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VISSIM: A microscopic Simulation Tool to Evaluate Actuated Signal Control including Bus Priority

1 Introduction

Vehicle or traffic actuated signal control strategies are well documented in the design manuals of various countries. However the efficiency of the different strategies can not be evaluated in real test sites. The variety of strategies itself and parameter settings of each single strategy can not be tested in field trials due to the vast number of possibilities, limitations of the present controllers, legal restrictions and acceptance by the users. Simulation has proven to be a valuable tool in case of such restrictions.

For economical as well as environmental reasons the signal control should be as good as possible within a given political framework. Tools are asked to evaluate the quality of vehicle actuated signal control. Because of the stochastic features of traffic no analytical formulae can be applied for this detailed evaluation. Sophisticated control strategies respond to single vehicles as it is for example required in bus/tram priority programs. These fluctuations in arrival times can not be modelled accurately enough by purely analytical methods.

VISSIM (german acronym for Traffic In Towns: SIMulation) is an innovative simulation tool for the design of traffic actuated control systems.

As a general purpose computer based traffic simulation system VISSIM models links, junctions and "small" networks at a high level of detail. However, this paper concentrates on the abilities of VISSIM as a simulation tool for signal control.

2 The simulation model

2.1 System architecture of VISSIM

The simulation system consists of two separate programs. The first program is the traffic flow model (the kernel of VISSIM), the second the signal control model. VISSIM is the master program which sends second by second detector values to the signal control program (slave). The signal control uses the detector values to decide the current signal aspects. VISSIM receives the signal aspects and the next iteration of traffic-flow starts. The simulation is microscopic (single vehicle modelling) and stochastic with fixed time-slices (1 second intervals). The result of the simulation is an online animation of the traffic flow and offline reports of travel time and waiting time distributions.

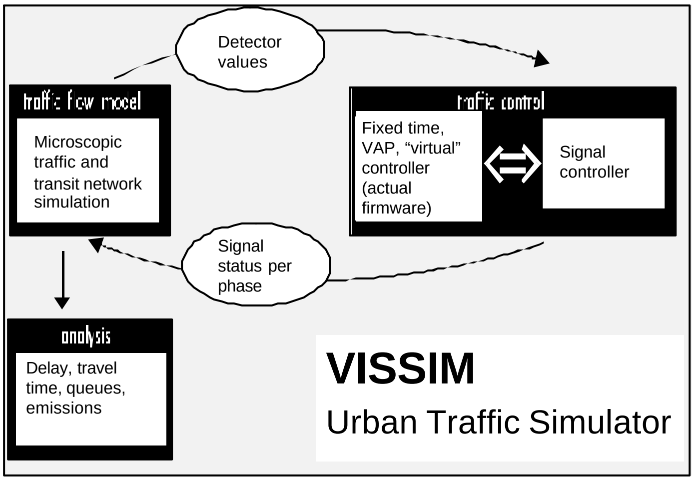


Fig.1 System architecture of VISSIM

The traffic flow model and the signal control communicate via standarized interfaces (i.e. DDE under MS-Windows respectively pipes under UNIX). Flexibility is the basic advantage of splitting the two tasks into two programs. As long as the signal control strategy is available as a C-program it can be implemented in VISSIM. Even if the signal control is only available on the controller as Assembler code, the whole controller can be joined with VISSIM. A hardware solution via serial RS-232 ports is then required.

2.2 The traffic flow model

The quality of a traffic simulation system depends highly on the quality of the traffic flow model at its core. The car-following and the lane-changing model are part of this kernel. The car-following model (also called spacing -model) describes the movement of a vehicle whose driver wants to drive faster than the present speed of the preceding vehicle. If more than one lane is available vehicles tend to overtake which is modelled in the lane-changing algorithm.

Instead of a deterministic car-following model VISSIM uses the psycho-physical model of WIEDEMANN (1974; see also LEUTZBACH/ WIEDEMANN, 1986; LEUTZBACH, 1988). FRITSCHE (1994) describes the same concept in a more recent paper. Perceptual thresholds are the basic idea of psycho-physical spacing models. A vehicle and its driver is linked as driver-vehicle-element (DVE). Figure 2 shows a faster vehicle (DVE_j) approaching a slower one. The DVE_j moves faster than the preceeding DVE_i. Driver *j* begins to decelerate until he reaches his individual threshold which is a function of speed difference and spacing. Since driver *j* is not able to perceive indefinete small speed differences and to control his speed sufficiently well enough, he will decelerate below the current speed of DVE_i. As *j* reaches the opposite threshold he will accelerate again. This results in a bunching effect which can be observed in various traffic conditions.

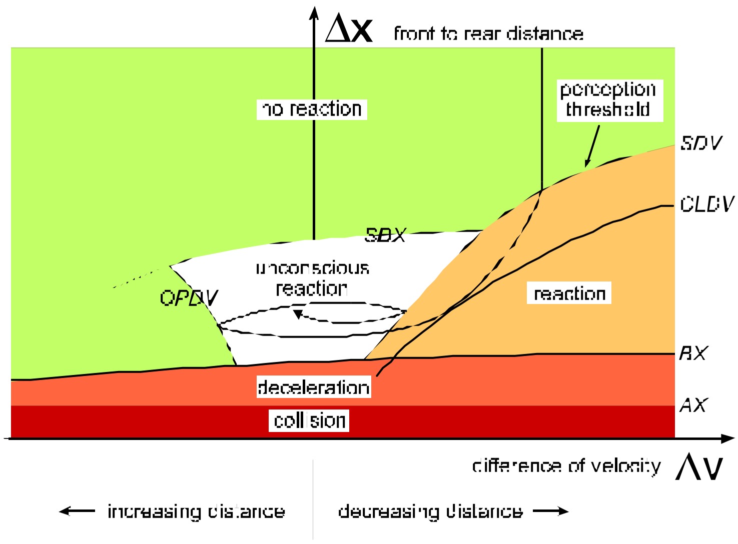


Fig.2: Car-following model by WIEDEMANN

The difficulty of such a psycho-physical model starts with the random distribution of the thresholds. Continous measurements of different traffic conditions on highways and urban streets are required to model the traffic in a realistic way, which is done at the University of Karlsruhe.

Complex set of rules are required to model the lane-changing behaviour which depends very much on the type of street. In Europe for example legally the near-side-lane on motorways has to be used as long as possible. On urban roads this rule is not valid since the next turning direction is one of the most important parameters for the decision on the choice of the present lane. If a faster DVE approaches a slower one on the same lane it checks if it could improve its position by changing to a neighboring lane. Doing so it respects up to six other vehicles at each second (Figure 3).

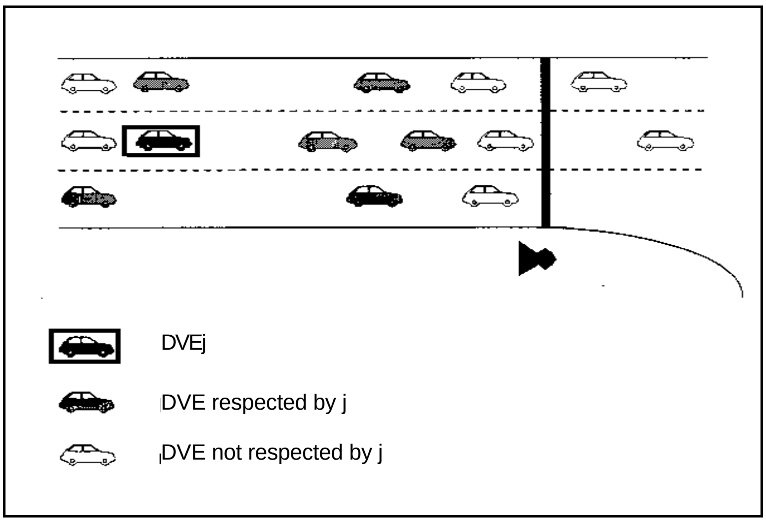


Fig.3 Each vehicle regards up to six neighboring vehicles

Each DVE can be characterized by a set of parameters describing the above mentioned traffic flow model. The values are randomly chosen out of user-defined distributions. The most important parameters of a DVE are classified into three groups as follows:

1. Technical description of a vehicle
   - vehicle length and type (car, truck, bus, tram, pedestrian)
   - maximum speed
   - maximum acceleration and deceleration as a function of speed
   - present position within the network
   - present vehicle speed and acceleration

2. Behaviour of a DVE
   - desired speed of the driver
   - perceptual threshold of the driver (ability to estimate differences in spacing and speed, desire of safety and perception of risk)
   - acceleration as a function of present speed and desired speed of the driver

3. Interaction between several DVE´s
   - Pointers to the DVE´s direct in front and rear on the same and the neighboring lanes
   - Pointers to the present link and the next intersection
   - Pointers to the next traffic light

2.3 Network of streets and lines

The basic element of the street network is a one or multilane link. The network is composed of links and its connectors. A connector can be placed on any position of a link. It can be valid for all vehicles, certain types (i.e. buses) or a set of vehicles (i.e. only right turning vehicles). Cross sections for turning decisions have to be placed. They become valid at the next possibility.

Signal control is modelled by placing the signal heads at the positions of the stop lines. The signal aspects are part of the underlying signal control strategy. Detectors measure the traffic for the signal control (i.e. gap, occupancy, presence) and they are used for microscopic and macroscopic measurements (i.e. speeds, volumes, travel times). The desired speed in urban areas does not derive directly from the technical data of a car but rather from the geometrical layout of the street and its junctions. Usually the desired speed is reduced around junctions. Semi-compatible movements are modelled via gap acceptance. The values of gap acceptance and waiting positions are user-definable.

A public transport route is defined as a sequence of stops along lines. The stops are either on the link or next to it.

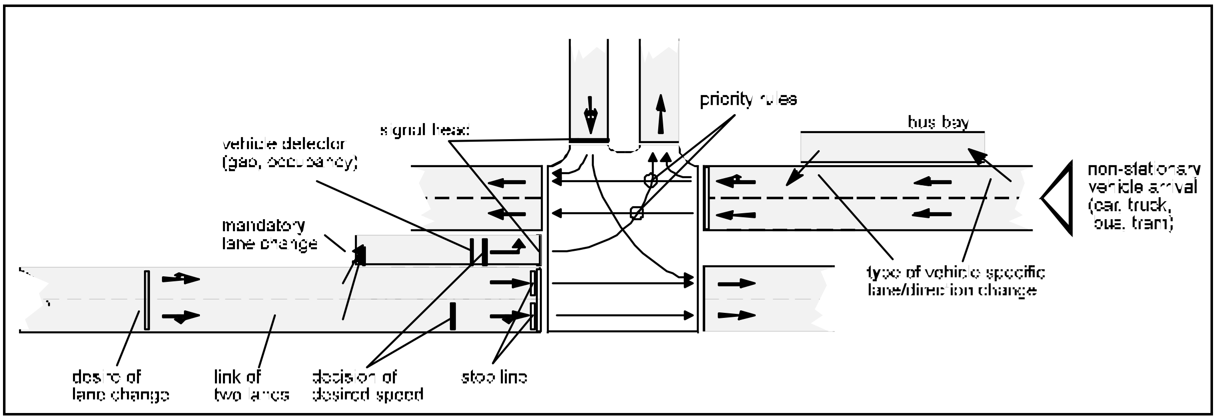


Fig.4 Junction being modelled by VISSIM

2.4 Vehicle arrivals

For every vehicle arriving at the entry points of the network, VISSIM has to generate the arrival time. The volumes at the entry points are user-definable. The arrival profile is entered as 5 or 15 min interval values. Within one time interval VISSIM assumes a POISSON arrival distribution. The following data can be entered:

- entry points,
- vehicle composition (car, trucks) of the streams,
- distribution of arrivals over time,
- time-table for bus and tram,
- bus and tram routes.

3 Examples

3.1 The control strategy VS-PLUS

VS-PLUS (KAUL, 1994) is a control strategy which is currently applied in Switzerland, Austria and Germany. VS-PLUS is taken as an example for VISSIM because of some of its remarkable features:

- Runs on controllers of different manufacturers because it is a separate capsulated C-program.
- Whole flow chart of the control strategy is entered by parameter values within tables. Once the engineer has learned the complete set of parameters he can easily design and more inportantly adjust existing VS-PLUS plans.
- Vehicle activation is based on vehicle streams which are controlled by signal groups (phases) instead of preset stages. Refer to SILCOCK (1990) for the additional flexibility gained.
- Group of parameters is reserved for detection and priorisation of public transport vehicles (i.e. several detection points along a link including continous comparison of present and expected arrival times by time table; rules of priority for conflicting public transport lines)

3.2 Evaluation of VS-PLUS using VISSIM

A rather complex example is choosen to present a typical application of VISSIM. Examples of this kind can be seen in most cities of Middle Europe as the priorisation programs for the public transport have been one of the major tasks in traffic engineering since the late 80´s.

A 2.5 km long arterial road had to be signalized with some contradictory restrictions. No bus or tram should wait at a traffic light unless they stopped at a stop light in front of a traffic light anyway**.** There are tram lines which cross each other. Overall arterial co-ordination for the car-traffic should be implemented. Each vehicle stream is controlled seperately. Compatible movements are not assembled to preset stages since this might reduce the flexibility of the timings. The intergreen times differ considerably.

Figure 5 shows the geometrical outline of the arterial road as it is modelled by VISSIM. The leftmost intersection of the arterial has even 6 arms. Note the two close junctions (80 m distance between) in the middle which are controlled by one controller (no. 145).

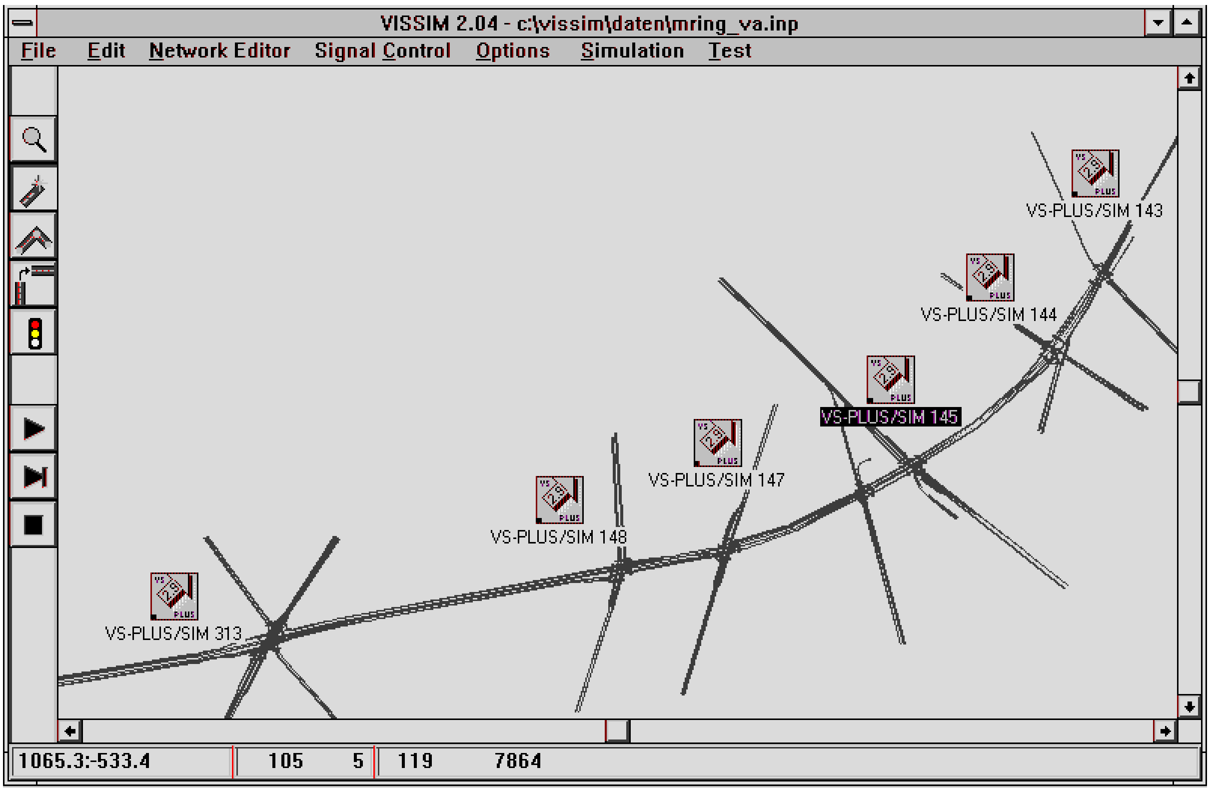


Fig. 5 Arterial road with 7 signal controlled junctions modelled by VISSIM

In Figure 6 node 145 is shown in detail. Additionally the positions of the vehicles after 425 seconds of simulation are shown. A tram (line 208 coming from north-east) is turning left, while a conflicting tram (line 101 going north-east) stops for boarding passengers. Below the animation the dynamic signal timing table over the past 150s is shown in another window. The dark rectangles (green) present the green times of the signal groups (here 18-26). Analysing the data of the right window a traffic engineer with VS-PLUS knowledge can find the cause of change in the signal aspects. This is important to adjust VS-PLUS parameters so that line 208 (group 26) receives green before line 101 (group 28). The parameters of this window differ while using other control stategies.

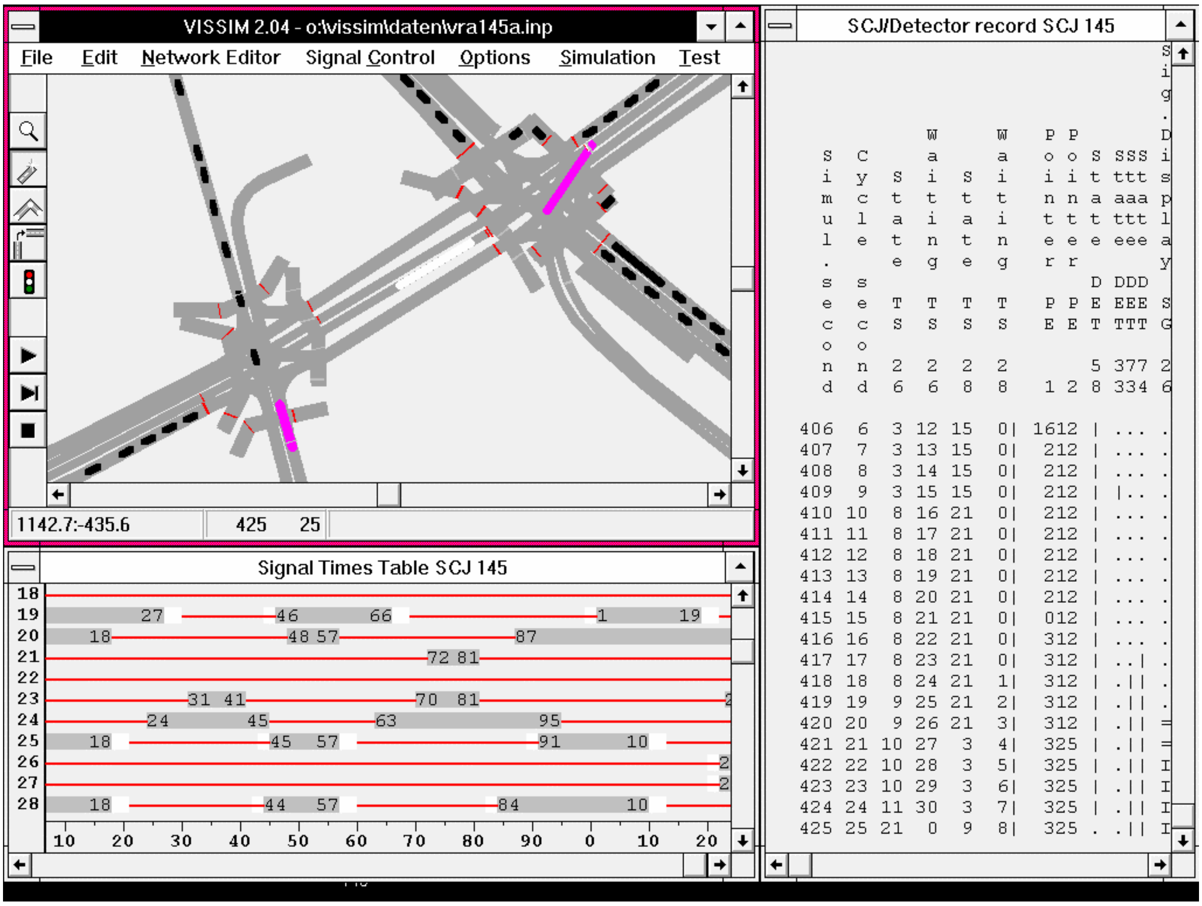


Fig. 6. Animation of traffic flow (node 145), the dynamic signal timing table and a listing of signal group and detector data (right) on one screen

3.3 Data analysis and reports

VISSIM offers a number of different graphical displays and numerical listings. First as seen above is the animation of the traffic flow. In Figure 7 the traffic situation of Figure 6 is shown in detail. The vehicles move on a scanned junction layout for more realistic representation. Current vehicle parameters are shown for two vehicles.

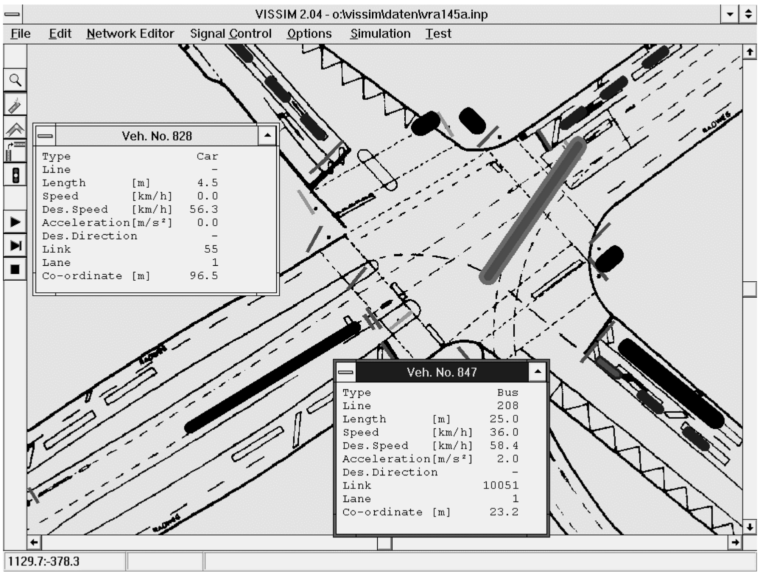


Fig. 7 Animation of vehicle movements on scanned layout map

Cross-sectional and link measurements are a rich source for analysis and comparison of different signal control settings. Cross-sectional analysis allows only pure local measurements like volume and velocity over time. Travel-time analysis is more helpful. Usually a pair of travel-time detectors are used: one before a stop line of a traffic light and one right after the junction. VISSIM measures the travel time of each vehicle for the section between the two detectors. The difference between unhindered movement and the travel time gives the waiting time. Travel times can be aggregated over user-definable intervals. Figure 8 shows the travel time distributions for three movements with an aggregation interval of 10 minutes.

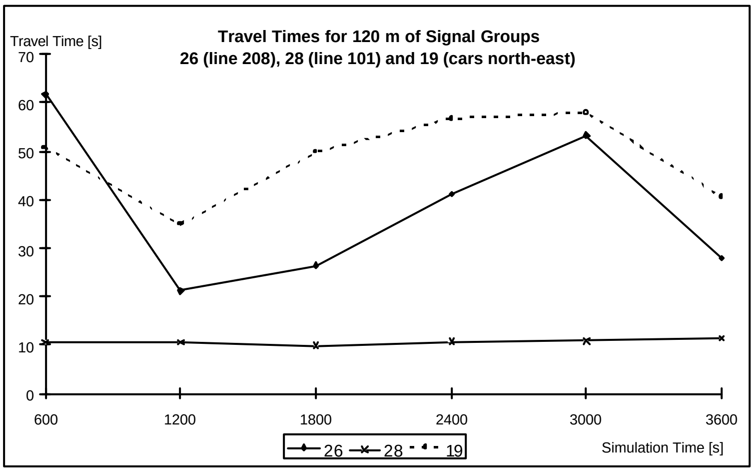


Fig. 8: Travel times for three movements each travel a section of 120 m

The variation of green times by volume is a useful statistic for the design of v.a. signal programs. In Figure 6 a dynamic signal time table was shown. These green times are also reported and are graphically represented as a histogramm of green times. When simulating one hour of traffic the green times for the signal groups 19, 26 and 28 are as shown in Figure 9. The green durations are classified into 5s intervals. If no green was given within one cycle the duration was 0s which occurs for trams if they do not appear during that cycle.

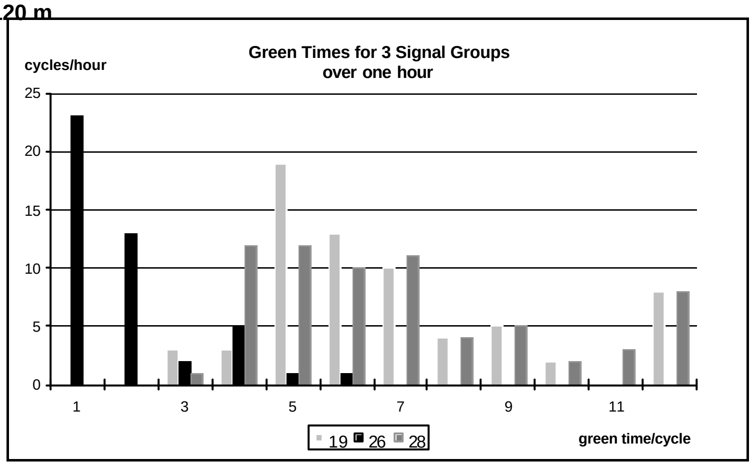
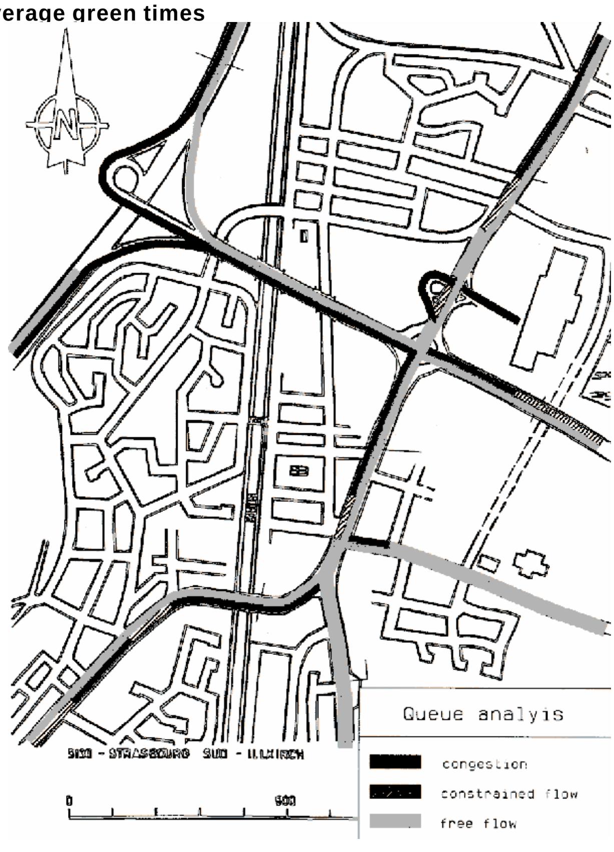


Fig. 9 Average green times

When analysing queuing the average speed on sections of a link is computed. The graphical representation is the queue-plot (Fig.10). The average speeds are classified into the categories *congestion*, *constrained* and *free flow traffic*. The classes are user-defined.



3.4 Other applications of VISSIM

In spite of its recent market-introduction, VISSIM already has been applied for a variety of complex traffic tasks. Some of the typical ones are:

- VISSIM calls **vehicle actuated signal control strategies** which are identical to the implementations in the controller. Besides testing with generated traffic flow one can test by manually initiating detectors. The triggering of the detectors is reported in macro files which can be used for running identical test situation with altered signal control prameters.
- VISSIM has been used with a **variety of control systems** like SDM (by SIEMENS documented in BÖTTGER; 1989 and HURRLE, 1993), TRENDS/TRELAN (WULFIUS, 1994), VS-PLUS and a general stage-based control strategy documented in the German guidelines (RILSA,1992). The later one works together with the traffic signed design and assessment program VISSIG.
- VISSIM has also been applied to **fixed time controlled networks** when the assesssment of queuing was a major problem. Time-space diagrams or macroscopic programs like TRANSYT have difficulties when the staging is rather complex and times of fully compatible and semi-compatible movements overlap.
- VISSIM models all kinds of **different junction layout** and control like signalized and non-signalized roundabouts and junctions.
- Because of the detailed modelling of **public transport** VISSIM was used to evaluate different stop layouts.

4 Conclusion

Vehicle actuated signal control is a growing market and there is certainly a need for better quality control strategies. Even if the first set of parameter values has been close to optimal continous adjustments are required as traffic flow and behaviour alters over years. Standarized control systems will be of increasing importance. Standarized systems can be tested with the traffic simulation system VISSIM via software interfaces. Using simulation helps to assess different vehicle actuated control strategies and ?these? parameter adjustment in the office rather than by field trials. It becomes more likely that the initial parameter setting do what the traffic engineer expects when releasing a new junction control. The traffic model of VISSIM provides a realistic representation of traffic flow of cars, trucks, buses and trams.

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