Parking search modelling in freight transport and private traffic simulation

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Abstract

This paper presents the work carried out in order to achieve better approximation to reality in traffic simulation. It is embedded within a line of research in the Organisation Department of the University of Seville aimed at developing a microscopic traffic simulator to use as a tool for urban planning issues related to freight transport and private traffic.

For private traffic, the simulator uses traffic assignation algorithms which, from an O-D matrix, give the input to generate the route that each vehicle will follow through the links of the city network. Then, real-time movement algorithms calculate the actual movement of the vehicle through each link, interacting with the other vehicles present in the simulation. The model presented in this work is used for representation of the parking procedure at the end of the vehicle’s route.

For freight transport, the shortest path algorithm was used for direct calculation of routes for freight vehicles. Knowing the different delivery stops that have to be made by the vehicle, the algorithm calculates the links that form the shortest route between each pair of consecutive stops. Then, when the freight vehicle arrives to a link where it must stop, the parking search model examines the parking spaces available, and determines which is the best one according to its distance to the final delivery point. That best parking space is then assigned to the vehicle.
1 Introduction

Models that represent the movement of vehicles through a network (acceleration models, turning models, generation models...) are widely studied and present in the literature (May, [1]). However, the development of the microscopic traffic simulator TRAMOS (Traffic Analysis, Modelling and Optimisation Simulator) in the University of Sevilla (Eguia, [2]) found the need to create a model for the extraction of vehicles from the network: a parking search model, according to which vehicles would determine when and where to park. This model would also have to include freight delivery vehicles, to illustrate their routes and delivery stops along the network.

This paper describes the general operating principles of the parking search model, as well as a test run carried out after implementing it in the simulator TRAMOS.

2 Microscopic traffic simulation

This section describes briefly the sequence of procedures followed in a microscopic traffic simulation.

2.1 Initial input

In order to start the microscopic simulation, several input data is required:

- Network data: all the links and nodes of the network, distributed in zones, and including the capacity functions for all links.
- An O-D matrix, needed to determine how many vehicles are generated in each zone of the network.
- A previous four-step macroscopic traffic assignment, in order to determine flow volumes for each turn in the network.

2.2 Microscopic simulation models

All the different models included in microscopic traffic simulation are described here, as well as showing an overview of the general simulation procedure. The models are (Yang, [3]):

- **Vehicle generation model**: this model is used to incorporate vehicles to the network. It consists of a probability distribution that spreads vehicle generation over the simulation period for each origin zone. Private vehicles are thus generated randomly in each zone, with a uniform probability distribution that depends on the number of trips generated in each zone, extracted from the O-D matrix.

- **Follow-up model**: this model establishes dynamically the reference for the
movement of each vehicle, that is, the input used by that vehicle to adjust its speed. This reference can be either the vehicle driving in front of it, the end of the link in case there is no such vehicle, or, if the vehicle is to park in the current link, the parking space assigned to it (Gipps, [4]).

- **Overtaking model**: model used to make vehicles change lanes within a link when the lane they are in is moving too slow, or when they need to be in a certain lane to make the next turn, or when they are approaching a parking space. Every time a vehicle changes lanes, its reference changes.

- **Acceleration model**: this model, for each simulation instant, receiver as input the position, speed, acceleration and reference of each vehicle in the previous instant. The output is the new acceleration, which then is used to determine the new speed and position.

- **Intersections model**: this is the model used to simulate the movement of vehicles from one link to the next one in their route (in TRAMOS, it considers “give way” priorities and traffic light regulations). Private vehicles move randomly through the network, keeping in mind the fact that flow volume proportions must be maintained for all turns in the network. Every time a vehicle reaches the end of a link, the model retrieves the number of vehicles that follow each one of the possible turns, data obtained from the macroscopic traffic assignment. These proportions are then used as probabilities, which will determine the next link to be entered by the vehicle.

To simulate the parking process both for private vehicles and for freight transport vehicles, the two following models were developed for TRAMOS:

- **Parking search model**: this model is used for determining whether vehicles are going to park in the link they are entering, and to assign parking spaces to them. The next sections will focus on carrying out a deeper description of this model, both for private vehicles and for freight delivery vehicles.

- **Parking model**: when a vehicle is approaching thane assigned parking space, its reference is set to it, which makes the vehicle change lanes and reduce speed until it stops in front of the space. Then the vehicle is extracted from the simulation after a certain time (parking manoeuvring time).

The integration of all these models, which results in the microscopic traffic simulation procedure, is represented on figure 1.

### 3 The parking search model

The parking search model for the microscopic traffic simulator reflects the process followed by a vehicle, whether private or for freight delivery, to choose a parking space in a certain link. The parking search model is used:
To determine, when a vehicle enters a link, whether it is going to park in it.
To assign parking spaces to vehicles: after it has been determined by the model that the vehicle will park in the link, it scans all available parking spaces in the link and assigns the best one for the vehicle to park in it.

Figure 1: Schematic representation of a microscopic traffic simulation algorithm.
For description of the parking search procedure, the different types of parking spaces existing in the network will be described in the first place, and after that the specific parking characteristics of both private vehicles and freight transport vehicles will be shown.

### 3.1 Types of parking places

When a certain vehicle enters a link in which it has to park, it searches for available parking spaces and chooses the one that best meets its needs, depending, among other aspects, on the type of parking spaces available. These different types of parking spaces that can exist in a link are:

- **Normal** parking space: available for all types of vehicles.
- **Load/unload zone**: available only for freight delivery vehicles, during certain periods of time.
- **Double-parking**: illegal parking space, which blocks the corresponding lane.
- **Parking on sidewalk**: illegal parking procedure that does not block the lane. It is frequently used for freight delivery stops, hence its introduction in the model.

*Normal* and *load/unload* parking spaces exist in the network a priori (that is, every link must have all these parking spaces assigned before the simulation starts). On the other hand, *sidewalk* and *double-parking* spaces are generated automatically every time they are needed by a freight transport vehicle (they will not be used by private vehicles) in front of their delivery destination point. The vehicle will then stay in parked for a given time length (necessary for delivery), and then continue the route, with the illegal parking space eliminated from the network.

It is possible to eliminate the possibility of generating *sidewalk* parking spaces in a link (to represent streets where parking on the sidewalk is not possible). In that case, *double-parking* would be the only illegal possibility for freight delivery vehicles to park close to their destination points.

When the vehicle enters a link where it has to stop, it compares the weights of the available parking spaces with the weight that would have *double-parking* or *sidewalk* parking in front of the delivery point. In case this type of parking had the highest weight, the *double-parking* or *sidewalk* space would be generated, and assigned to the vehicle for parking.

### 3.2 Private vehicles

Private vehicles will only park once during the simulation period, because private traffic assignments only consider routes between an origin and a final destination. Thus, in the simulation, every private vehicle is generated in a
certain link of the network (origin) and, after finishing its route, will search for parking in another link (destination), and will exit the simulation after parking. This is why illegal parking (double-parking and sidewalk) will not be allowed for private vehicles (a possible extension of the work would include developing a model for double-parking of private vehicles, to illustrate the capacity reduction in urban networks due to irregular parking patterns).

The decision to park for a private vehicle depends on the total distance covered since it was generated at its origin, estimating the maximum trip length typically as 1.25 times the width of the network. Then, every time the vehicle enters a certain link, the probability of parking in it is determined from a function like the one shown in figure 2, that takes a value 0 when the vehicle is generated and 1 for the maximum trip length.

By calculating a random number between 0 and 1 and comparing it with the parking probability, the decision of whether to park or not is made. Then, two scenarios can occur:

- There are parking spaces available in the link: the vehicle will choose the first one it finds and park there.
- There are no parking spaces available in the link: the vehicle will continue its route and park in the first available space it finds.

### 3.3 Freight delivery vehicles

Freight delivery vehicles, on the other hand, do not park only once, but several times along their route, depending on the different delivery points spread
throughout the network. These vehicles do not move randomly through the network, but the following data must be assigned to each one of them before the simulation starts:

- Origin link.
- Stops (link, position in the link and time spent at each one of them). The route that the vehicle will follow between them is then calculated via a shortest path algorithm.
- Destination link (which can be the same one as the origin, in case the vehicle follows a circular route).

At each stop, the freight delivery vehicle will search for the most suitable parking space available, including all different types of parking spaces. The choice will be made according to the type of parking spaces available and their distance to the final destination point in the link, represented as a series of weighing functions. These weighing functions were estimated according to the following assumptions:

- Legal parking is preferred to illegal parking: a load/unload parking space 20 meters away from the destination point will be equally preferred to a sidewalk parking right in front of it.
- Load/unload parking is preferred to normal parking: a load/unload parking space 15 meters away from the destination point will be equally preferred to a normal parking right in front of it.
- The choice between sidewalk parking or double-parking depends on the number of lanes in the link:
  - 3 or more lanes: double-parking is always preferred to sidewalk parking.
  - 2 lanes: a sidewalk parking space 15 meters away from the destination point will be equally preferred to double-parking right in front of it.
  - 1 lane: double-parking in front of the final destination only when there is no other space available in 50 meters.
- For long distances to the destination point, the type of parking space is irrelevant, the closest one to the destination will be chosen.

Following these assumptions, the weighing functions shown below were estimated. It is important to note that the actual weight value for each parking space is not relevant, but the choice will be made depending on the relative values for all the available parking spaces in the link. That is why the coefficients in the weighing functions could take different values, as long as their relative proportions were the same.

The parking space weighing functions (y) depending on the distance to the final destination point in the link (x) are:
- **Load/unload zone parking**: $y = 9.5 \cdot e^{-0.001x^2}$
- **Normal parking**: $y = 8.0 \cdot e^{-0.001x^2}$
- **Sidewalk parking**: $y = 6.5 \cdot e^{-0.001x^2}$
- **Double-parking (for single-lane links)**: $y = 1.0 \cdot e^{-0.001x^2}$
- **Double-parking (for two-lane links)**: $y = 5.0 \cdot e^{-0.001x^2}$
- **Double-parking (for three or more lanes in the link)**: $y = 7.0 \cdot e^{-0.001x^2}$

These expressions are shown graphically on figure 3:

![Graph showing the weight of different types of parking spaces depending on their distance to the final delivery point.](image)

**Figure 3**: Weight of the different types of parking spaces depending on their distance to the final delivery point (the distance takes positive and negative values to account for the fact that the parking space can be located before or after the delivery point in the link).

### 4 Test run

The work concludes with an illustration of the model operation, once it has been implemented in the TRAMOS simulator. To this effect, the test network represented on figure 4 was generated.
Three vehicles participated in the test, all of them generated at the beginning of link 1:
- Freight delivery vehicle F1, generated at simulation instant 0.5
- Freight delivery vehicle F2, generated at simulation instant 0.5
- Private vehicle P, generated at simulation instant 4

Figure 4: Test network for the experiment (3 links and 4 nodes).

The network characteristics in terms of predefined “legal” parking places, and the scheduled stops for the two freight delivery vehicles, are represented in tables 1 and 2. With respect to the private vehicle P, it has an assigned maximum route length of 250 meters.

Table 1: Parking spaces defined in the test network

<table>
<thead>
<tr>
<th>LINK</th>
<th>POSITION</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35</td>
<td>Load/unload</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>Load/unload</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>Normal</td>
</tr>
<tr>
<td>2</td>
<td>35</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>Load/unload</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>Load/unload</td>
</tr>
</tbody>
</table>

Table 2: Scheduled stops for freight delivery vehicles

<table>
<thead>
<tr>
<th>VEHICLE</th>
<th>LINK</th>
<th>POSITION</th>
<th>TIME LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>1</td>
<td>30</td>
<td>15 sec</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>40</td>
<td>10 sec</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>120</td>
<td>10 sec</td>
</tr>
<tr>
<td>F2</td>
<td>1</td>
<td>50</td>
<td>10 sec</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>120</td>
<td>5 sec</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>20</td>
<td>15 sec</td>
</tr>
</tbody>
</table>
The results of the test run carried out using TRAMOS are shown in table 3. It can be seen how the private vehicle \((P)\) does not park in the first link, but chooses to park in the second one, in the existing normal parking place. The first freight delivery vehicle \((F_1)\) makes its first stop at a load/unload zone, which is very close to its destination, but for the other two stops chooses to park in front of them on the sidewalk. The other freight delivery vehicle \((F_2)\) makes its two first stops with double-parking, since the first link has three lanes. For its last stop, it uses a normal parking space close to its delivery destination.

Table 3: Actual parking spaces chosen by the vehicles during the test run.

<table>
<thead>
<tr>
<th>VEHICLE</th>
<th>LINK</th>
<th>POSITION</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>1</td>
<td>35</td>
<td>Load/unload</td>
</tr>
<tr>
<td>F2</td>
<td>1</td>
<td>50</td>
<td>Double-parking</td>
</tr>
<tr>
<td>P</td>
<td>2</td>
<td>35</td>
<td>Normal</td>
</tr>
<tr>
<td>F2</td>
<td>1</td>
<td>120</td>
<td>Double-parking</td>
</tr>
<tr>
<td>F1</td>
<td>2</td>
<td>40</td>
<td>Sidewalk</td>
</tr>
<tr>
<td>F2</td>
<td>3</td>
<td>10</td>
<td>Normal</td>
</tr>
<tr>
<td>F1</td>
<td>3</td>
<td>120</td>
<td>Sidewalk</td>
</tr>
</tbody>
</table>

References


