ANALYSIS AND VALIDATION OF VARIABLE MESSAGE SIGNS USING CELLULAR AUTOMATON TRAFFIC SIMULATIONS

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1 INTRODUCTION

In recent years the existing road network is no longer able to cope the growing traffic demand in many regions all over the world. Since the construction of new roads is often socially untenable, there is a seek to use the existing infrastructure more efficiently.

A possibility to improve the capacity of the freeway network is to control the traffic using Variable Message Signs (VMS) (Keller94). They can automatically display, e.g. an appropriate speed limit using the measured actual traffic state (for an overview see Papageorgiou00). One crucial point of all automatic traffic control systems is the optimisation of their infrastructure and control algorithms (Bonsall97).

In this contribution an algorithm for optimising VMS using a microscopic traffic simulation based on a cellular automaton is proposed. The benefit of simulations is the possibility to investigate implementations of many different constructional modifications fast and cost-efficiently.

This method is applied to the Variable Message Signs on the freeway A57 in North Rhine-Westphalia, Germany. Real data are provided from 83 loop detectors which measure among others flow and speed data. They are arranged in 39 cross sections that are placed on all lanes in each direction. Every cross section of loop detectors provides traffic data for one of the 27 VMS. For the analysis traffic and control data between October 10th, 2000 and March 24th, 2001 are used.

2 DATA ANALYSIS

One of the biggest problems of VMS is the lack of acceptance by the drivers. This is due to a high frequency of signs requesting drivers to change speed as often as every two minutes. Through statistical examination, it is shown that the mean time of appearance of the same sign is very short (about 4.4 minutes). At times the signs switch as often as 40 times per hour. The reason for this is the algorithm used that responds very sensitively to fluctuations in the traffic data.

Another question is the spatial relationship between the measuring point and the corresponding display. An analysis of the current situation shows the lack of a thorough concept when the system was installed. On the average the measuring points are placed 528 m downstream from the display. But there is a large variance. One loop detector section is, e.g. upstream the corresponding VMS and about half of VMS are assigned to two sections.
In Fig. 1 (a) the fundamental diagram of one day is shown exemplary. The data points lie in two regions that can be approximated with zero lines. The lines indicate free traffic flow and their slope corresponds to the maximum velocity of the vehicles. Beyond these lines other traffic states (e.g. congestion) appear (for a detailed discussion of the relationship between traffic phases and fundamental diagrams see, e.g. Kerner99).
A more restrictive speed limit shifts the maximum of the lines and a congestion occurs at higher densities. This is the reason why a congestion is preventable by a speed limit. Otherwise large variances indicate that the present solution is far away from the optimum (cf. Fig. 1 (b)).

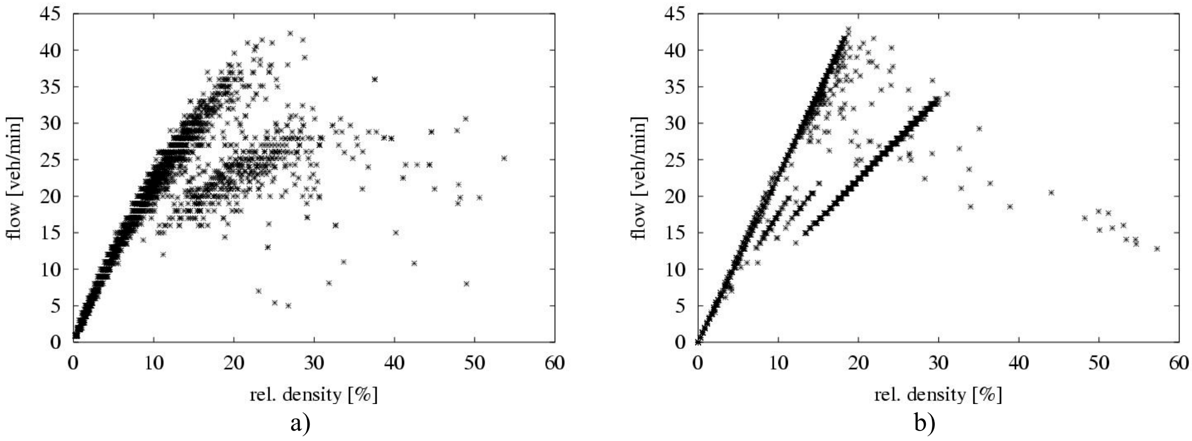

Figure 1: Local fundamental diagrams of a single loop detector on the right lane. (a) Measured data of January 8th, 2001. A relative density more than 15% leads to two regions indicating different velocities. (b) Results of an idealised simulation. You can see the lines with a maximum velocity (162 km/h) and with different additional speed limits (120, 100, 80 km/h).

3 SIMULATION

In general, traffic simulators are used to simulate traffic on various spatial and temporal scales. However, for the simulation of freeway traffic a few basic requirements have to be fulfilled. In several previous papers it has been pointed out that discrete traffic models, especially cellular automata, are a promising concept for high-speed micro-simulations.
Given that the simulation has to provide the possibility to implement VMS, several models are tested to see if they provide correct results. Since the microscopic properties of the original cellular automaton model by Nagel and Schreckenberg (Nagel92) do not reproduce the properties of real traffic in the necessitative detail the analysis is based on models especially with finer discretisation (Knospe00). For modelling multi-lane traffic we

employed lane changing rules (Nagel97). Results of the simulation are shown in Fig. 1 (b). Note that an instant driver response to the speed limit is assumed.

4 RESULTS

With the help of the models, the impact of speed limits at different densities is investigated. In Fig. 2 (a) the influence of different constant speed limits is shown. Obviously there is a negative effect in areas of low densities. The free flow is disturbed. But with a growing density the speed limits prevent congestions and the flow is higher than in the reference simulation (zero line) without speed limits.

Using dynamic speed limits only one curve is obtained (Fig. 2 (b)). To get the optimal solution the strategy is to minimise the area under the zero line representing negative effects and maximising the area above the zero line representing positive effects. Thereby it is important to have practical aspects in mind regulating speed limits. In particular only a few discrete velocities can be displayed.

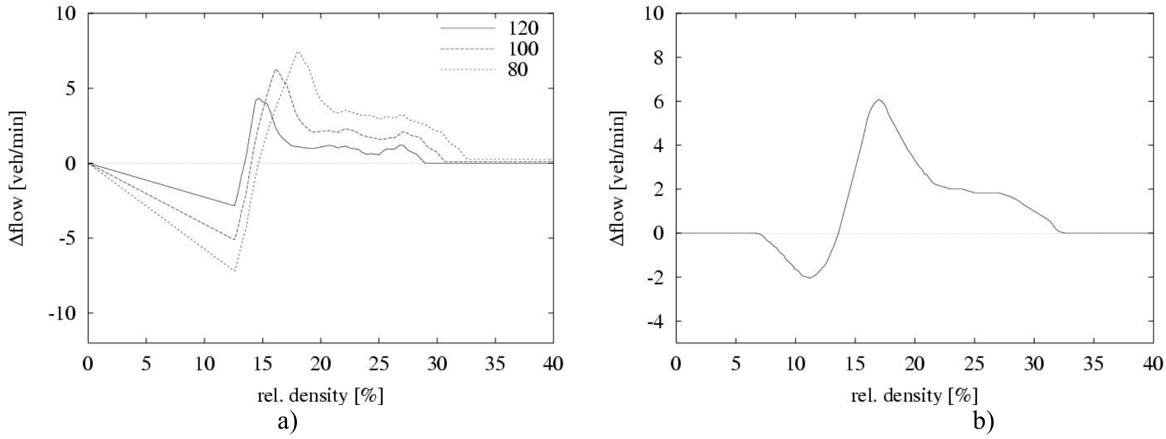

Figure 2: The difference between the traffic flow Δflow and a reference simulation without extra speed limits. (a) Each limit leads to a decreasing traffic flow in the range of low densities but with growing densities positive influence arises. The more restrictive the limit the higher is the influence. (b) With dynamic speed limits you obtain one curve.

Knowing this, the dependency of the traffic flow from the relative position of the loop detectors to the message signs is examined (Fig. 3). The simulations show the best results when the loop detectors are placed 816 m downstream of the signs, so that the driver passes the signs first and later reaches the detectors.

Furthermore, variations of the parameters used to control the VMS are surveyed. This shows that the parameters have a huge influence on the frequency of switching.

All these results are obtained assuming instant response of the drivers to the speed limits. Moreover, in reality the VMS operate with a time delay. For future estimations both effects have to be implemented enhancing the quality of the results.

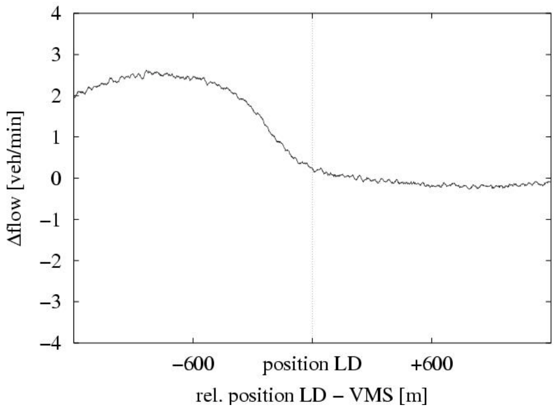

Figure 3: The increasing traffic flow depends strongly on the relative offset of the VMS to the corresponding loop detector. For an optimal effect the loop detector has to be about 816 meter downstream of the VMS.

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