Simulation of a Parking Phase for Urban Traffic Emission Models

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1 Introduction

This abstract introduces a methodology for the simulation of the characteristic variables during the phase of parking and insertion of a vehicle into the current flow leaving a parking lot. Research becomes part of an advanced program of disaggregated models developed by ENEA in order to evaluate polluting emissions due to traffic. ENEA collaborates with this kind of models in several European Projects (ISHTAR, HEARTS) in order to study integrated transport direct impacts in urban realities.

Traffic emissions in the atmosphere are tied to the searching time and temperature conditions of the engine. Searching time and warm – up time can assume many different values according to conditions of use, in particular if the phase of parking constitutes the initial point or the end of the path. The first phase of parking, the search of a free spot, happens at low speeds and the searching time is a significant percentage of the total time of movement (Axhausen and Polak, 1991), while the second phase, insertion into the current flow, is characterised by an engine that doesn't work in optimal conditions (cold start). Both of them have a strong impact on the environment.

Actually many models are based on the functions defined from the work group CORINAIR for the calculation of the fuel consumption and the emission of pollutants. The problem is that CORINAIR relationships depends only on total distance and they supply mean factors of emissions (Corinair Report, 1998). On the other hand most programs used in Europe are built from models created in foreign countries and it's difficult to apply them to Italian urban areas.

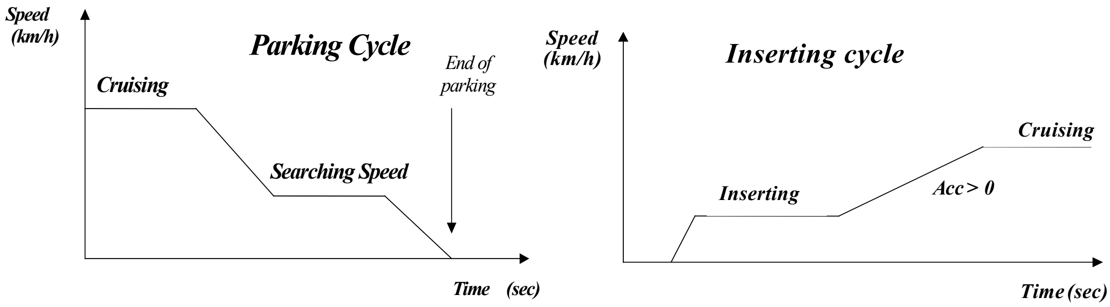

Figure 1: Parking Cycles

ENEA uses to estimate consumption and polluting emissions with a model of calculation called TEE. TEE is an innovative model of emissions aimed at providing detailed calculation of the several factors influencing vehicles fuel consumption and pollutant emissions. The particularity of this model consists in the fact that several kinematics options can be chosen to describe parking cycles and simulate driver's behaviour. This approach allows taking into account effective distribution of speed and some conditions of drive, as parking operations.

Parking in TEE is modelled through two speed–time cycles: a cycle of parking for customer looking for a free parking place and a cycle for customer who leaving its parking place (figure 1). Nowadays cycles in model TEE were characterised by constant parameters for any condition of flow or state of the net (Negrenti, 1996).

The contribution of this work is to estimate the parameters of a parking cycle in function of transient flow and network conditions, making an effort to define a number of models in order to calculate three main parameters: searching speed, searching time and time taken to raise warm up conditions.

2 Models for searching phase

Two models have been proposed to reach aims of project:

1. Searching Speed Model

2. Searching Time Model

1) Searching Speed Model

First model allows estimating searching speed like a function of parameters of net conditions and exiting free places in the destination area. Mean linear density of link (traffic congestion) and occupation rate are chosen in order to explain search speed in the study period of time. Behaviour models can be built with a classic statistical approach based on descriptive techniques, for example a Monte Carlo method. A statistical application requires an intense campaign of measures to supply a great number of data in order to define variable and its distribution of probability.

The decision was to exclude Monte Carlo approach and try to exceed these disadvantages pointing out a model based on fuzzy logic. Fuzzy theory is considered a valid approach to study human perception since early 60's (Zadeh, 1965). The decisional behaviour in the choice of a searching speed can be considered like a mechanism that uses, as input, subjective appraisals of some variable characterising situation of choice. In this case, occupation rate and density have been taken in consideration in order to explain the phenomenon. On a whole, a fuzzy system is formed by three essential sets that contribute to built the so called base of acknowledge.

1. Set of inputs: it contains the entire meaningful variable to explain the search behaviour. Each variable is defined by three membership functions that attributes at each value a real number $\in [0, 1]$ describing the degree at which real number belong to the set.
2. Set of output: it contains the definition of the searching speed means by three membership functions.
3. Matrix of rules with an interference MAX – MIN scheme to explain driver's behaviour, and it allows to associate input and output.

2) Searching Time Model

The second model estimates the time employed by a driver from the moment he decides to park until he finds a free space. A great number of parking models (Bifulco 94, Carrese – Gori 96, Coppola 91) are present in literature and many approaches have been used to understand and replicate parking choice behaviour. These models have been used to investigate parking policies, while the approach of this research is addressed to the study of the searching time in a known link, therefore it can't be represented with network models. Searching time will increase with the number of parked car and the occupation rate. The function will stretch asymptotically towards infinite when the number of occupied parking places is close to the capacity of the road or of the parking lot. Obviously a infinite time is not acceptable therefore one threshold of the maximum time has been marked. Searching time depends also another factor which the typology of parking.

In the parking model two great typologies of parking are considered: on street and off street. This research has started in the first moment with on street typology. Supposing an uniform distribution of the parking along a link, the user, once he reaches this arc, will proceed at searching speed, examining sequentially all the places until he finds a free one that satisfies all the conditions. The behavioural model of the searching time is then based on the analysis of probability number of attempts that a driver must carry out before finding a useful place to park. Relationship of searching time is the following:

$$T_{searching} = \mu \cdot \frac{L_p}{V_{searching}} = \frac{L_p}{V_{searching}} \cdot \frac{N+1}{occ_2 - occ_1} \cdot \log\left(\frac{N+1-occ_2}{N+1-occ_1}\right)$$

Where μ is the mean value of attemptings, N is the total parking places, Lp is the length of considered parking place Occ1 is the number of occupied places in the beginning of the study interval and Occ2 at the end of interval.

3 Models for searching phase

The third model, called Engine Warm Up Model (EWUM), deals with calculating how much time cold start transitory phase takes in function of ambient temperature, net end engine conditions. From a mechanical point of view cold start ends when catalyst temperature is high enough to allow chemical reactions to work correctly. Although a three way catalytic converts about 97% of the emissions of CO and HC, its efficiency is reduced for temperatures lower than 250° for carbon monoxide and 350° for the hydrocarbon emissions. Relationship to esteem time of warm up must have this functional form:

$$t_{warmup} = f\left(T_{amb,} T_{exh}, X_{i,exh}, T_{cat}\right)$$

where T_{amb} is the external temperature, T_{cat} is the temperature of the catalyst, T_{exh} is the temperature of the gas flow that leaves from the engine and catches up the surface of the catalyst, $X_{i,exh}$ is the concentrations of various pollutants entering into the catalyst (i= HC, CO, NO_x).
Engine Warm Up Model is formed by two models, the first points to study the heating of the engine and the second one aims to examine the thermal behaviour of the catalyst.

The first model has as purpose to supply the values T_{exh} and $T_{coolant}$ in the time. The model of heating engine esteem instantaneous consumption of fuel (Akcelik, 1982) and useful power developed in an interval of time in order to calculate the exhaust gas temperature. The intake air drawn into the engine is mixed with the injected fuel and burnt inside of engine. Some of combustion energy produces engine power and the rest is transferred to the ambient air, engine block, oil and engine coolant. In order to esteem coolant temperature, a coolant engine model has been defined. The second model, called Thermal Catalyst Model, studies the thermodynamic behaviour of a three ways catalytic converter. The model divides the system of drainage in three sections:

1. the landing zone between the motor and the catalyst where a convection thermal exchange with the surface happens,
2. the zone inside the catalyst where there are a conduction, a forced convection and chemistry reactions of oxidation a reduction of the pollutants,
3. the thermal exchange between the catalyst and the environment.

The equilibrium is expressed applying the first principle of the thermodynamics:

$$Q_{cat} = m_p c_p \frac{\partial T_{cat}}{\partial t} = Q_{gen} + Q_{in} + Q_s + \lambda \frac{\delta^2 T_{cat}}{\delta x^2}$$

where Q_{cat} is the heat transferred from the catalyst, Q_{gen} is the heat generated from the conversion of the pollutants inside of catalyst, Q_{in} is the heat transferred to the catalyst from the engine flow of drainage, m_p is the mass of catalyst converter and c_p is the specific heat at constant pressure.

4 Results and conclusions

Searching time and searching speed models have been applied to a number of real cases. In figure 2 searching speed in function of the speed flow (for some value of occupation rate) is shown. The shape of the curves is characterised by marked local oscillations and it seems to evidence an effect of the flow speed and occupation rate that are coherent with the expected results. Searching speed increases with link flow speed and decreases for bigger values of the occupation rate for the same value of speed. From figure 3, a clear relationship between flow speed and occupation rate emerges. The trend of the searching speed in function of the occupation rate is more homogeneous than that one in function of the flow speed

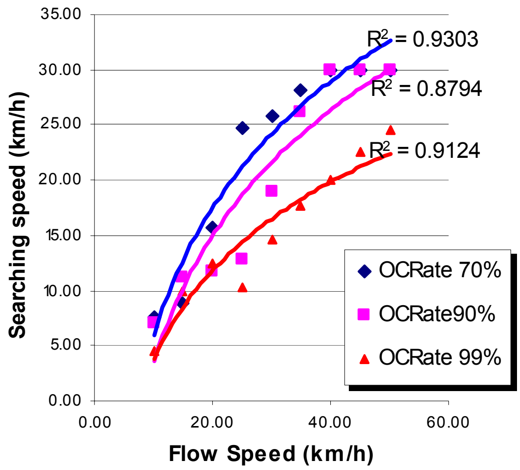

Figure 2: Relationship between searching speed and flow speed for several OC Rates.

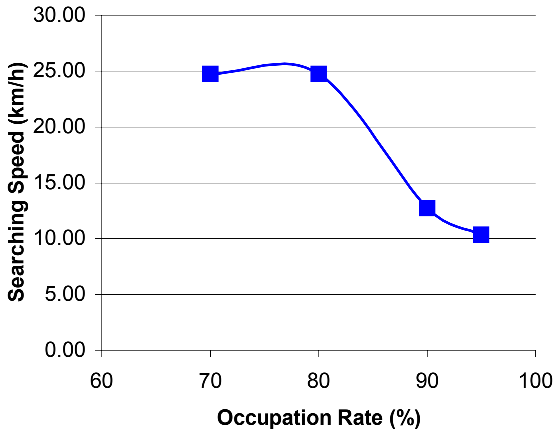

Figure 3: Relationship between searching speed and Occupation Rate

Results of the searching time coincide with the trend forecast from previous analyses (figure 4). The value of the variable is crescent with the increase of the number of occupied places, stretching asymptotically to infinite with the reach of the occupation rate to 100%. The maximum values of the searching time are around 20 minutes. In figure 4 the results of searching time in function of the occupation rate for some values of density (vehicles/km) are shown

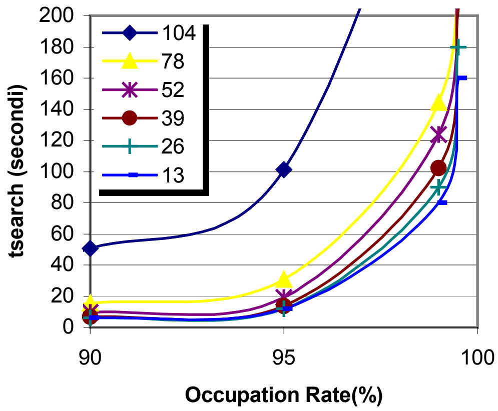

Figure 4: Searching Time and Occupation Rate for several densities.

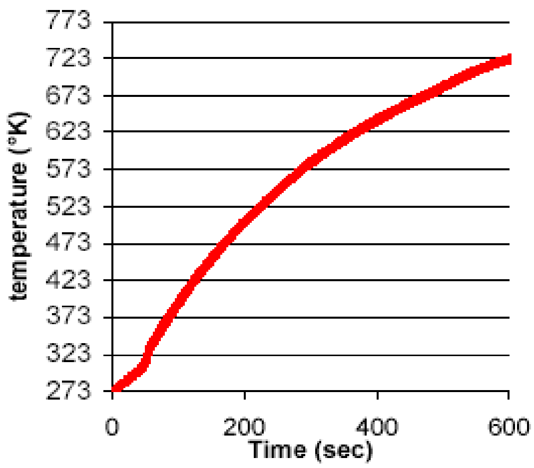

Figure 5: Catalyst Temperature.

The application of the engine model has been carried out on a catalyst converter of type TA-CC3. All of physical and geometric characteristics were known. Results obtained from the application are tested with experimental measures presents in literature (Shaw II, 2002) (Fig 5).

The next steps in the research will be a new model of searching time in an off street parking and when there are two types of parking (on street and off street) in the same link. The prosecution of the collaboration between Roma Tre and ENEA must conclude with the embedding of these models in the TEE software and successive application to different European Cases. The application of these models within the model of calculation TEE must allow a greater ability to estimate the vehicular emissions in the phase of parking and the cold start emissions.

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