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Middelham, Frans; Taale, Henk

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THE APPLICATION OF ’FLEXSYT’ IN TRAFFIC MANAGEMENT SYSTEMS

Frans Middelham and Henk Taale
Ministry of Transport and Public Works
Transportation and Traffic Research Division
P.O.Box 1031, 3000 BA Rotterdam
The Netherlands

Introduction

The importance of traffic-management systems using on-line information to control traffic is rapidly growing. In The Netherlands, the first pilot projects on for instance ramp-metering have been successful. Other pilot projects like main-line metering, coordinated ramp metering, special usergroup lanes, tidal flow lanes, etc. are under development. One of the main tasks in the development of these new systems is to find proper algorithms and to prototype the software.

Originally FLEXSYT [Middelham, 1986] is a study tool for the development of traffic-control schemes by means of conventional traffic-lights. But thanks to the well defined traffic-control language and the open input structure, FLEXSYT proves to be a simulation tool that offers the opportunity to study (the effect of) control programs for any kind of traffic-management system.

Recent extensions of the FLEXSYT-program with a graphical user interface and animation display, offer the opportunity to get an insight view in the operation of the traffic-management system under development. The development of a new version of FLEXSYT, with better behaviour models, routechoice, more vehicletypes, etc. is now completed.

This paper contains some remarks about the main design requirements and the structure of the program. Then it will continue with the description of the results of the application of the program on examples with a tidal flow lane, a toll-plaza and ramp-metering.

Structure of the program FLEXSYT

The **FLEX**ible-traffic-network-**S**imulation-stud**Y**-**T**ool (FLEXSYT) simulates traffic on a microscopic scale. Objects in the specification of the physical dimensions of the network are traffic-lanes (called network-elements), detectors and stoplines with signals. Objects in the specification of the dynamics of traffic-volumes are vehicle generators. FLXNET is the program to test and check the inputdata.

An important design requirement of FLEXSYT was that it shouldn’t have properties of a specific control philosophy nor have properties of a specific computer. Moreover the definition of a traffic-control language had to be unambiguous so misinterpretation shouldn’t occur while using the language. The result was a computerlanguage called FLEXCOL-76-. FLXMAN and FLXCON are the compilers for this language.

Vehicles move through the network on a stochastic basis with respect to lane choice, speed and headway. Travel times, delay, stops and lengths of queues are calculated. In this way it is possible to do research on the structure of the network, such as the lay-out of intersections, length and number of lanes, effects of bus lanes, etc. FLXSIM and FLXMON are the simulation modules, FLXRES is the output module.

Objects in the specification of controlprograms are timers, detectors and memory-elements. These elements can be given typical names by the user. As the program even doesn’t know the aspect sequence of for instance traffic-lights, the user has to ’learn’ the program how his/her control philosophy acts. Nowadays we would call the specification lines in FLEXCOL-76- ’expert-rules’, which could look like:

```
S_GREEN_,E_RED .= S(INTERGREEN_timer=INTERGREEN_time)
```

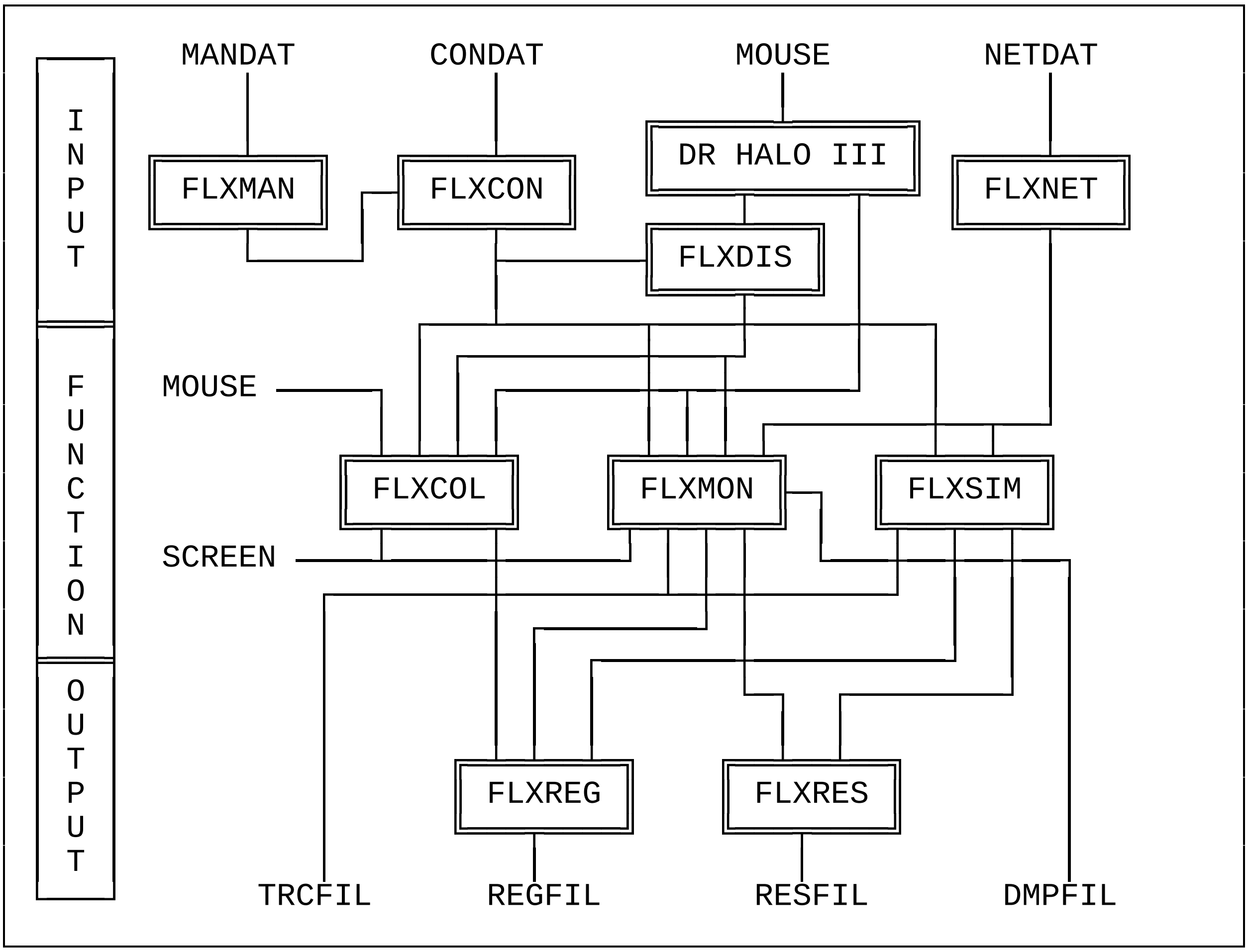

Fig. 1. Structure of the program package FLEXSYT

The structure of FLEXSYT is shown in figure 1. FLEXSYT consists of a number of programs. It is beyond the scope of this paper to go in more detail. That the design requirements were met, may be illustrated by references to work done in Hong Kong [Bodell e.a, 1987] and Budapest [Middelham, 1991]. The program was also applied in the context of the DRIVE-project CHRISTIANE in which the Dutch RWS-algorithm for ramp-metering and the German ALINEA-algorithm were prototyped. [Taale, 1991].

The tidal flow example

The first application described here is the tidal flow example. It was performed on a situation in which a bridge, being designed with four lanes of a really poor width, could probably be transformed to a bridge with three lanes of a more comfortable width. From traffic-counts it is known that the capacity of the bridge is 3100 pcu/hour for two lanes in one direction. It is also known that flow-ratios change from 25%-75% in the early morning rush hour to 55%-45% in the evening rush hour.

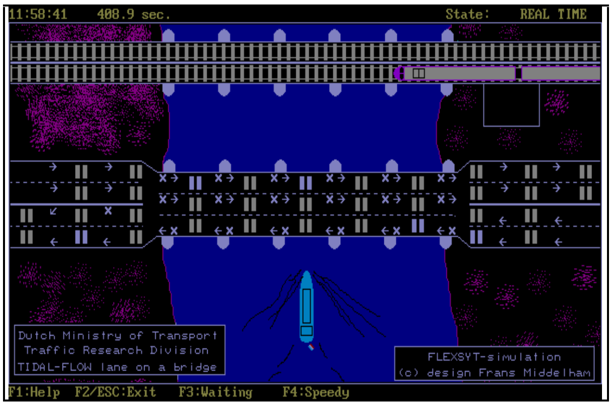

Fig. 2. Snap-shot from display

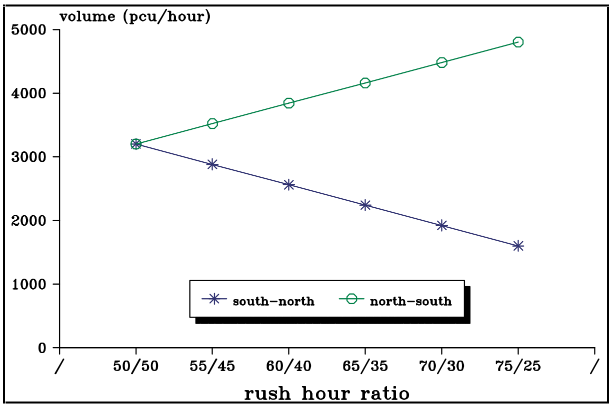

Fig. 3. Traffic volumes

A snapshot from the screen for the 'three lanes' case was made during one simulation and is displayed in figure 2. The experiment with FLEXSYT was conducted with the following assumptions:

- four lane capacity: 1800+1300+1300+1800=6200 pcu/hour;
- three lane capacity: 2000+2200+2000=6200 pcu/hour;
- hourly traffic-volumes rising from 4800 to 6400 pcu/hour and lowering back from 6400 to 4800 pcu /hour;
- flow-ratio changing from 50%-50% to 25%-75% in steps of 5%;
- simulations with 5 subruns of 3600 seconds each.

The total traffic-volumes in the peak hour are 6400 pcu/hour (figure 3). In the figures each marker denotes the results of a simulation run. In cases were no marker is displayed (for instance three lanes, south-north, 55%-45%, in figure 4), the simulation stopped prior to the whole period to be investigated, due to a queue exceeding more than 5 kilometres in length.

The conclusion from these figures may be that the present situation (four lanes) is the best choice. In the evening, when ratios are 55%-45% for north-south compared against south-north, the average delays are some 100 seconds. From other figures in the tables (not shown here) the conclusion is that the maximum delay is about 6 to 7 minutes in the peak hour with queues of 2 to 3 kilometres. This fits quite reasonably with real-life.

The break-even point between four lanes and three lanes is a ratio of about 60%-40% (see figures 4 and 5). In both cases already long queues exist either in the north (four lanes, which is real life) or in the south (three lanes). From the control point of view it will be difficult to control the three lanes. The minimum delay in this case appears to occur for a ratio of 65%-35%. The volumes during the day will not allow for a proper switch between a two lane north-south and one lane south-north regime in the reverse state.

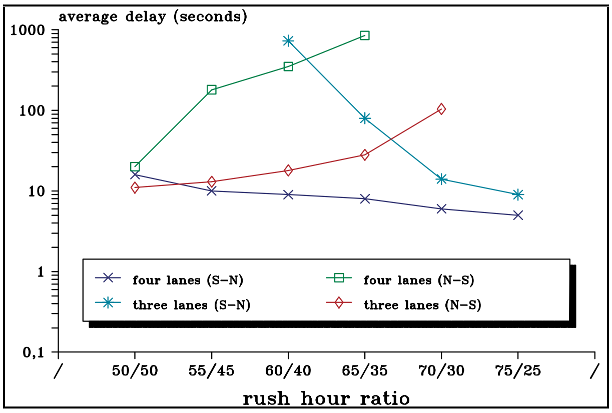

Fig. 4. Average delay for each direction

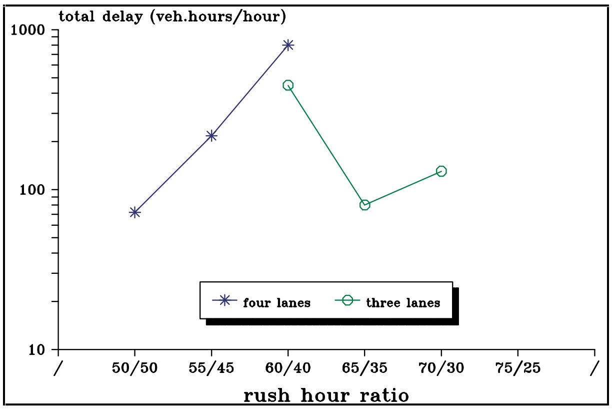

Fig. 5. Total delay for both cases

The whole site is in fact very sensitive, due to the minor number of lanes involved. In situations of more lanes available, for instance seven lanes in a three-four regime, results may show to be quite different.

The toll-plaza example

With FLEXSYT it is possible to study certain characteristics of toll-plaza’s, such as the number of gates, the percentage of smartcard users and the serving time of the gates, in relation with the time spent in the network and the delay. Here the flexibility of the program is again proved against other dedicated developments like TOLLSIM [Jawkuan Lin e.a, 1991].

The situation is displayed in figure 6. The experiment with FLEXSYT was conducted with the following assumptions being made:
- two lane motorway stretch of 3.6 kilometres;
- toll-plaza with a maximum of 9 gates;
- traffic-volume on the motorway 3600 pcu/hour;
- capacity of the motorway 4000 pcu/hour;
- serving time varying from 2 to 10 seconds;
- start delay after each visit of a gate is 2 seconds.

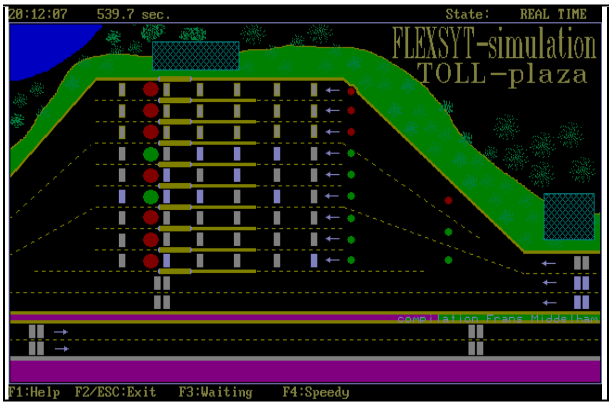

Fig. 6. Snap-shot from display

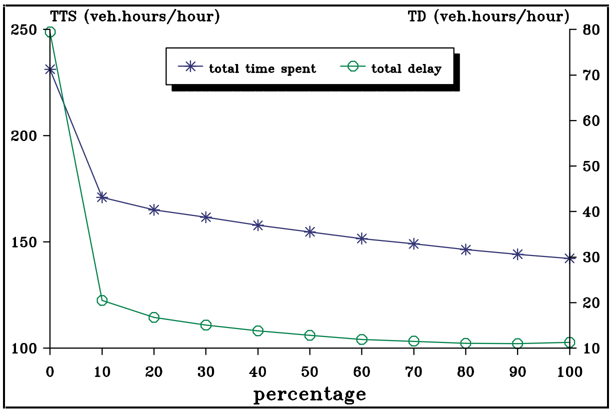

Fig. 7. Varying smartcard users

First, the percentage of smartcard users (that is the percentage of drivers not visiting the gates) was varied, with 9 gates at service and a average serving time of 6 seconds at each gate. The results are shown in figure 7.

It is clear that the time spent in the network and the delay are decreasing and converging to a minimum when the number of smartcard users increases. The peak with a percentage of zero smartcard users is due to the fact that the flow approximates the capacity of the toll-plaza. One has to realize that some delay is not calculated as the model calculates no delay due to the lower speed on the toll-plaza itself.

A variation in serving time was studied with 9 gates at service and a percentage of smartcard users of 30. The results are shown in figure 8.

The time spent and the delay increase when the serving time increases. The relation is approximately linear, what is to be expected. If serving time would have been higher it will increase exponentially, because the tollplaza will then be acting near it’s capacity.

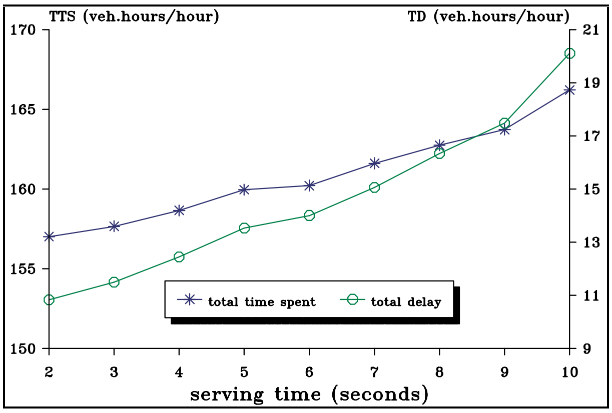

Fig. 8. Varying serving time

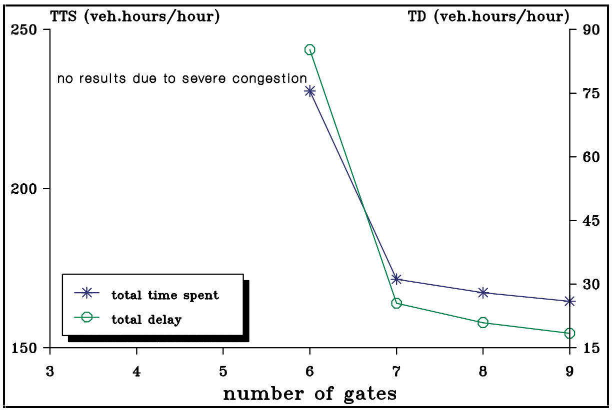

Fig. 9. Varying number of gates

Finally, the number of gates was studied, with a 30 percent of smartcard users and a serving time of 7 seconds. The results are shown in figure 9.

It is clear that for the used flow, the number of gates open must be at least 6. The time spent in the network and the delay decrease rapidly and converge to a minimum when the number of gates open increases.

The ramp-metering example

Research has been done with FLEXSYT on the control-strategy used at the Coentunnel site in the Netherlands (figure 10 and 11), known as the RWS-strategy. This strategy uses the following algorithm to calculate the on-ramp volume:

Picture: Meetkundige Dienst

Fig. 10. The rampmetering installation near the Coentunnel

ON-RAMP VOLUME = CAPACITY - MEASURED FLOW

The parameter which can be varied is the capacity. The algorithm is described more detailed in [Taale, 1991].

The following assumptions were made:
- upstream capacity of 4000 pcu/hour (2 lanes);
- capacity of 5800 pcu/hour of the weaving segment (3 lanes);
- downstream capacity of 4300 pcu/hour (2 lanes);
- the change in ramp volume distribution was simulated with

different runs, using different traffic volumes;

- without ramp-metering: motorway traffic volumes rising from 3200 to 3800 pcu/hour and lowering back from 3800 to 1500 pcu/hour, on-ramp traffic volumes rising from 800 to 1200 pcu/hour and lowering back from 1200 to 200 pcu/hour.
- with ramp-metering: motorway traffic volumes rising from 3500 to 3800 pcu/hour and lowering back from 3800 to 1500 pcu/hour, on-ramp traffic volumes rising from 500 to 800 pcu/hour and lowering back from 800 to 200 pcu/hour.

Fig. 11. Snap-shot from display

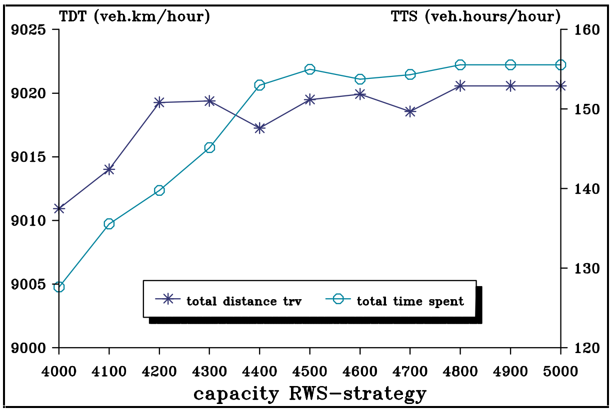

Fig. 12. Results for the motorway

The last two assumptions are based on real-life data and had to be made because FLEXSYT doesn't dynamically assign traffic and the size of the network studied is limited here.

From figure 12 it may be concluded that the RWS-strategy is sensitive with respect to its capacity parameter until that capacity reaches the downstream capacity. Then the total distance travelled and the total time spent on the motorway begin to stabilize.

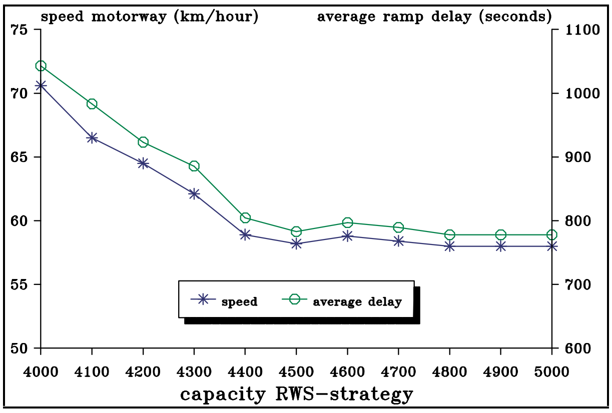

Fig. 13. Results on the on-ramp

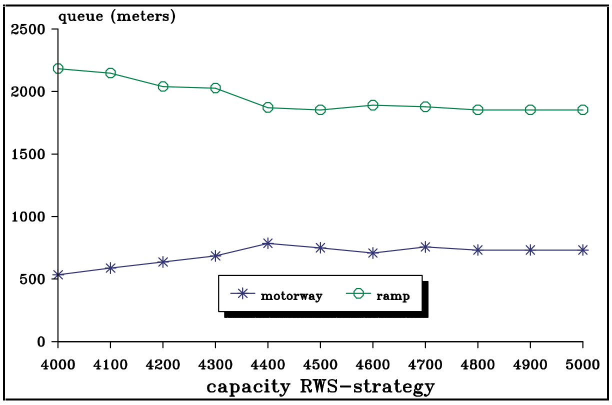

Fig. 14. Average of maximum queue

Figure 13 shows that the speed on the motorway and the average delay on the on-ramp decrease when the capacity parameter increases, because then more on-ramp traffic is allowed to enter the motorway.
The maximum queues on the motorway and the on-ramp are shown in figure 14. They also stabilize when the RWS-strategy capacity reaches the real capacity.

A comparison between the situations with and without ramp-metering is given in table 1.

	total distance travelled on the motorway (veh.km/hr)	total time spent on the motorway (veh.hrs/hr)	average speed motorway (km/hr)	average on-ramp delay (seconds)	maximum queue motorway (m)	maximum queue on-ramp (m)
with metering	9018	148	61	849	694	1951
without metering	8503	278	31	34	2438	420

Table 1. Comparison of the situation with and without ramp-metering
From this table it is clear that ramp-metering causes a shift in delay from the motorway to the on-ramp and increases the average speed on the motorway. Again this results fits quite reasonably with results found in real-life.

Conclusions

The examples given in this paper have not yet been explored in its full spectrum. A number of other aspects could have been studied e.g. for the toll-plaza: the dimensions, different serving times for different gates, variable flows, dynamic assignment of the number of gates, etc, and for the ramp-metering example: different strategies, more on-ramps, etc.

It took experienced users of FLEXSYT only 3 to 4 days to explore each example in this paper. This may underline the conclusion that this package is a handsome and useful tool not only for any type of traffic control problem but as well for a lot of dynamic traffic management systems now under development.

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