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Simulation Model for Calculating the Route Time of a Vehicle

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Abstract

The paper presents a model created for the calculation of a vehicle route time between two chosen points: departure and arrival. The designed simulation model can be used for the calculation of route time, comparing route options and evaluating traffic management strategies. The goal is to provide the user with a representation of the network in real route time, starting from the data provided from the traffic data collection equipment.

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Keywords: Simulation model; route time; vehicle.

1. Introduction

Turning to simulation is mandatory today in more and more fields. Regarding traffic, the arguments are in terms of technical: price, safety, difficulty in performing real tests on road infrastructure and caused by the complexity of traffic phenomena; more versions can be evaluated and compared through simulation.

The simulation of a complex system consists of a system decomposition into several elements and of describing the behavior of each element, along with the interactions between the elements throughout the studied period. The system evolution was reproduced by using the technique called: event simulation, where system conditions, which are of finite number, are defined [1]. The crossing of a system from one condition to another is called an "event". We manage future events and examine the system in a unique manner, at the moments when an event occurs [1][2].

The simulation processing methodology includes 3 levels, [1]:

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- the strategic level, refers to: defining objectives, defining systems, data collection and analysis;
- the technical level, refers to: model designing, data processing, modelling of various system directing processing operations, programming, calibration, validation;
- the operational level, refers to: experience plan, experiments on a model, result analysis, documentation.

One of the European transport policy objectives is the implementation of Intelligent transport systems, that will allow optimized trip planning, better traffic management and easier demand management. An important aspect in urban networks mobility is for travelers to be informed about various travel modes and times, and can this way choose the optimal option for them [3].

By researching other traffic simulation software, it was obvious that there are not many such simulators that can be used for real-time simulation of urban traffic networks [4][5].

Due to the evolution in network operation and modification, the data obtained through simulation helps traffic administrators to approximately foresee the consequences of performed modifications. The simulation model named SIM-TP was created for the calculation of a vehicle route time between two chosen points: departure and arrival.

2. The architecture of the simulation model

The simulator sees a street network as a Petri (graph) network, a system of discrete events, RPt (Petri transport network). The Petri transport network model allows the studying of a system's evolution with discrete events, modelled through RPt [6]. Execution invariants define the roads within the network, and the maximum capacity of the transitions participating to the road, determine the road's transport capacity. In Fig. 1, the diagram of the RPt network is shown. The graph joints (Place), represent major intersections on the city map. The vector connecting two intersections is oriented ($P_1 – P_2$) and guided by a transition rule T_1. Position P_1 is the entry into the network (source), while position P_2 is the destination (exit from the network).

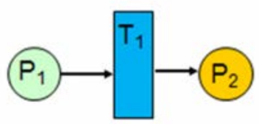

Fig. 1. The diagram of the Petri transport network.

The simulator SIM-TP includes the following items [5]:

- Virtual vehicle – Token, having the following properties attached:
  - origin lane;
  - current lane;
  - average vehicle length (m): 7 m;
  - timer (s): route time meter;
  - route: is the navigation option.
- Traffic lane – Lane, having the following properties attached:
  - identification number;
  - length (m);
  - average route speed (km/h);
  - average route speed (m/s);
  - lane capacity: maximum number of token units;
  - transit time (s);
  - occupation level, current number of token units.
- Transition – Transiting, having the following properties attached:
  - identification name;
  - source lane (in), destination lane (out);

  - synchronous connections (link);
  - lane length (m);
  - green time (s), red time (s);
  - route speed km/h;
  - route speed m/s;
  - transit time (s);
  - transit capacity, token units.
- Order – Temporary sequence;

Simulation is the transfer, according to certain rules (time functions and restrictions) in one direction (source to destination), of the tokens. Transfer is the responsibility of transit type objects. A token is a transition right of the transition activated at a certain point. The right is assigned successively, in a specified order, and is exclusive throughout the transition's activity state – this is the fundamental principle of discrete event simulation.

- Route.

The route notion is necessary when there are route options: move forward or to the right. The number of routes equals the number of possible options. "No route" is when the token is guided on the first activated link by a transit on row.

SIM-TP simulation is used for the calculation of the elapsed time between 2 points. The simulation, is performed for a route version, resulting the time elapsed between the departure and arrival point. The diagram of the route time simulation is presented in Fig.2.

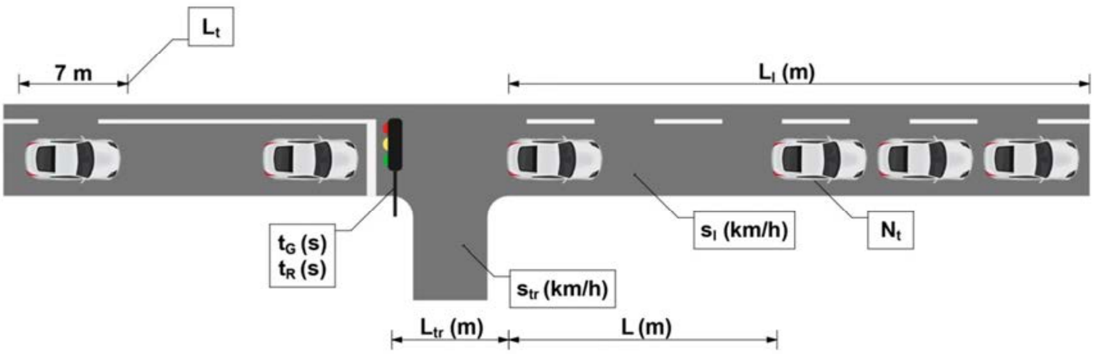

Fig. 2. The diagram of the route time simulation. L_t = average length of token, L_l = lane length,

L_{tr} = transit area length, L = clear lane length, t_G = green time, t_R = red time, S_l = average lane speed , S_{tr} = average transit speed, N_t = occupation (charge) of lane.

3. Calculation of the route time

The simulation model of the proposed traffic simulates the network consisting of 4 traffic light intersections and can be extended up to 6 intersections.

The user provides specific data related to the sector's geometry, the intersections and the density-speed relationship. The other necessary input variables are of dynamic nature, such as the flows determined by the collectors and the traffic light cycle. For each lane (sector), the results include the average number of vehicles and the average speed per sections and time intervals. The variables, such as total time or length, can be easily obtained [1] [7] [8] [9].

For each sector, the necessary input data is:

- specific data related to the geometry of the sector, of intersections (the length of the access lane and intersection, the name of the access lane and intersection, the average length of the vehicle);the speed limit;

- the average forwarding speed;
- the intersection crossing speed;
- vehicle accumulation;
- traffic light cycle: duration of the color green and color red.

Output variables include, for each lane and intersection:

- the lane's maximum capacity;
- the intersection crossing time;
- the number of vehicles transiting on the green color in an intersection.

The results refer to the witness vehicle and include the lane and transit time, the waiting time (in queue and at the traffic light), the total route time for each sector of the route, Fig.2. The variables were determined using the following relations:

Transit time – T_{tr} [s]:

$$T_{tr} = \frac{(L_{tr} + L_t)}{S_{tr}} \tag{1}$$

Transit capacity – C_{tr}:

$$C_{tr} = \frac{t_G}{T_{tr}} \tag{2}$$

Destination Lane crossing – T_l [s]:

$$T_l = \frac{L + (N_t * L_t)}{S_l} \tag{3}$$

Destination Lane capacity – C_l:

$$C_l = \frac{L}{L_t} \tag{4}$$

Traffic time for transiting token – Crono(t):

$$Crono(t) = T_{tr} + T_l \tag{5}$$

Traffic time for waiting token in source lane – Crono(w):

$$Crono(w) = Crono(t) + t_R \tag{6}$$

Upon the insertion of the input data, the option 'Start simulation' is accessed, Fig.3. At the end of the simulation, the total route time for transiting the chosen route is obtained. Results are also edited as a Report, Fig.4, including the results according to phases and the final one.

The software was written using Notepad++ and Dreamweaver through HTML and Javascript language, which permit up-to-date changes in the SQL and PHP data bases.

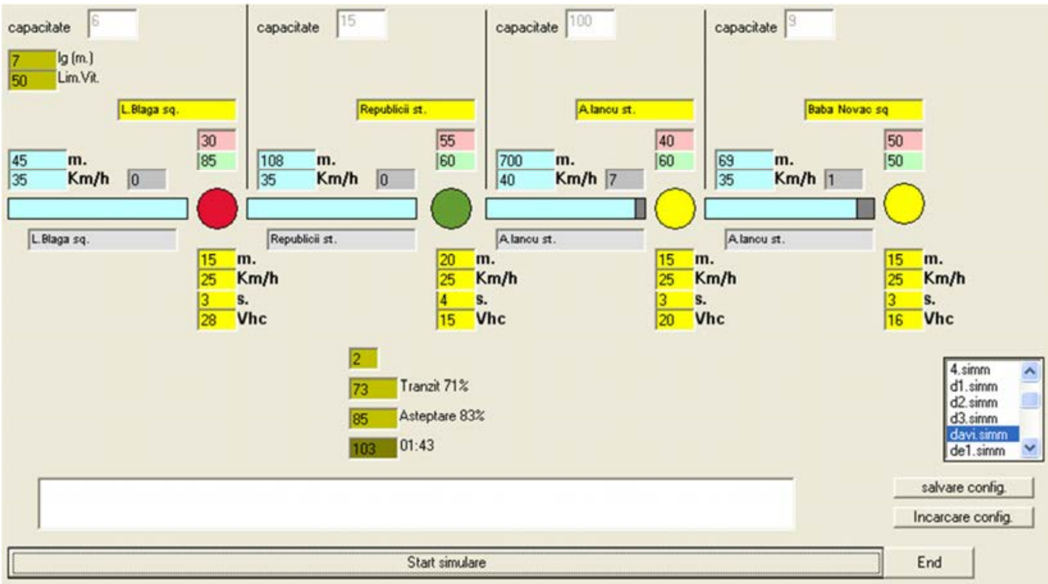

Fig. 3. Calculation of the route time

```
"---------------------------------------------------TRANSFER prin intersectia: Eroilor blv., strob timp 153"
"Eroilor blv. [15m/3 s.] verde [80]s. tranziteaza [26] vehicule la v.medie [25]Km/h"
"---------------------------------------------------"
"Intersectia:: Eroilor blv. [15m/3 s.] verde [80]s. tranziteaza [26] vehicule la v.medie [25]Km/h"
"-  Intrare din Eroilor blv. cu incarcare 8 vehicule"
""
"*********************************************** "
"Eroilor blv.> X Eroilor blv. [q::0] X > ..."
"Vehicul martor virtual secunda 153 tronson [3]"
"ASTEPTARE 20s. / cumulat= 20s."
"TRANZIT 33s. "
"TOTAL 233s.      3:53"
"=============================="
"========== ETAPA 3"
"========== | "
"L.Blaga sq.{q 0}_X_L.Blaga sq._X_"
"Napoca st.{q 0}_X_Napoca st._X_"
"Unirii sq.{q 0}_X_Unirii sq._X_"
"Eroilor blv.{q 0}_X_Eroilor blv. |"
"=============================="
"============================================================================="
"Raport Final:"
"Tranzitare intersectii si benzi de circulatie 33s.  din total 233 s."
"Asteptare in benzi de circulatie di cauza semafor rosu:200s.  85 %"
"============================================================================="
"END"
"============================================================================="
```

Fig. 4. Extract from Report

4. Results

The application of the simulation model SIM-TP was performed on routes in Cluj-Napoca City, including several traffic light and monitored intersections. For the simulation, the specific input data for each sector was inserted. Simulations have been performed for several times of the day, chosen according to the traffic flowchart obtained from collecting data in intersections [10]. Following the simulations, the elapsed time between the chosen departure (origin) and arrival (destination) intersections was obtained. The SIM-TP simulation reports were also edited**,** containing partial times obtained per phases, between intersections, and the final result. For example, the routes chosen for simulation (on a working day, time span 14h-18h) are:

- (1) Lucian Blaga Sq. – Napoca St. – Unirii Sq. – Eroilor Blv.
- (2) Eroilor Blv. – Avram Iancu Sq. – Stefan cel Mare Sq. – Baba Novac Sq.
- (3) Lucian Blaga Sq. – Republicii St. – Avram Iancu St. – Baba Novac Sq.

The final report is shown in Table 1.

Table 1. Route time Final Report.

Route chosen for simulation	Total route time s	Transiting intersections and traffic lanes s	Waiting on traffic lanes for a red light s	% of the time
(1)	233	33	200	85%
(2)	196	76	120	61%
(3)	205	80	125	60%

Also, for determining the best travel option between Piaţa Lucian Blaga sq. (origin) and Baba Novac sq (destination), 2 route options were simulated:

a) Lucian Blaga Sq. – Napoca St. – Unirii Sq. – Eroilor Blv. – Avram Iancu Sq. – Stefan cel Mare Sq. – Baba Novac Sq. The resulting route time is 6 min 18s.
b) Lucian Blaga Sq – Republicii St. – Avram Iancu St. – Baba Novac Sq. The resulting route time is 3min 25s.

After the simulation, the final route times for these two options were compared, resulting the optimal travel option. The best travel option is option (b).

5. Contribution

The designed simulation model SIM-TP can be used for the calculation of route time, comparing route options and evaluating traffic management strategies. The goal is to provide the user with a representation of the network in real route time, starting from the data provided from the traffic data collection equipment (detection loop, sensors, video cameras).

The simulation program for the calculation of the route time was designed as part of a software platform of modern traffic management system, for informing the users regarding the route times and best travel options, and helps traffic administrators to approximately foresee the consequences of performed modifications.

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