dimensional case by introducing the probability characteristics

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of possibility of lane change and necessity of this action, which allowed to consider the behavior of vehicles when turning at a crossroads.

For the considered model was developed complex computer programs BTS SIM, which perform a series of numerical experiments. The microscopic model was used to solve the problem of movement of vehicles on the signal-controlled road intersections. Consider the motion of vehicles at crossroad with predetermined heterogeneous multi-purpose flows. we calculated the optimal duration of the phases of traffic light mode on the grid of values for maximum throughput at crossroad with given intensity of flows at each direction. The resulting phase distribution were tested for resistance to small changes in the input flow rates from the various directions that showed the possibility of working with inexact data.

Let us introduce the concept of «effective number of lanes» which can be illustrated by the following example. Suppose that the vehicle flow, moving along six-lane road arrived to a three-way road intersection (T junction). Assume that the goal of the third of drivers is turning to the left, and the aim of of other is going straight.

In this case, the two leftmost lanes will take vehicles whose goal is to turn left. Thus, at the moment the green light is on for forward movement, the flow of vehicles won't be maximum for the given number of lanes as we might expect, but less by one third, meaning not six thousand but four thousand vehicles per hour.

Let us state the following lemma:

Lemma on the equilibrium maximum capacity on the signal-controlled road intersection. Consider controlled multilane intersection with Poisson traffic. Consider the flow of cars from one direction at a fixed traffic light phase. Let $N$ — number of incoming lanes, $N_i$ — number of lanes at target road $i$, $S$ — maximum capacity per lane , $\Omega_i(t)$ — vehicle queue from incoming road to the direction $i$ at time $t$ , $\Omega(t)$ — vehicle queue at incoming road at time $t$, $\Omega_a(t)$ — vehicle queue from incoming road, which can continue their motion to the direction $i$ on current phase at time $t$. Then expectation of equilibrium maximum capacity on the signal-controlled road intersection on this phase in time T is:

$$E[S_{max} \cdot T] = \int_0^T min(S \cdot N \cdot \frac{\Omega_a(t)}{\Omega(t)}, \sum_i S \cdot N_i \cdot \frac{\Omega_i(t)}{\Omega(t)})dt.$$

Because of this lemma it was obtained the following consequence:

Corollary of effective number of lanes in the absence of asymmetry queues. Consider controlled multilane intersection with Poisson traffic. Consider the flow of cars from one direction at a fixed traffic light phase. Suppose there is no queue at initial time on the crossroad.

Let $q$ to be intensity of the incoming traffic, $k$ — total intensity of vehicles from the incoming traffic, which can continue their motion on current phase, $S$ — maximum capacity per lane, $N$ — number of incoming lanes, $N_i$ — number of lanes at target road $i$, $k_i$ — total intensity of vehicles from the incoming traffic, which can continue their motion to the direction $i$ on current phase.

Then expectation of equilibrium maximum capacity on the signal-controlled road intersection on this phase is:

$$E[S_{max}] = \min\left(S \cdot N \cdot \frac{k}{q}, \sum_i S \cdot N_i \cdot \frac{k_i}{q}\right).$$

To solve the problem of searching for the expected delay occurring at overcoming of signal-controlled road intersection with a fixed duration phases queuing theory has been applied.

Let's introduce the following abbreviations and symbols: