A Program for the Monte Carlo Simulation of Vehicle Traffic along Two-lane Rural Roads

by Anders Brodin

Presented at SIMULA Workshop "SIMULA and Industrial Systems" in Budapest, March 4-5, 1980
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PREFACE

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1. Introduction to the original problem

Knowledge of traffic and its behaviour is essential for the authorities responsible for the road network on different levels in order to allow

- planning of the road network in the short and long term
- development of a road design policy
- maintenance and operation of the road network in order to estimate the different components of the road user cost as well as for defining a level of service concept.

It is essential, however, that the traffic models thus established for use in the different decision situations are consistent and also that they are validated for real traffic conditions.

In order to furnish relevant information about the traffic mechanisms in the interurban road network, a comprehensive traffic behaviour model has been built.

Simultaneously, field studies have been carried out applying an integrated data technique for traffic registration, data processing and evaluation in order to validate the traffic behaviour model.
2. The systems approach

The research approach can be seen as an input/output problem in which the operator consists of the traffic process in accordance with figure 1 below. The input parameters describe measures by authorities and the output constitutes measures of effectiveness of the level of service concept and the components of road user cost.

2.1 The input parameters are defined on strategic as well as operational levels.

On the strategic level the ultimate goal is to fit together the needs of transportation and the traffic demand with regard to the resources available.

On the operational level the road design factors, the traffic regulations introduced, the types and characteristics of the vehicles and the road-user characteristics interact and constitute the traffic process and its quality on the individual road stretches in the road network.

2.2 The operator - the traffic process

The operator "traffic process" in the centre of figure 1 converts the input parameters into the requested effects.

2.3 The output - measures of effectiveness

Factors taken into account in the road users' cost and which will be included in the level of service concept are as follows

<table>
<thead>
<tr>
<th></th>
<th>road users' cost</th>
<th>level of service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Journey time</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Accident consequences/</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>result</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic comfort</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Vehicle deterioration</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1.
3. Introduction into the model to be analysed

The traffic model is split up into two parts

- The traffic stream generation model constituting the individual driver-vehicle units (equipage) and putting them into the two directions of the road stretch.

- The traffic behaviour model describing the consecutive adaptions of the speed of the equipage along the road with regard to the road parameters and the different types of interactions with equipages in the vicinity.

3.1 Free flow traffic

In the model, each vehicle is allotted a basic desired speed, i.e. the speed on an ideal road, a wide, straight road with no speed limit. The following factors reduce the basic desired speed of a free-moving equipage

(1) Road width
(2) Bends
(3) Speed limits
(4) Hills

The road to be simulated is described in the model as two series of homogeneous blocks (one in each direction).

Within each block, the road is considered to be of constant quality in respect of each of the factors (1) to (4) above.

With regard to road width, speed limit and bend the speed distribution ($V_0$) for this ideal situation is transformed to separate speed distributions ($V_3$) for each road block as shown in figure 2.
These speed distributions – block speeds – indicate the driver's "wish".

Each vehicle has been allotted a power/weight ratio, or p-value, as well as air and rolling resistance, which decide its "ability" to reach or maintain its block speed on the particular slope. If the momentary speed is lower than the block speed the speed is ordinarily computed by Newton's force equation.

3.2 Interaction model

In addition to the basic desired speed and p-value each equipage is allotted an entry time and a road coordinate for starting as well as a direction of travel and an entry speed. Faster equipages may catch up with slower equipages which leads to overtaking or following. After following an accelerated overtaking may take place.

On a road without a wide shoulder overtaking takes place if

1) the equipage has sufficient acceleration ability to carry out an overtaking
2) space is available for overtaking with regard to surrounding equipages
3) there is no overtaking prohibition
4) a stochastic function is true. The probability of being true depends on
   a) the type and speed of impeding equipages
   b) available sight distance
   c) oncoming equipages within the sight distance available

If the road has a wide shoulder overtaking can also take place by "passing", which means that the leading equipage moves with a particular probability onto the shoulder.

If the road has a climbing lane the impeding equipage will move into this lane.

During the overtaking procedure a sequence of movements takes place as described in the freely-moving equipage model. When following occurs, however, the equipage follows the preceding vehicle with a constant time headway depending on preceding vehicle's type.
The traffic process is reproduced by an aggregation of micro level submodels adapted for simulation on a digital computer.

Traffic characteristics differentiated by traffic category as functions of traffic flow and composition

- Traffic volume
- Traffic composition

Journey speed distribution
- Mean value
- Dispersion

Journey time distribution

Road width
- Alignment
- Speed limit
- Desired speed

Power/mass ratio

Road width
- Overtaking restrictions
- Sight distance available

Inclination to overtake
- Power/mass ratio

Number of "catchings up"

Possible overtaking situations

Accepted overtaking situations

Number of overtakings

Percentage of
- Free moving vehicles
- Queue length
- Queue frequency

Headway distribution
4. Introduction into the SIMULA-program

The simulation program described below comprises the "heart" of a program system as shown in figure 4.
An inventory of existing techniques and programming languages was made. The results were:

a) application of Jackson Structured Programming Technique (JSP)
b) choice of SIMULA-67, which has exceptional qualities for simulation as well as permitting a lucid organisation of the program text and well-structured data.

The program is implemented in the following way:

```
BEGIN
  Simulation BEGIN
    REF(Head) direction1, direction2;
    REF(Head) ARRAY track(1:2,1:3);
    REAL ARRAY breakpcoord1(1:n1), breakpcoord2(1:n2),
      sightdistan1(1:n1), sightdistan2(1:n2);
    Process CLASS vehicle;
    BEGIN INTEGER idnu, owntrack;
      BOOLEAN following, behcatchup, finish;
      INTEGER origin, dest, vehtype, blnu, dirnu;
      REAL c2, predblbordertime, predictnextevtime,
        localsp, localcoord, localtime, mintime, aversp, w,
        predictblbordersp, pnormal, timeheadway, v0n;
    END PROCESS CLASS VEHICLE;
    REAL PROCEDURE p;
    END PROCESS CLASS VEHICLE;
  LINK CLASS roadblock;
  BEGIN INTEGER rco, rblength, ri, rnonovert, rsightlmax,
    rsightref, roadwidth, lane;
    REAL dvq, rq;
  END ROADBLOCK;
  Process CLASS generatorprocess;
  BEGIN
    REF(veh)b;
    REAL arrivaltime;
    PROCEDURE givevehattribut;
  END GENERATORPROCESS;
END;
END
```
The main principle of SIMULA is pseudo-parallel execution, which can be regarded as a further development of event control of dynamic sequences. The descriptions of the events which relate to a particular type of object are collected into a single process. The program consists of two processes:

a) Process CLASS generator process
b) Process CLASS vehicle.

The process, which also contains data and procedures, provides a natural picture of the object these describe. In this way good similarity to the model is obtained which is very important since simulation models tend to be highly complex.

The vehicle process describes all the possibilities for action of a particular vehicle e.g.: "drive as a freely-moving equipage", "follow another vehicle" or "overtake the vehicle in front".

The road block describes

a) location and length
b) road geometry and traffic regulation
c) references to sight distance function

The roadblock object is linked in each direction in a Simset list.

The vehicle generator process creates vehicle objects and allots them individual driver-vehicle attributes. They are also allotted their traffic attributes. Parameters which define vehicles consist of e.g.: identity number, basic desired speed and power/weight ratio.

Parameters giving their traffic attributes consist of e.g. starting point, starting time and direction of travel. The equipage generator process also activates the equipages at their starting times.
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