Parking Search Model

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1 Introduction

The methodology proposed has been developed in the framework of the VPQ HEARTS project (Health Effects and Risks of Transport Systems) that address the need for more integrated methods for health risk assessment which consider the full range of exposures and health effects and can be applied in the policy or planning process.

Parking and re-entering traffic are a source of traffic congestion and pollution: half of the cars driving downtown during peak hours in heavily congested areas cruise for parking . Parking, on street and off street, can create pollution problems regarding additional emissions because of vehicle movements at low speed and low gear, number of decelerations and accelerations, long searching time, low temperature of engine during cold and warm start operations or presence of ramps on parking lots [2].

The behavior of the parking and inserting vehicle flows (going to and leaving from parking areas) can be described by means of simplified speed cycles, based on the vehicle kinematics during the parking and the re-insertion. Parameters defining the shape of such cycles are searching speed, searching time and time of warm up, on which our research is focused.

Parking search phase is represented by dedicated ‘searching speed’ and ‘searching time’ models. Such models are further split in two sub-models depending on the category of parking: on-street and off-street. In the on-street parking, searching speed is modeled by a fuzzy model as a function of the linear traffic density and the occupation rate of the parking facility. Searching time for on street parking uses a probabilistic approach to calculate the searching time based on the occupation rate of the link connecting parking areas and searching speed.

The second aspect related to parking emissions is the cold start phase. For this specific phase a model to calculate the time of warm up, the start up temperature and the cold start fraction have been proposed and validated.

The next step concerns the validation of the models with the data collected during a experimental campaign conducted in conjunction with the IM-CNR in Naples and it has been conceived to simulate parking with an board sensor car in a set of streets monitored by traffic cameras at the intersections. Monitoring cameras in the street provide traffic data as flows and speeds that are necessary to correlate the results given by the models.

The software version developed in the HEARTS Project has been tested in the city of Florence for the analysis of the effects of various transport measures and the most representative results have been reported in the paper.

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2 Methodologies and simulation results

2.1 Simulation of parking

Parking search phase is represented by dedicated 'searching speed' and 'searching time' models. Such models are further split in two sub-models depending on the category of parking: on-street and off-street. In the on-street parking, searching speed is modeled by a fuzzy model as a function of the linear traffic density and the occupation rate of the parking facility. Searching time for on street parking uses a probabilistic approach to calculate the searching time based on the occupation rate of the link connecting parking areas and searching speed. Searching time model estimates the time employed by a driver from the moment he decides to park up to he finds the first available space lot to park. Given an uniform distribution of the parking along a link, the user, once he reaches this arc, will proceed at searching speed and examine sequentially all the places up to he finds the first free slot. The 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.

The methodology is extended in order to consider parking off street and a detailed simulation of choice of parking place is proposed to reproduce the vehicle movements from entrance to the parking lot. The model is still in a validation stage and it has not been included in the paper.

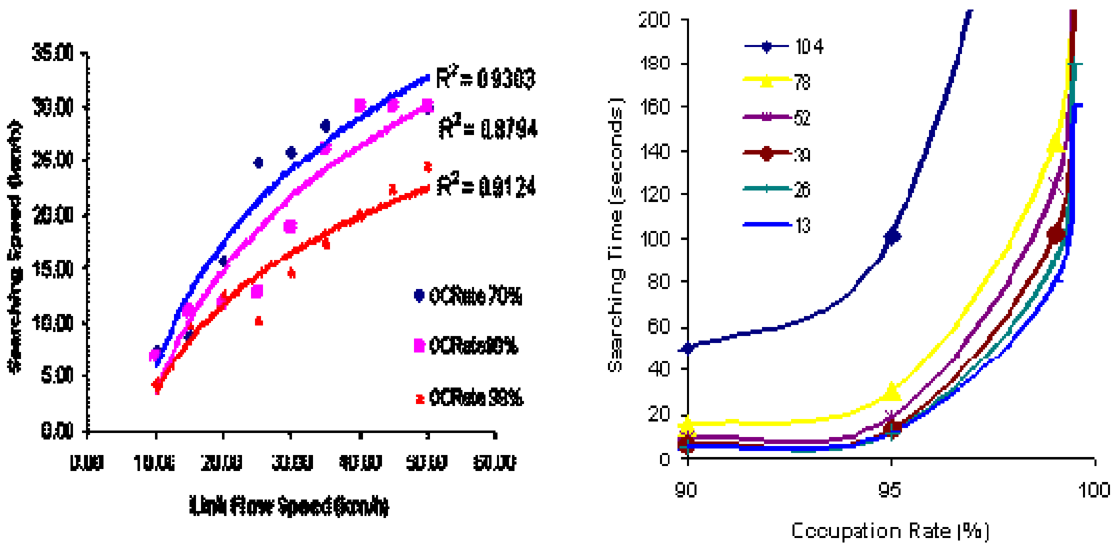

Figure 1: Relationship between searching speed as function of flow speed for several occupation rate (OCRate) on the left and relationship between searching time and occupation rate on the right.

2.2 Models for the cold start phase

The variables influencing car emissions in the cold start phase are the temperature of the engine and the chemical conversion of catalyst. In order to provide this information, a set of models has been set up:

1. Engine Warm up Model to simulate the vehicle cooling profile
2. Thermal Catalyst Model
3. Temperature of Start Up

The application of this models in a traffic simulation provides useful information about time of warm up, rate of catalyst conversion and vehicular cold start fraction (number of cars cruising in cold start conditions) in a link that allows to properly analyse the cold and warm emissions.

3 Validation of models with survey data

The next step concerns the validation of the models with the data collected during the field survey. The experimental campaign has been conducted in conjunction with the IM-CNR in Naples and it has been conceived to simulate parking in a set of streets monitored by traffic cameras at the intersections. Monitoring cameras in the street provide traffic data as flows and speeds that are necessary to correlate the results given by the models.

The car used for the measures is a Fiat Punto that it has been equipped with an on-board system that allows the data acquisition of engine, vehicle and geographic position by means of a GPS receiver. The system supplies monitoring position, instant speed, gear, engine and catalyst temperature second by second by means of a data acquisition program developed with Labview. The engine variables have been used to validate the models regarding the time of warm up and the vehicle and kinematics variables have been used for the validation of searching models, i.e. searching speed and time.

The data were collected during the last week of January 2006 from Monday to Friday in the peak hour morning (9- 11 AM) and in the afternoon (14-16 PM).

The first validation regards the vehicle cooling profile for validating the time of warm up. Two kinds of validation have been achieved: time of warm up in cold start conditions in the morning when temperature of engine was equal to temperature of ambient, and time of warm up in warm conditions in the afternoon after two or three hours of pause. In this way it has been also possible to validate the model concerning the temperature of start up after vehicle is parked for a period of time (i.e. parking duration).

The first results from the field survey show an accurate calibration of simulated vehicle heating profile. The simulated and observed measures are linearly correlated with a R^2 over 0.90 for any temperature of start up during the phase of warm up. The vehicle cooling profile model offers a good approximation of temperature of start up with an error non exceeding 20% in all considered cases.

The validation of searching models requires the use of available traffic data in the monitored streets. The first results of the validation show that models fit quite properly the phenomena.

The searching speed model is correlated with a R2 of 0.405 (figure 3) considering all the sample. The searching speed depends on linear density and the occupation rate. After a detailed analyze of the sample, the measures with a major error or worse explained by the model are the speed related to small densities in the sample (around 60 veh/km). In fact, if only the densities superior to 80 veh/km are considered (85% of

the sample) the R2 of the correlation is 0.698, reaching a R2 equal to 0.73 densities greater than 90 veh/km (figure 3).
The model fits accurately the searching speeds related to high densities. However the small densities are not well explained by the model. The only reasonable explanation is the calibration of the current fuzzy model that penalizes the low densities. The experimental data will be used to recalibrate the model in order to define the new membership functions.

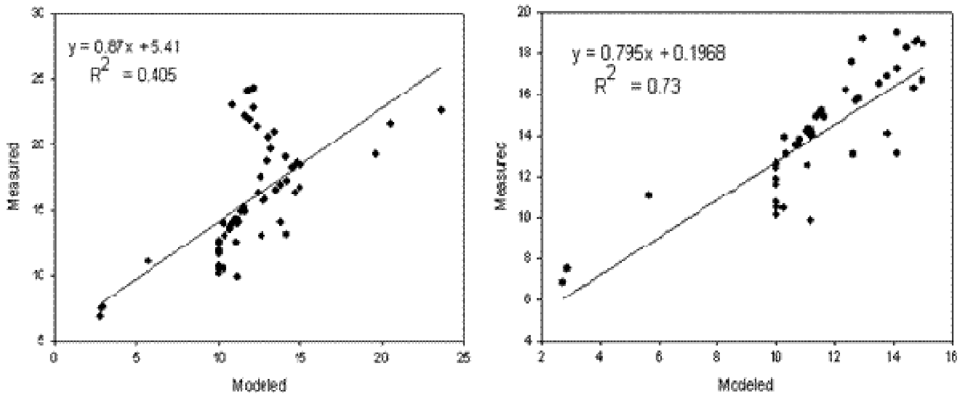

Figure 2: Correlation of measured and modeled searching speed (left) and correlation of measured and modeled searching speed for density greater than 90 veh/km (right)

The modelled searching time is correlated with experimental data with a R2 of 0.52 and results show the difficulty of simulating the phenomena with a discrete probabilistic approach. The model tends to overestimate the searching time, and only in a small number of cases the time is hugely underestimated. The correlation of searching time is shown in figure 4.

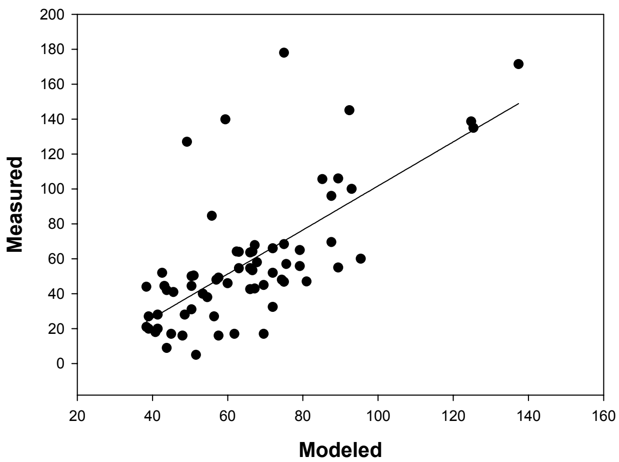

Figure 3: Correlation of measured and modeled searching time

4 Application of models in the case study of Florence

The model has been applied in two scenarios: current 2003 scenario and in a future policy scenario 'year 2010'. In synthesis, the most important changes in the forecast fleet are the insertion of future new micro-classes of vehicles according to EU standards and the very high reduction of the old 2-strokes mopeds (PRE EURO) with the increase of 4-strokes motorbikes. To run TEE emission model it is necessary to complete the information obtained from traffic model EMME2 used in Florence. We need the traffic flow for the other hours of the day (hourly profiles) and the traffic flow for the other travel modes (i.e. two wheelers, duty vehicles, touristic coaches and extra-urban buses etc.). Moreover we need some data relating to the geometric characteristics of the links (e.g. link length, mean slope of link, etc.) and other data on traffic type of the link (link class, location and timing of traffic light, link area type, availability of parking and number of parking places etc.).

For each road category we know the hourly profiles of total vehicular flows; from direct measurements on sample roads we estimate the subdivision of total flows in sub-flows of macro-classes of vehicles. The number of vehicles belonging to micro-classes is obtained by splitting the total flow of a macro-class into single micro-classes flows according to the "weight" of the micro-class.

On each node of the network we calculated the balance of input and output vehicles from all the links connected to the node. The node is defined as "parking" or "inserting" whether input vehicles are larger than outgoing ones and viceversa. For parking nodes, the difference between input and output vehicles divided by the total number (input+output) of vehicles yields the percentage of parking vehicles assigned to the node considered. For inserting nodes we used the difference between output and input. It is clear that these values are a lower bound for link parking (inserting) vehicles. In addition to these data, a fixed rate for both inserting and parking vehicles is assigned to each link of the network. We have geo-referenced in a GIS framework the main concentrated parking areas of Florence town, with the related properties (number of car places, mean time of parking, hourly percentage of filling up etc.) obtained from data given from the local authority and management. Finally we have assigned link parking places by GIS calculation routine.

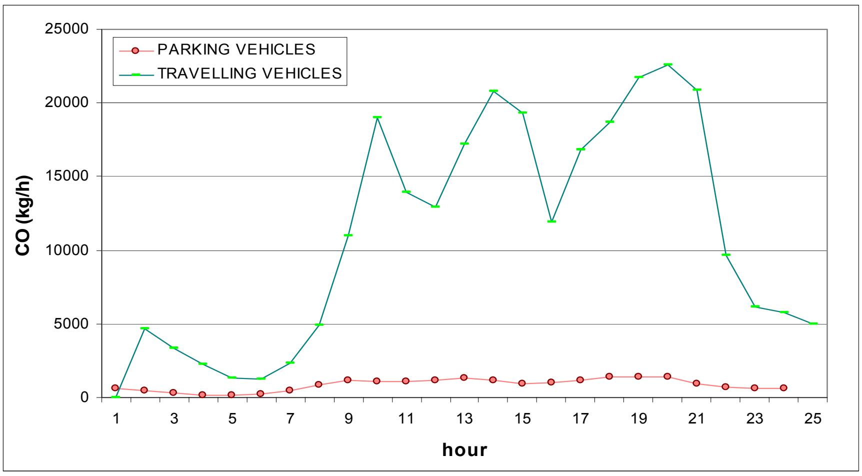

Figure 4: Hourly CO concentrations (June 2003) measured by an air monitoring station and those modelled by OSPM model and TEE with KCF (top) and average speed (bottom) kinematics options.

5 Results and conclusions

The methodology is a first step in order to characterise the parking procedures and its environmental and transportation effects. The validation of models with survey data offers an opportunity to evaluate the robustness of the methodology and brings out new prospective to deep and improve the models. The first validation has provided several correction factors that improve the accuracy of the simulation and they have contributed to calibrate the models and demonstrate that methodology is appropriate to study the problem. The results encourage the next step focused on improvement the detail of the approach using new experimental data.

Next step will regard the calibration of parking fuzzy model with a Neural Network approach in order to avoid using a fixed matrix of rules, and validation of parking off streets with a new field survey.

6 References

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