SIMULATION STUDY OF A SERIES OF SYNCHRONIZED INTERSECTIONS

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SUMMARY

Traffic control at isolated intersections or as part of a more complex system is designed to ensure optimum traffic flow for all road users at each intersection, whether considered separately or as part of a network

Increasing use is being made of the simulation method, to study complex planifications for individual transport. In view of the number and characteristics of the parameters, which must be taken into consideration; it is often more successful than conventional empirical or analytical methods. This article introduces a study of green waves, using simulation and its application. The model has to be simple, and economical.

The programming language used is GPSS III, the computer an IBM 7040/40 belonging to the "Centre de calcul électronique de l'Ecole Polytechnique de l'Université de Lausanne".

1 INTRODUCTION

Control by means of traffic signals at isolated intersections have been sufficient for many years, but now, it has become essential to coordinate traffic control on major highways, and to introduce green waves or coordination of traffic within urban networks of varying size.

2 GREEN WAVE

A green wave is obtained through a synchronization of the control installations of one or more traffic movements. His synchronization is obtained, by the projection in time and space, of the green time in a cycle of traffic control.

Its aim is to achieve the highest possible level of service, which means the largest individual freedom of movement obtainable.

This implies, that the synchronization of the traffic signals on this itinerary is correct, if the signal becomes green when the first vehicle of a platoon arrives within braking distance and becomes red when the last vehicle has passed it.

Synchronization is easy when the traffic flows in one direction but, on the other hand, it becomes difficult when one studies all the traffic movements. Such as cross traffic, merging and diverging traffic, pedestrians and traffic volume variations which one encounters at each intersection.

Traffic control of a chain of intersections, is in fact a problem of optimization. They are two types of optimization, local and overall :

- local optimization is the choice of optimum cycle length and phase system at each intersection;
- overall optimization is the coordination of control programes for a group of intersections, considering average vehicle speed.

The most commonly used optimization criteria is the mean waiting time per vehicle. It is the one adopted without omitting such important factors, as the number of stops effectuated by each vehicle on the main route and the length of the stationary line.

There are many parameters to be included in this type of simulation model. The most important parameters can be divided into four groups :

- those concerning drivers; such as his reaction time and behaviour at a series of coordinated intersections...
- those concerning vehicles; such as structural characteristics and perfor-

mance...
- those concerning streets; such as layout, physical characteristics, number of intersections, number of preselections or lanes allotted to each route...
- those concerning control systems; such as programes, and especially, length of cycle, phase structure and synchronization speed.

Moreover, the parameters of the last group for a given road design can be constant or variable depending on whether the control device is either pretimed or fully traffic actuated. A pretimed system will have one programe for traffic control, whereas a more flexible one will demand a signal timing programe, based on information given by traffic detection devices, elaborated by a computer working on line.

The classical means of designing a green wave is graphical, based on the use of a time-space diagram. This represents traffic flow lines defined by signal timing programes of the different intersections (Fig. 1). There are many setbacks in the use of this method. These studies are time consuming and they must be repeated for each value of the parameter. Moreover, this method does not indicate the number of stops and delay.

With the use of simulation one can better analyse these phenomenons. Simulation shows the future performance of the systems before they are put into practice, thus providing criteria for choising between different designs.

Simulation also permits the possibility of adaptation to the evolution of traffic which facilitates the establishment of a calender-programe.

3 DESCRIPTION OF THE MODEL

In its actual state, the present model simulates a pretimed green wave. It satisfies the imposed constraints. It is simple to use and of low cost.

Whichever intersection is considered, the ensemble of events which take place are basically the same, the only difference being their numerical values.

GPSS indirect addressing permits the creation of a compact model. Two different types of transactions correspond to the two dynamic elements of the system : vehicles and traffic signals. The complete model thus includes a model for vehicles and a model for signals; a permanent dialogue between the two models provides a link between vehicle progression and signal indications (Fig. 2).

Vehicles are generated at the border of the system wherever traffic flow can penetrate. Headway distribution can be calculated according to mathematical laws such as those of Poisson or Erlang depending on the traffic conditions, or according to empirical data if vehicle arrival is not at random, but conditioned by other elements further back into the traffic flow.

When a vehicle arrives at an intersection, a random choice based on statistical distribution is taken as to whether it will go straight on or turn off the main flow. The statistical distribution is either based on data collected on the spot or on traffic forecast.

For any given vehicles, there are two possibilities :

- the signal is green and there is no other vehicle waiting, the vehicle in question goes straight across the intersection.
- either the signal is red or the vehicle in front has not yet moved off when the signal was green : the vehicle in question stops and joins the queue. It will only move when the signal is green and when the vehicle or the vehicles in front of it have started to move (Fig. 3).

The distribution of vehicles in a platoon changes as it gets further away from the intersection, as a result of different vehicle speeds. Choice of the average speed for different vehicles is based on a normal distribution. The average speed (V) is the synchronization speed. The ratio between standart deviation of speeds (σ) and (V) depends on traffic conditions and especially on traffic density. Here, the value (σ/V) has been estimated to be 0,15. A vehicle leaves the system once it has crossed the last intersection.

Different simplifications have been introduced into the model, such as plitting the yellow interval into red and green times and including the loss of time due to acceleration or deacceleration into the waiting time. Experience has proved that these simplifications were of little influence.

This model is composed of 130 blocks, and the computer utilised has the capacity for treating 20 intersections.

4 APPLICATION

(Fig. 1, 4, 5, 6)
The first practical application of the model was the study of a project for a semi-urban radial artery linking the centre of Lausanne with an industrial suburb (Bussigny). This artery has 14 intersections.

The use of the model made it possible :

- to verifie the layout of the project as a whole, to correct certain details of the geometrical layout and to improve the scope of synchronization.
- to work out traffic control programes.
- to estimate future performance for the scheme, taking into account the probable evolution of traffic structure and volume.
- to determine the various stages of development for different parts of the system.

Simulation of traffic travelling in one direction took 0,14 hour for a run, or a ratio of:machine time/real time=0,3.

5 CONCLUSION

It would have been possible to use an existing simulation programe, but we did not think that this would have been the best solution.

Available models would have had to be adapted, with infinite precautions, to the data at our disposal and to the special characteristics of our design. It would, moreover, have been too expensive to use some of the more sophisticated models. With the use of GPSS language and various carefully checked simplifications, it took an engineer only a few weeks to construct an operational model which was tailored to meet our special requirement.

Studies are at present being conducted in two different directions. The model is being developed to simulate a traffic actuated control system, and on the other hand, it is being developed to study a process which would give some sort of priority to public transport systems by means of appropriate detectors and control.

ILLUSTRATIONS

1. RC 151 Lausanne-Bussigny (Switzerland)
   Progressive Signal System
   Time Space Diagram
2. Complete Simulation Model
   Flow Chart
3. Vehicle Simulation Model
   Explanatory Flow Chart
4. RC 151 Lausanne-Bussigny (Switzerland)
   General Design
5. RC 151 Lausanne-Bussigny (Switzerland)
   General Design Detail
6. RC 151 Lausanne-Bussigny (Switzerland)
   Mean Waiting Time at Intersections

REFERENCES

- Anders M. Löf : "Computation of an optimal control for a signalized traffic intersection". Transportation science. Operational research society of America. Vol. 1 No. 1 Febr. 1967
- Blum A.M. : "Digital simulation of urban traffic". IBM systems journal- Vol, 3 No. 3 1964 p.41
- Gerlough D.L. : "Simulation of traffic flow". Highway Research Board. Special report 79. An introduction to traffic flow theory. Washington 1964
- Kell J.H. : "Intersection delay obtained by simulation traffic on a computer" Highway Research Record No 15 1963
- Sagen R. : "Traffic simulation with cathode raytube output". The University of Denmark, Department for road and railway construction and town planning. Report No 36 Copenhagen 1967
- Wätjen W.D. : "Computer.simulation of traffic behaviour through three signals" Traffic Eng. & Control. Febr. 1965. Vol. 6 No.10 p. 623-626
- Gerlough-Wagner : "Improved criteria for traffic signals at individual intersections". Highway Research Board NCHRP No. 32 (1967)
- Webster F.W. : "Traffic signal settings" Road research technical paper No. 39
- Yardeni L.A. : "Algorythms for traffic signal control". IBM systems journal. Vol. 4 No. 2 1965

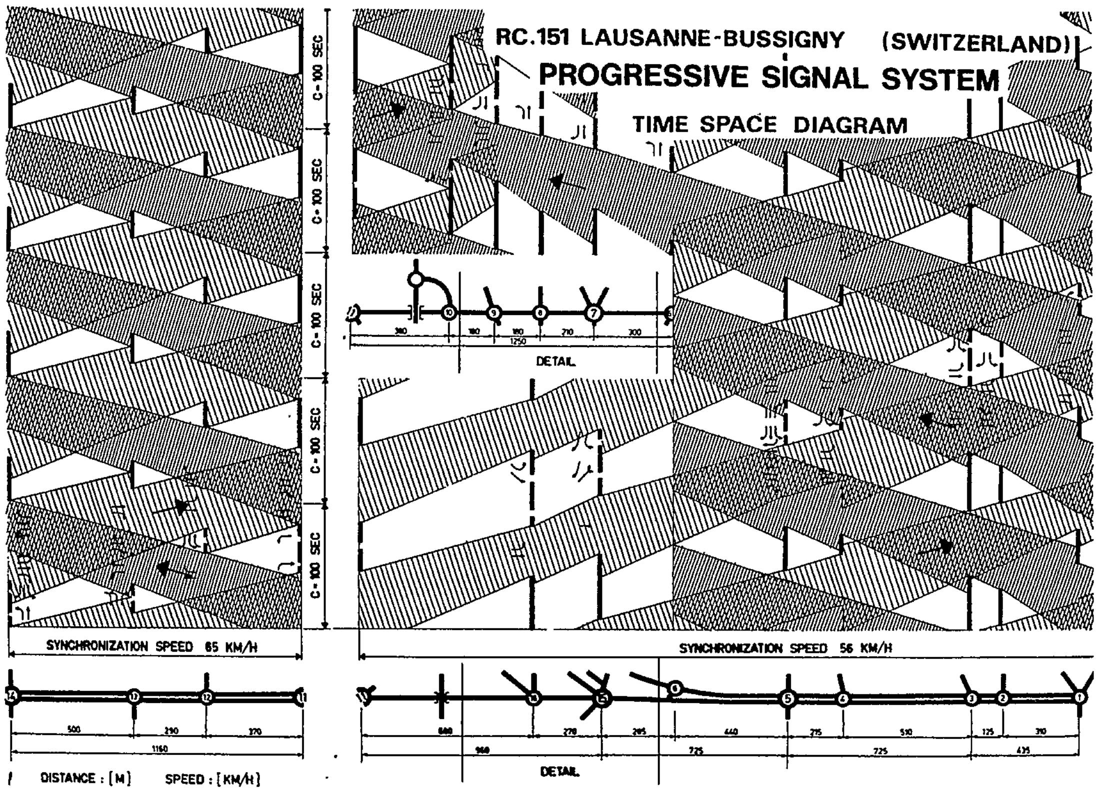


Fig. 1

COMPLETE SIMULATION MODEL

FLOW CHART

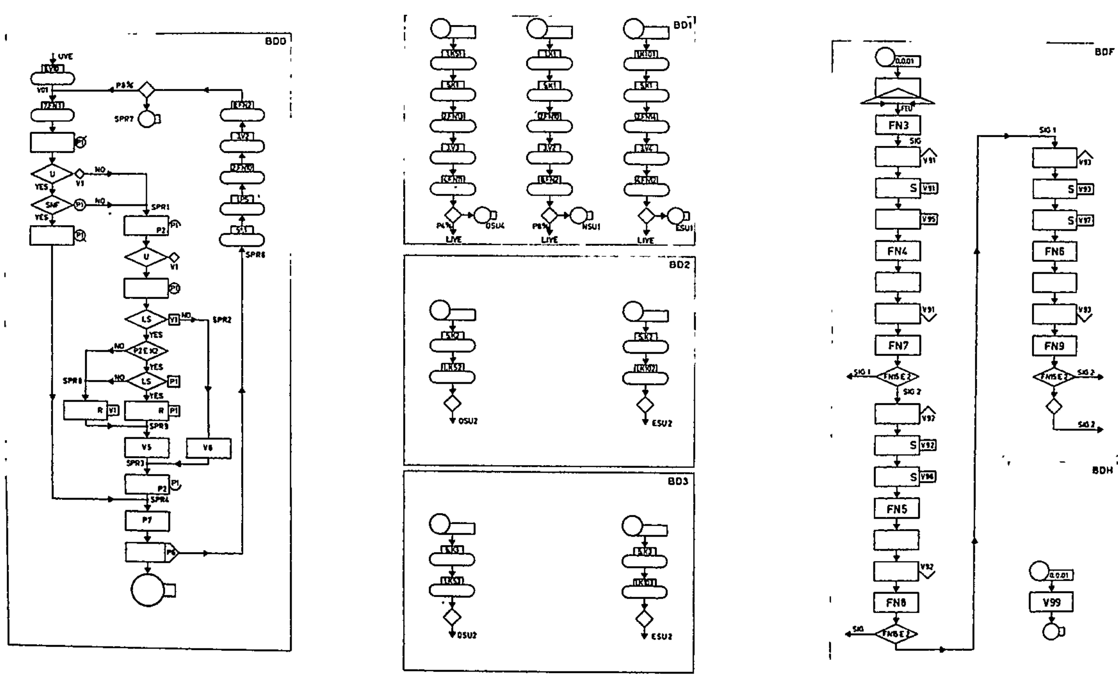


Fig. 2

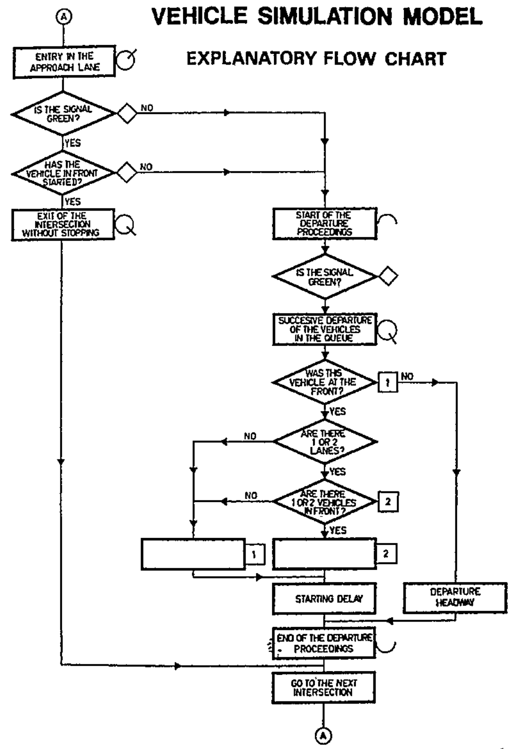

VEHICLE SIMULATION MODEL
EXPLANATORY FLOW CHART
ENTRY IN THE APPROACH LANE
IS THE SIGNAL GREEN?
NO
YES
HAS THE VEHICLE IN FRONT STARTED?
NO
YES
EXIT OF THE INTERSECTION WITHOUT STOPPING
START OF THE DEPARTURE PROCEEDINGS
IS THE SIGNAL GREEN?
SUCCESIVE DEPARTURE OF THE VEHICLES IN THE QUEUE
WAS THIS VEHICLE AT THE FRONT?
1
NO
YES
ARE THERE 1 OR 2 LANES?
NO
YES
ARE THERE 1 OR 2 VEHICLES IN FRONT?
NO
2
YES
1
2
STARTING DELAY
DEPARTURE HEADWAY
END OF THE DEPARTURE PROCEEDINGS
GO TO THE NEXT INTERSECTION
A

Fig. 3

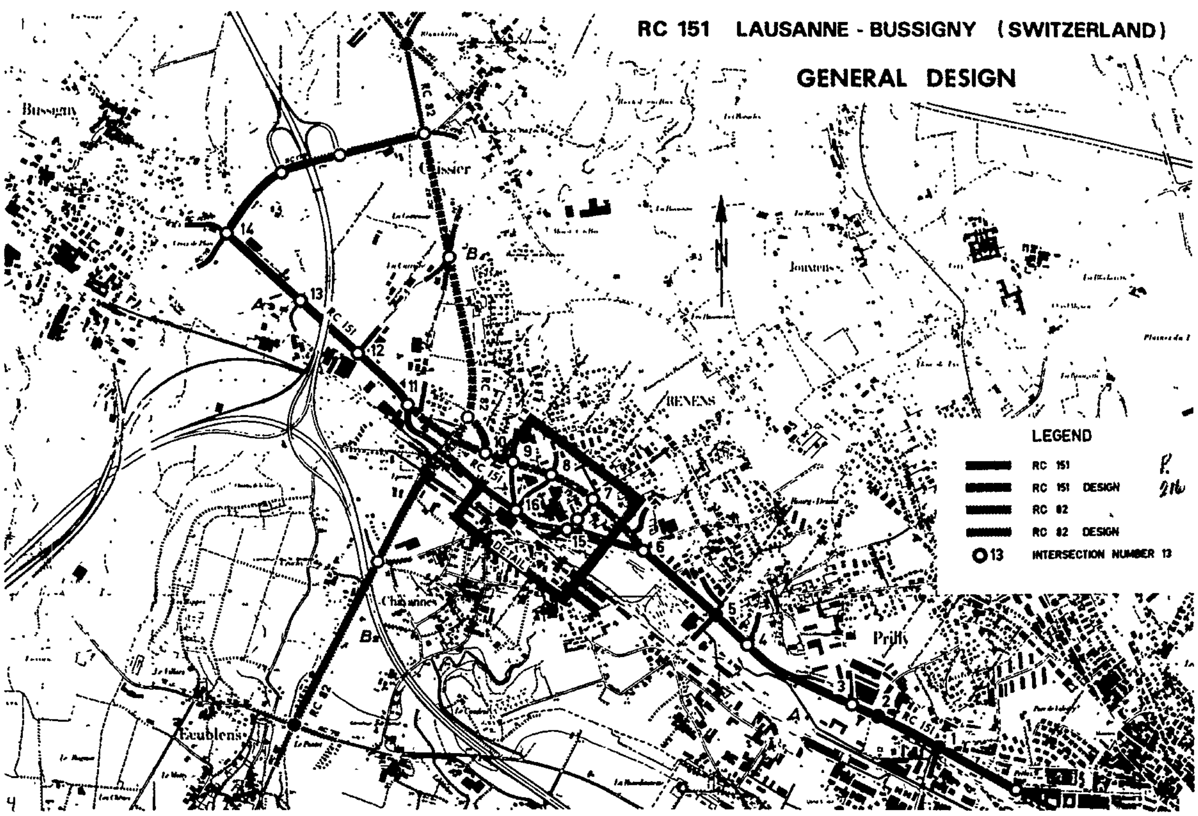
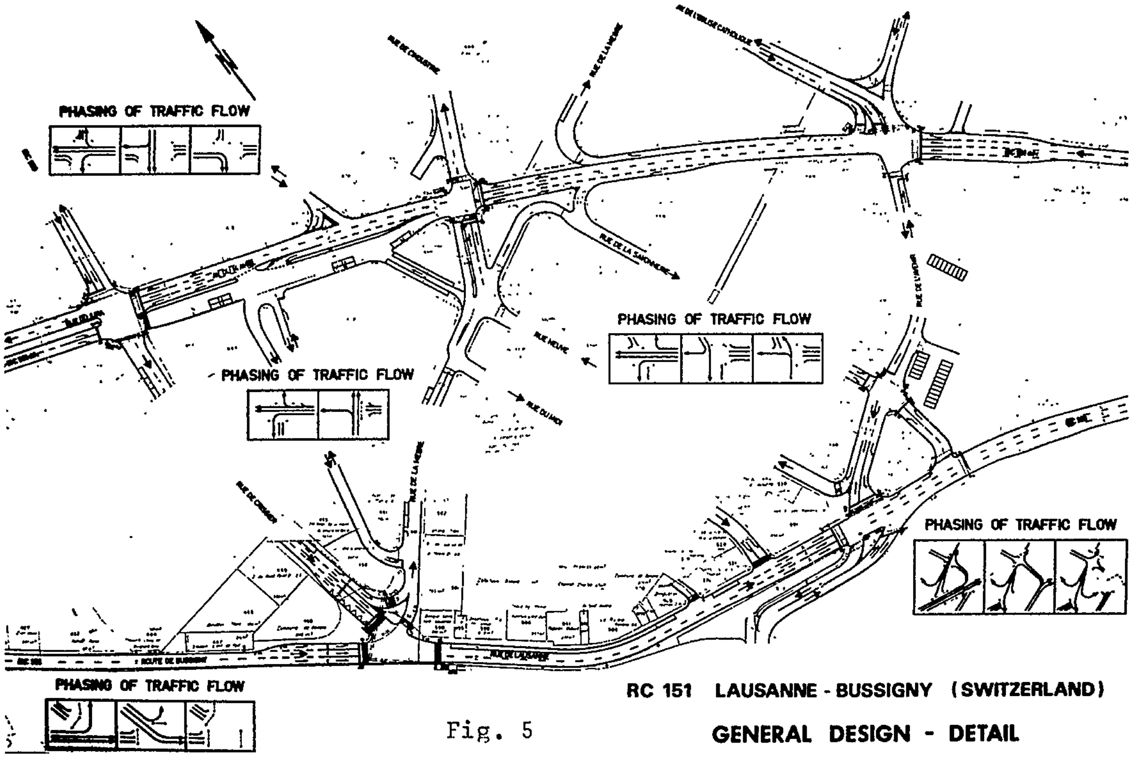

RC 151 LAUSANNE - BUSSIGNY (SWITZERLAND)
GENERAL DESIGN
LEGEND
RC 151
RC 151 DESIGN
RC 82
RC 82 DESIGN
13 INTERSECTION NUMBER 13
Bussigny
Crissier
RENENS
Jouxtens
Chavannes
Ecublens
Prilly
DETAIL
RC 82
RC 151

Fig. 4


PHASING OF TRAFFIC FLOW
PHASING OF TRAFFIC FLOW
PHASING OF TRAFFIC FLOW
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PHASING OF TRAFFIC FLOW
RC 151 LAUSANNE - BUSSIGNY (SWITZERLAND)
GENERAL DESIGN - DETAIL

Fig. 5

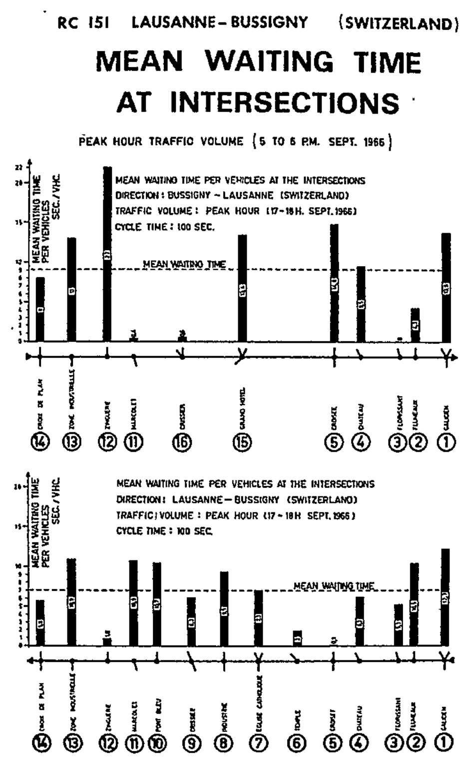
RC 151 LAUSANNE-BUSSIGNY (SWITZERLAND)
MEAN WAITING TIME
AT INTERSECTIONS
PEAK HOUR TRAFFIC VOLUME (5 TO 6 P.M. SEPT. 1966)
MEAN WAITING TIME PER VEHICLES SEC./VHC.
MEAN WAITING TIME PER VEHICLES AT THE INTERSECTIONS
DIRECTION : BUSSIGNY - LAUSANNE (SWITZERLAND)
TRAFFIC VOLUME : PEAK HOUR (17-18H. SEPT. 1966)
CYCLE TIME : 100 SEC.
MEAN WAITING TIME
MEAN WAITING TIME PER VEHICLES AT THE INTERSECTIONS
DIRECTION : LAUSANNE - BUSSIGNY (SWITZERLAND)
TRAFFIC VOLUME : PEAK HOUR (17-18H SEPT. 1966)
CYCLE TIME : 100 SEC.
MEAN WAITING TIME

Fig. 6