REDUCE ENVIRONMENTAL IMPACTS BY OPTIMIZING THE PROCESS OF GOODS DELIVERY

BOUSSIER, Jean-Marie, Département LOG, EIGSI, La Rochelle, France and Laboratory L3I, University of La Rochelle, France

CUCU, Tatiana, Département LOG, EIGSI, La Rochelle, France and Laboratory IMS, Dep LAPS - Groupe GRAI, University of Bordeaux 1, France

ION, Luminita, Département LOG, EIGSI, La Rochelle, France

BREUIL, Dominique, Département LOG, EIGSI, La Rochelle, France

ABSTRACT

The main objective of our works is the specification and design of a software tool for the management of a fleet for goods distribution in small and medium sized cities. This paper focuses on the modelling of the management process of the sharing the parking places between private cars and vans for goods delivery. The activity-based model and multi-agent paradigm have been chosen in order to capture the interactions between the transportation network users. The end-user can simulate scenarios in agreement with local traffic regulations, the capacity of the infrastructure and the routing alternatives. A study case shows the environmental benefits after the implementation of a strategy for places sharing.

Keywords: goods delivery, agent-based simulation, modelling, city logistics, environmental impacts

1. INTRODUCTION

Small and medium sized cities, built around an historical centre, are quite often rich with several types of shops as well as craftsmen and small industries. The urban goods distribution is vital for the prosperity of inner cities and must be done when the customers need it (it means frequently during peak hours when the congestion level is important). The lack of dedicated places for delivering or the dedicated places which are blocked by private cars which have not found another available parking place induce the increase of travel delays, lower quality of delivery process.

On the other hand, the congestion created by vans stopped on street (delivery duration is about 10 minutes in the most cases) involves a pollution peak by several cars which wait with

running motors. This uncomfortable situation is associated to nervous state of the drivers, and sometimes with dangerous actions for traffic safety.
In practice, there are two strategies to decrease the congestion level due to goods distribution in the proximity of the delivery area: 1) to share the street when several lanes exist (some experiences exist in U.K. for parts of bus lanes shared with freight transport). But within urban areas of small or medium sized cities there are only limited opportunities to enhance physical capacity of road infrastructure at surface level. 2) to share the parking spaces between the vans for goods delivery and private cars. This solution seems be more appropriate for small cities. Our proposal is to analyze the impacts (traffic and environment) of a spatial and temporal dynamic booking of on-street stopping places (to park or to deliver). In order to capture the impacts of network users interactions, behavioural models must be built. The optimization of the goods delivery activities must take into account all actors: freight vans and private vehicles. For that, simulations seem to be the most appropriate in order to capture the impacts of their coexistence.
The main objective of these works is to design a software tool for local authorities in order to optimize the spatial and temporal sharing of the parking places between private cars and freight vans.
This paper is organized as follows. The second section gives a brief overview about previous works treating about the interactions between vans and private cars. In third section, are described the main principles of an agent-based demonstrator taking into account the interactions between the network users. A study case is presented in section 4 and points out the environmental advantages of this strategy. Section 5 is dedicated to the analysis of our approach and the presentation of works in progress. Finally the main conclusions and perspectives are presented.

2. LITERATURE REVIEW: COEXISTENCE OF PRIVATE VEHICLES WITH VANS OF GOODS DELIVERY

Generally studies are focused on the generation of freight or on itinerary of vehicles. Several researchers [List1994], [He1998], [Gorys1994], [Harris1998], [Holguin-Veras2000] have try to integrate the trips of private cars by using the gravitational model, four-steps model and input-output models. Oppenheim [Oppenheim1913] attempted to develop a combined approach considering the passenger travels and goods movements with a spatial equilibrium model. But, once again, this kind of models needs a lot of data. More recently, Munuzuri [Munuzuri2004] proposed a methodology based on entropy maximization in order to build an Origin-Destination (O-D) matrix for freight transport taking into account house deliveries and deliveries within several branches of industry. Thompson and Taniguchi [Thompson1999] have tackled the problem of vehicle routing inside the city.
The interest of the development of operational research taking into account the vehicle routing is in progress because of the improvement of computers and ITS (Intelligent Transport System) technologies (Yannis [Yannis2006]).
For generating and for controlling urban goods transport, simulation tools have been developed. Main functional tools are Freturb© [LET2001] (France), Goodtrip©

[Boerkcamps1999] (Netherlands), Wiver© [Meimbresse2000] (Germany) and Distra© [Inregia2003] (Sweden). These four tools are based on different dynamics: Econometric models to compute key figures without any spatial distribution; Transport Demand Models to compute traffic volume per area (only lines and columns of O-D matrices); Transport Distribution Models in order to compute complete O-D matrix. The models which compute traffic volume per hour could be interesting but very hard to implement because of the necessity to build a dynamic origin-destination matrix.
Few works have treated the congestion created by freight vans during the goods delivery and the problem of parking policy (on-street) is frequently neglected.
Numerous city-specific parking studies have been undertaken and many research works have been done mainly referring to descriptions of parking patterns, effects of on-street parking as well as strategies of parking regulations or parking cost (see [Kurri2004] for a good analysis). Few models have focused on searching of parking place [Arnott2005]; in those, urban areas are simplified and spatially homogeneous. The interactions between vans and light cars can not be captured.
In traffic simulation, several mathematical approaches can be successfully applied: discrete choice models [Ben-Akiva1999] based on maximisation of utility of a driver, stochastic models, hierarchical models or recently, techniques based on artificial intelligence such as the Bayesian approach [Verhoeven2005] or neural networks [Xie2003]. Generally, works concerning car park activities are designed by using the utility-based model where the user satisfaction is associated to the cost minimization [Dell'Orco2003]. Recently, the multi agent paradigm showed that it is able to capture with a lot of realism the behavior of road network users and the consequences of their interactions in a dynamic environment. A great number of individual agents can be treated in a consistent simulation framework. In past years, multi agent systems have been successfully applied in building distributed intelligent systems in various domains, in particular, for designing traffic simulators. There are a few operational tools based on activity based-models and using the agent technology [Arentze2000], [Nagel2003] but problems about car parks are vaguely treated or simply neglected.
The problem of most part of approaches is to capture the behavioural changes faced with new situations. Few works based on multi-agent paradigm are done for the simulation of goods transportation process [Cavezalli2003], [Wisetjindawat 2007] but the impacts of the interactions between the road network users during the goods delivery process are difficult to be simulated because of the lack of a behavioural models

3. SIMULATION OF THE SHARING OF THE PARKING PLACES

3.1. Principle of the sharing

Our proposal is to analyze the impacts of a spatial and temporal dynamic booking of on-street parking places (to park or to deliver). The basic idea is to decompose the on-street parking places in several units; the basic unit can be the street or a part of the street. the on-street parking spaces could be shared between road network users as follows:

- Each day, before the beginning of goods distribution, the on-street places are reserved near the delivery site. The length of vans is taken into account. It is the spatial booking.

- Reservations are done only for periods of delivery; each period is computed according the tour planning of each known supplier. It is the temporal booking.

When on-street parking places are not reserved, there are available to park individual cars under some conditions.
To avoid conflicts, variable message panels (VPM) must display information about the state of each place (e.g. reserved, available with authorized duration of the stop, ...). Car drivers can identify available places to park their individual cars and conditions (hour of the end of the parking). Indeed, the authorized parking places must be available before the beginning of the delivery. If the place is not available for the delivery, the police office is informed by an alarm in order to evacuate the vehicle if possible. Similarly, freight drivers identify the reserved places to deliver goods according the day period.
Our solution could be interesting for local authorities who want to keep parking incomes and to reduce the congestion and so to decrease the pollution created by the search of an available place.

3.2. Main agents: rules and behaviours

Figure 1 presents the main agents and interactions between agents concerned by the occupation of the street during the delivery process.

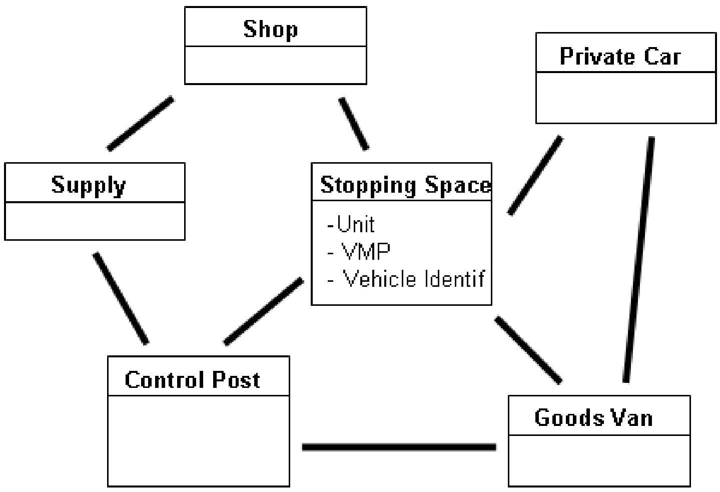

Figure 1 – The main reactive and cognitive agents concerned by the sharing of parking places

3.2.a-) Reactive agents:

They have a partial perception of their environment and they react directly to stimulus.

<u>Control post:</u> this agent receives from the agents "supply" some information such as: the address and number of customers, number of parcels, itinerary, hour of arrival, average duration for delivering.

<u>Control agent (named Stopping Space):</u> Each unit of parking places is supervised by a control agent (named Stopping Space) in order to book on-street places for deliveries. It is autonomous to adapt itself to environment changes and to communicate with a control post for the area (or the city according the decomposition level). It communicates with agents “private cars” and “Goods vans” by using the same principle than Traffic Signalling Control (e.g. traffic light) of Intelligent Traffic Management.

Each control agent is associated to an object VMP (Variable Message Panel). It indicates the status of the parking space for drivers and the duration of the delivery process. In the same time, this agent can recognize the type of vehicles (agents) and can alert, if necessary, the “police”. Its role is to manage and to control the set of parking places of a street or a part of the street. Figure 2 shows the different states of an agent “Stopping Space” in the simulator.

<u>Shop agents:</u> interact with Stopping Space agents to define the location and the duration of the delivery process.

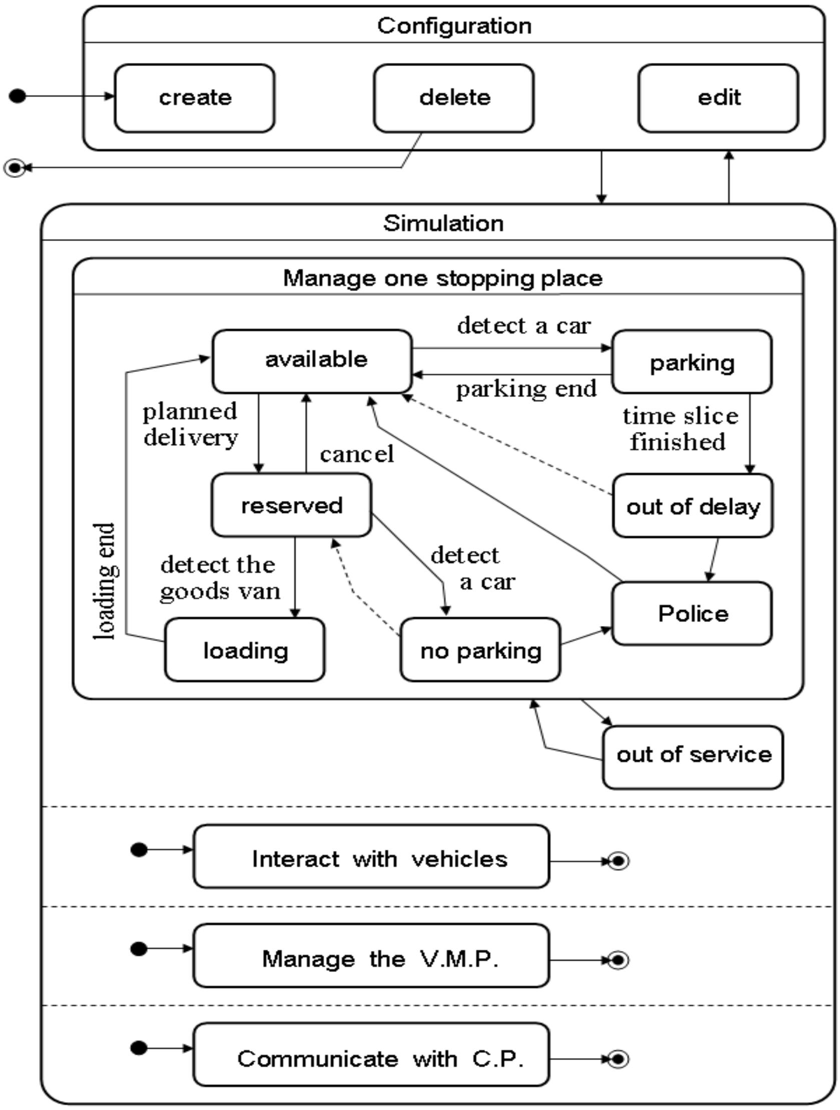

Figure 2 – State diagram of a “stopping space” agent

3.2.b-) Cognitive agents:

They have an explicit representation of their environment, are able to negotiate and to learn from past experiences (learning mechanism).

The drivers of goods delivery vans: Before the beginning of the deliveries, each agent has an agenda containing the destinations for the delivering process, the itineraries, the dedicated places for delivering in agreement with the length of the van and the expected duration of the delivery process. Their behaviour is simple and don’t necessitate a learning mechanism

Drivers of private vehicles: Experimental studies support the notion that seeking for a parking space is not a random procedure, but an activity undertaken by the driver for a specific purpose having a pre-set objective and which is based on certain individual decision rules. In multi agent simulation, the analysis of travel behaviour is typically disaggregated so it means that a decision-making model must represent the behaviour of each traveller. The simulation is the result obtained from concurrent execution of the various agents' behaviours taking into account the feedback process: in this case, the multi agent system becomes more complex to represent than the system itself. A solution to outline it could be to ensure the hypothesis that the “individual” decision-making entity depends on the particular application (for example, a household or an organization in order to ignore all internal interactions within the group and to consider only decisions of the group, as an entity).

We assumed that there are two types of drivers of light cars: having an urgent activity with temporal constraints (work, meeting, etc) or having one flexible activity (shopping, recreational activities…).

Arriving to a car park near its destination, the driver of private car has 2 possibilities (see Figure 3):

- if a place is available, the agent can park the car ;
- if no place is available (or the stopping agent gives a duration of the place dedicated for goods delivery less than the duration of its activity). In this case, the agent has 4 choices (to do loops by waiting an available place, to search another car park, to choose an illicit place or to defer the activity).

Figure 3 – The possibilities of a driver agent when they go to a car park in order to carry out an activity at a location

We are specially interested by the alternative "no place is available" (with its 4 potential choices) which could be source of conflict between the drivers of vans and the drivers of private cars.

For designing behavioural models, we have used data obtained from stated preferences surveys. Such kind of questionnaire is strongly indicated to identify significant criteria into a decision-making process and to test new strategies. A criterion can be a quantitative indicator (e.g. parking duration) as well as a qualitative indicator (e.g. type of activity). The levels of a criterion are values (or modalities) of this criterion which are to be analyzed in the studied range.

In order to draw the maximum amount of information, a full matrix of questions is needed and contains all possible combinations of internal criteria at all levels. Let us suppose a questionnaire to test the effects of 7 input criteria, each one having 2 levels. A full array with 128 questions would be strongly inappropriate for this kind of analysis. The solution is to use an orthogonal factorial which is a subset of full factorial design (it means that one model must be built in order to evaluate all untested scenarii). For a jointly analysis of the effects of the criteria and the interactions, the questionnaire must contain particular combinations: each level of each criterion must be present an equal number of times, each combination between the levels of two distinct criteria appears an equal number of times. Simultaneous variation of several input levels of criteria may have interactive effects on the studied response. When the effect of a criterion depends on the level of another one, an interaction exists. Taguchi [Taguchi1987] provides many standard orthogonal arrays and corresponding linear graphs in order to affect columns for input criteria and interactions.

One example is presented in Figure 4.

Actions: criteria or interactions

Question	A	B	C	D	E	F	G
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

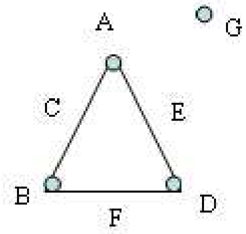

Figure 4 – the fractional array L8(2)7 and one of its linear graph (columns attribution : nodes for criteria and arcs for interactions)

For our analysis suppose four input criteria:

- walking distance with level 1 : “<200m” and level 2 : “>200 m” (named A),
- parking price/hour with level 1 : ”< 1 Euro” and level 2 : ”> 1 Euros” (named B),
- type of activity with level 1 :“urgent” and level 2 : “flexible” (named D),
- duration of activity with level 1 : <“20 min” and level 2 : “>20 min” (named G).

The linear graph also agrees to evaluate interaction between three criteria: AB, AD and BD.

Placed in hypothetical scenarios, respondents (drivers of private cars) are asked to assign a preference modality for scenarios obtained by different criteria at different levels.
The response to be studied (output criteria) is the “choice frequency” (captured by semantic modalities such as “sometimes”, “rarely” …). See one example in table I.
For example the scenario 6 submitted to respondents is: “distance is >200 m, price is <1 Euro, the activity is urgent and the duration of the activity is > 20 min”.
The responses of one respondent for this scenario are (see list in figure 5):

- for “to do loops” : frequently,
- for “choose a second car” : sometimes
- for “illicit place” :rarely
- for “defer the activity” : sometimes

Line from $L_8(2)^7$	To do loops	To choose the 2nd car park	To choose an illicit place	To defer the activity
1	very freq^{tly}	sometimes	frequently	rarely
2	...	...	...	...
3	...	...	...	...
4	...	...	...	...
5	...	...	...	...
6	very freq^{tly}	sometimes	rarely	sometimes
7	...	...	...	...
8	...	...	...	...

Figure 5 – Example of responses given by a respondent for the 4 potential choices

For each potential choice, a model must be designed for the drivers of private cars by the aggregation of all responses. After a statistical filter of "aberrant" responses collected by questionnaire, the fusion of information is done with Dezert-Smarandache theory [Smarandache2004]. It is a new extension of Dempster-Schafer theory [Schafer1976] which efficiently takes into account the doubt during a decision-making process and the conflict between information sources. The fusion process (presented in our past works [Boussier2009] is briefly described below.
Let us take

$$\Theta = \{ H_1, H_2, H_3, H_4 \} \qquad (1)$$

being the set of hypothesis which make up the frame of discernment with Hi potential choices. In our case:

$$\Theta = \left\{ do\ loops,\ 2^{nd}\ \ car\ park\ ,\ illicit\ place\ ,defer\ \ activity \right\}. \qquad (2)$$

One response is done for each alternative by each respondent and can be among: very frequently (VF), frequently (F), sometimes (S), rarely (R).
The assigned probability $m_\Theta(A)$ measures the belief exactly assigned to A and represents how strongly the evidence supports A. A basic probability assignment is a function which is called a mass function and satisfies:

$$D^{\Theta} = \{\Phi, H_1, \dots H_1 \cup H_2, \dots \Theta\};\ m_{\Theta} : 2^{\Theta} \rightarrow [0,1];\ m_{\Theta}(\Phi) = 0\ ;\ \sum_{A \subseteq \Theta} m_{\Theta}(A) = 1 \qquad (3)$$

where D^Θ is the power set of Θ; Φ is the null set; A is any subset of Θ, $m_\Theta(\Theta)$ is the degree of ignorance. The mass assignment is proposed, in agreement with a linear utility function is m(VF)=0.4; m(F)=0.3; m(S)=0.2; m(VR)=0.1.
No classification is asked in order to ensure the evolutionary character of the models, and it means that a respondent can give the same evaluation for different alternatives. In this case, the doubt of respondents can be taken into account. A discounting operation, done before the fusion, consists in taking into account the reliability of source (respondent) Rj (αRj).
The discounted belief function is:

$$\forall A \neq \Theta,\ {m_\Theta^{R_j}}^{\alpha}(A) = \alpha^{R_j} \cdot m_\Theta^{R_j}(A)\ ;\quad {m_\Theta^{R_j}}^{\alpha}(\Theta) = \left(1 - \alpha^{R_j}\right) + \alpha^{R_j} \cdot m_\Theta^{R_j}(\Theta) \qquad (4)$$

where α is an coefficient defined according to:

$$\alpha = \left(1 - \frac{n-1}{N}\right) \tag{5}$$

with n –number of alternatives having the same response, N – number of studied alternatives. People who give different responses for all alternatives is a "decided" person (α=1); for people who give the same answer for all alternatives, the mass is strongly discounted without completely reject their opinion (α=0.25 if 4 alternatives have the same response).

After the successive application of the fusion rules, a single belief function is obtained for all focal elements and subsets of the discernment framework. Finally, for each scenario, the mass of the subsets which are not singletons is redistributed by the pignistic transformation [Smets1994]:

$$\forall\, H_i \in \Theta, \quad P_\Theta(H_i) = \sum_{\substack{A \in 2^\Theta \\ H_i \subset A}} \frac{1}{|A|} m_\Theta(A) \tag{6}$$

where $P_\Theta(Hi)$ is the pignistic probability for Hi; |A| is the cardinality of A.

In order to give a global evaluation for each scenario j and each alternative k, a score is defined:

$$S_j^k = \lambda \cdot P_\Theta{}^j(H_k) \tag{7}$$

where λ is an arbitrary crisp value and $P_\Theta j(H_k)$ is the pignistic probability of the alternative k belonging to the scenario j. Finally a score is obtained for each scenario of the array and for each alternative.

The simulator must be able to simulate scenarios not tested by the respondents (there are only 8 questions for 128 possible combinations when the number of tested criteria is 7). We adopted a model based on Analysis of Means (ANOM) proposed by Vigier [Vigier1988] in order to design the score function. It is an additive model with effects of criteria and interactions:

$$S = S_{av} + (a_1 \quad a_2)A + (b_1 \quad b_2)B + \ldots + \begin{pmatrix} a_1b_1 & a_1b_2 \\ a_2b_1 & a_2b_2 \end{pmatrix} AB + \ldots + \varepsilon \tag{8}$$

with $a_i = S_{av}(A_i) - S_{av} \quad ; a_ib_j = S_{av}(A_i, B_j) - S_{av} - a_i - b_j$

where S_{av} is the average of all scores; a_i are matrix elements representing the effects of criteria A at level i; a_ib_j are matrix elements for the effect of the AB interaction when A is at level i and B at level j; $S_{av}(A_i)$ is the average of all scores where A is at level i; S_{av} (A_i, B_i) is the average of all scores when A is at level i and B at level j.

To improve computing time, the analysis of variance (ANOVA) is used. This phase is very important for the efficiency of the simulation: insignificant information will be not communicated to the agents "drivers of private cars".

By using this model, the simulator can compute the score associated to any combination untested.

For example, for a scenario with only two criteria (A at level 1, B at level 2), the determinist part of the model gives:

$$S\ (A1,B2) = S_{av} + a_1 + b_2 + a_1 b_2 \qquad (9)$$

Finally, 4 different behavioural models have been built for each possible choice when no place to park is available (do loops, search a 2nd car park, search an illicit place, defer the activity- figure 5). For the first simulation and for a given scenario (price, walking distance, etc), according to the utility theory, the agent will select the alternative having the higher score. This choice is the same for all drivers of private cars but interactions during the first trip and parking process could change the choice for the next simulation etc.

Indeed, one of the interests of the agent-based simulation is that the behaviour of each agent can change thanks to a mechanism called learning. It is well known that the result of a choice previously done can be affected by external conditions as accessibility, safety, traffic information, which are independent of input variables.
A jointly study of the effects of input variables and external conditions must be done. For that, we used a combination between two arrays: inner array (input criteria) and outer array (external criteria); see one example in Figure 6.

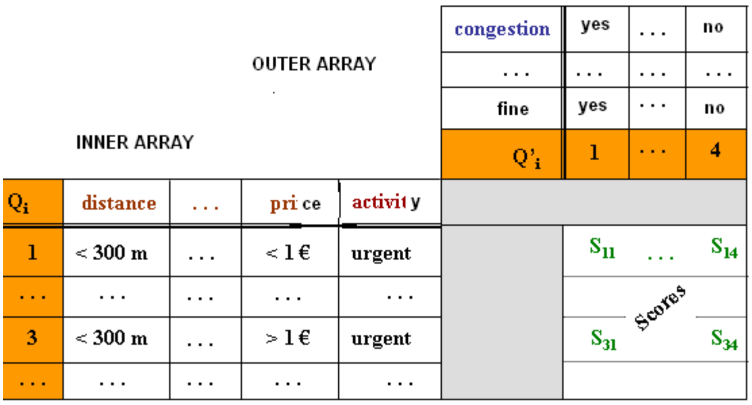

Figure 6 – array to establish links between variables about behaviour of driver agents

After choosing firstly one alternative (for example, illicit parking), the fact to have one fine (external criteria) could change the score of this alternative and his choice for the next simulation (for example, to choose a second car park). For that, a jointly study of effects of input criteria (known before the trip beginning, e.g. the distance, the price, the duration of delivery ...) and external criteria (result of interrelations between agents, e.g. congestion, fines…) must be done. The principle of the learning mechanism based on stated preferences analysis is illustrated in Figure 7. It has been presented in an exhaustive manner in our past works [Boussier2009])

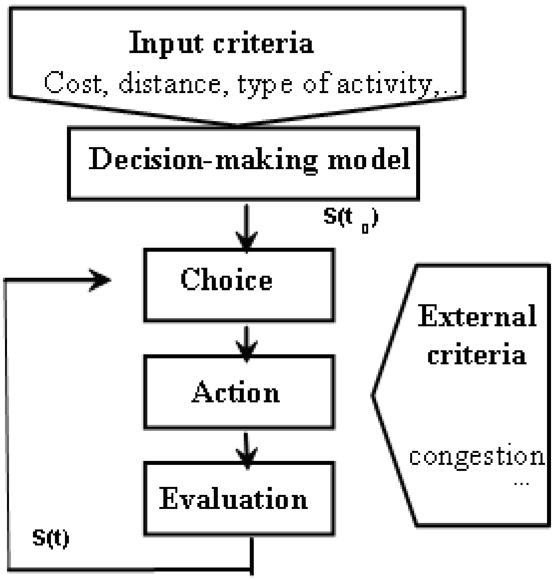

Figure 7 – Decisional and learning mechanisms

Based on these dynamic behavioural models, the end-user of the simulator is able to test several scenarios for different occupancy rate of the places dedicated for goods delivery, durations of the delivery process. He can capture the interaction between the actors of a car park (on-street or off-street) and compute the consequences on traffic characteristics and on environmental quality.

3.3. Our first demonstrator

A micro-simulator based on VIS-SIM prototype [Fortherby2002] has been developed by our team [Teng2008]. The prototype uses Model-View-Controller (MVC) The architecture is shown in Figure 8.

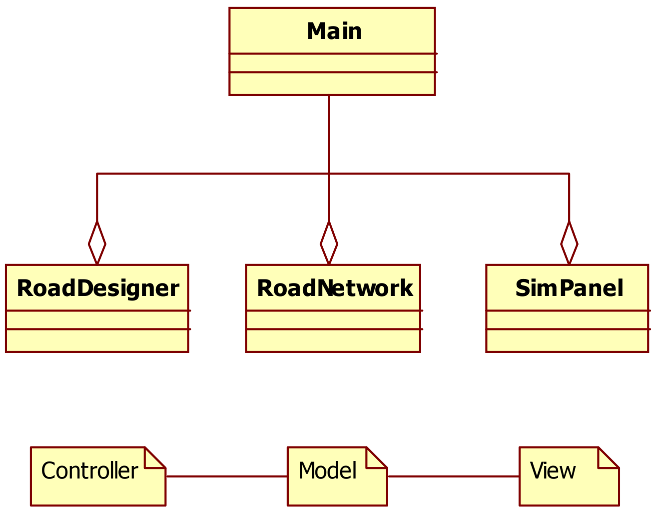

Figure 8 – Architecture of VIS_SIM

The end-user will be able to build roads in agreement with real or virtual situations, to add or to destruct lanes of street, junctions, car parks (Figure 9 at left).

Inputs of the simulation: The simulation can be provided with particular characteristics of traffic (number of vehicles, percentage of vans, limited speed, number of places for goods delivery, delivery duration)

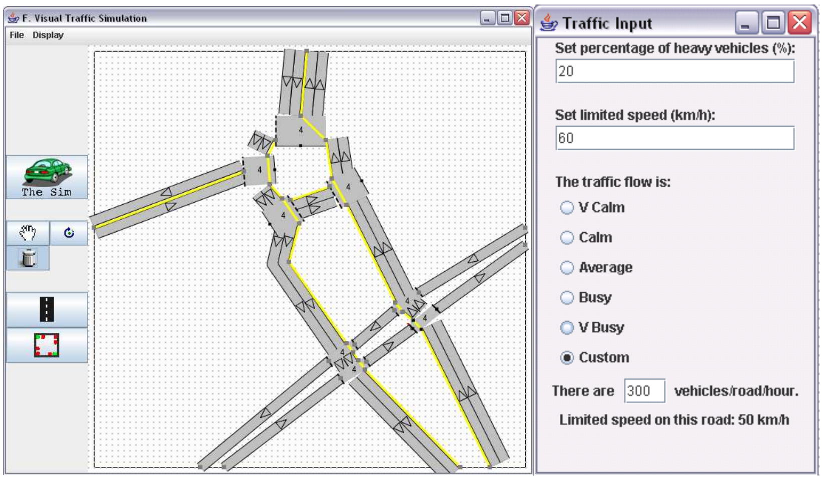

Figure 9 – Windows of road designer and inputs of traffic simulation

Outputs of the simulation:

The application provides statistical results for many traffic indicators (Figure10). Static models of road traffic congestion propose several indicators such as

- congestion level (C): based to the approximation based upon the average speed of vehicles during a period and the number of vehicles during the same duration.
- total road usage (N): the total number of trips (number of vehicles: cars and buses/trucks), over the entire period considered.
- flow level (F): measuring the number of vehicles passing a given point on the road per unit of time (1 hour, per example).

$$F = \frac{N_{veh}}{T} \qquad (10)$$

- density (D): the number of users per unit of road space with length L and width W usually the discrete number of lanes, L/t - value of fleet speed is the average of instantaneous speeds of vehicles (during an hour). When the private cars must stop on street because of the delivery process, this indicator illustrates very well the congestion degree.

$$D = \frac{N_{veh} \frac{t}{T}}{LW} \qquad (11)$$

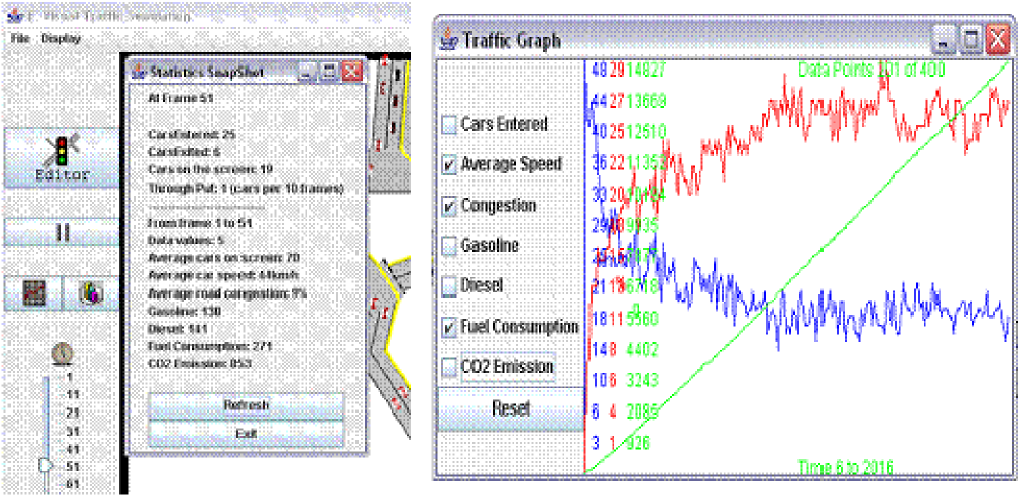

Figure 10 – Statistics Snapshot and graphical results

The fuel consumption per type of vehicles and the CO2 emissions can also be computed.
For a more rigorous analysis of the environmental impacts, the simulator is coupled with a software based on COPERT III methodology. The development of COPERT III [Ntziachristos2000] was financed by the European Environment Agency (EEA), in the framework of the activities of the European Topic Centre on Air Emissions. It is proposed to be used by EEA member countries for the compilation of CORINAIR emission inventories.
In principle, COPERT III methodology can be applied for the calculation of traffic emissions estimates at a relatively high aggregation level, both temporally and spatially. However, it has been shown that the methodology can also be used with a sufficient degree of certainty at a higher resolution too, for the compilation of urban emission inventories with a spatial resolution of 1x1 km2 and a temporal resolution of 1 hour.
COPERT III estimates emissions of all regulated air pollutants (CO, NOx, VOC, PM) produced by different vehicle categories (passenger cars, light duty vehicles, heavy duty vehicles, motorcycles) as well as CO2 emissions on the basis of fuel composition, the characteristics of the motors and the characteristics of the infrastructure (Figure 11).

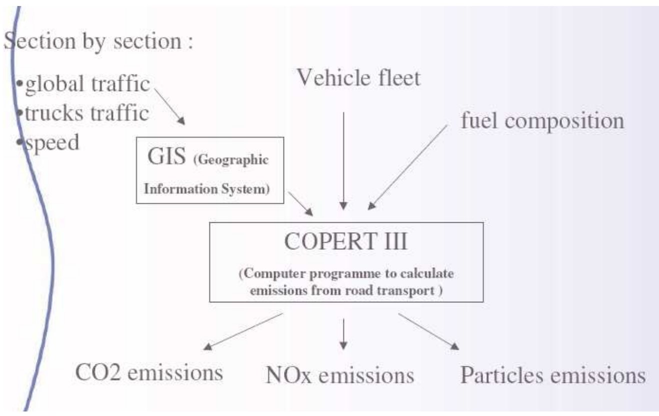

Figure 11 – COPERT inputs and outputs [Hulin2008]

For it, a traffic data base must be exploited in order to quantify number of vehicles and average value of speed of the fleet. When real data are absent (for example, a virtual scenario, such as the stop of vans), the only way to obtain it is by using traffic simulations.

4. THE STUDY CASE: ELCIDIS (AT LA ROCHELLE)

4.1. Interests of the electric van use

La Rochelle Urban Community launched the ELCIDIS experimental hub in February 2001 as part of the ELCIDIS European project. The objective was to optimize goods distribution in the historical city centre with an environmentally friendly approach. The ELCIDIS platform engages two activity types: delivery of parcels and auxiliary services with electric vehicles.
This kind of service, ELCIDIS platform, was also designed to relieve traffic congestion in the centre by reorganizing deliveries. However, freight transport in small and medium sized cities strongly depends on the topology, the organization of the city, the urban structure and the Local Authority's policies.
Figure 12 (on the left-hand side) shows positive results about the number of deliveries and kilometres for 20 months (2007-2008). The average of delivery number is about 320 a month and distance of trips for electric small vans is about 2 300 km a month. Another expected result is the decrease of the fuel consumption and of the emissions (NOx, NO2, COV, CO, CO2, PM2,5 PM10). Fuel consumption economy and corresponding emissions have been computed with COPERT software in the hypothesis that in the absence of electric cars, deliveries have been done by thermal vehicles (see Figure 12, on the right-hand side).

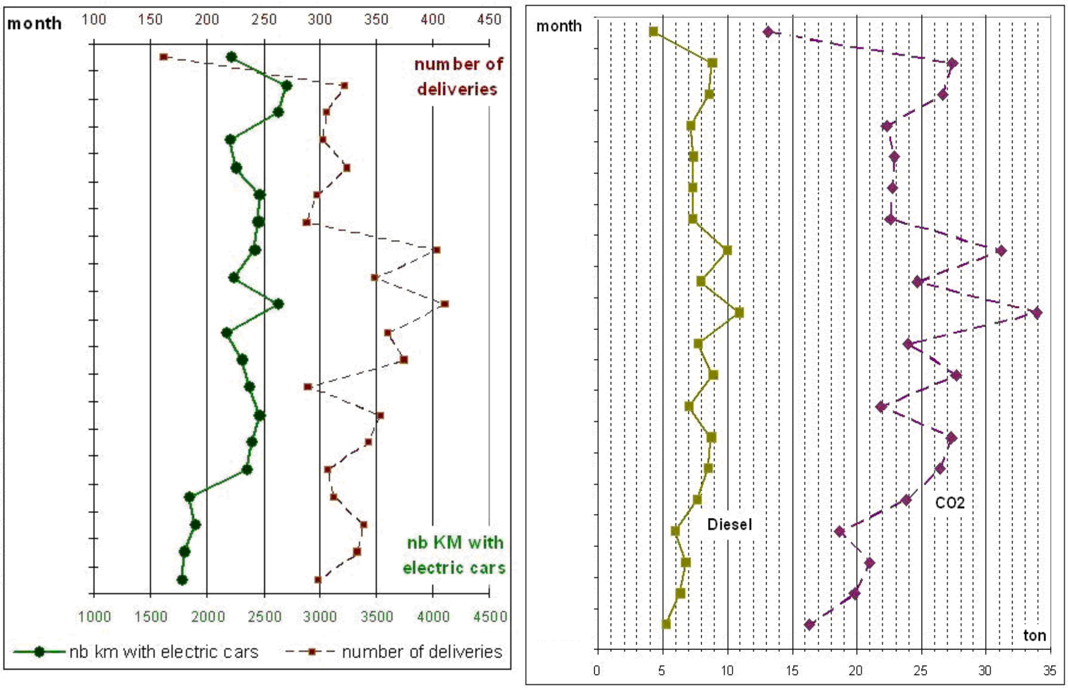

Figure 12 – Graphs of parcel deliveries with electric small vans, Diesel and CO2 economy /month

Monthly information such as the trip length, average value of speed, type of road and number of available cars are used to model the economy in fuel consumption. The average value of the speed was computed by the drivers of ELCIDIS vans and checked by the manager during several days. The algorithm takes into account the cold emissions because the value of the average distance a trip between the ELCIDIS platform and the customers is low (less than 10 km).

The freight transportation with electric vans is interesting thanks to the benefits on noise, energy and emissions. But when the occupancy rate of a car park is not managed, problems remain, because of the congestion created during searching of one available parking place in order to do the delivery.

4.2. Zone Coursive

Zone de la Coursive is an urban area with shops, companies and administrative sites. A car park situated in the centre of this area has a capacity of about 50 places with 5 places for goods delivery, generally booked all the day (even if there are only 10 deliveries/day (average) for one duration lower than 15 minutes each).
The primary necessity in Zone de la Coursive is to reduce the congestion level and the environmental impacts which are very important because of the traffic congestion. Another objective is to reduce the illegal parking, on on-street places or on places dedicated to goods delivery.

4.2.a-) Present situation

The average values of flows per day as well as the number of cars using the car park situated in this area have been obtained by survey and are presented below (table I):

Table I – Characteristics of traffic level and occupancy rate of the car park

Periods for traffic level	Hours	flow / hour (inputs n°1 - 2 - 3)	number of parked cars
1 - out of peak	8 pm - 7 am	50 - 10 - 5	20
2 - normal	10 am - 12 am 6 pm - 8 pm	150 - 35 - 20	full
3 - peak	7 am - 10 am 12 am - 2 pm 4 pm - 6 pm	200 - 50 - 20	full

For estimating the average value of the speed for these periods, simulations have been done.
Figure 13 shows the frame of the traffic simulation. The traffic model is a "car-following" model. The car park activities are represented by transferring vehicles out or into the grid (in agreement with the studied period).

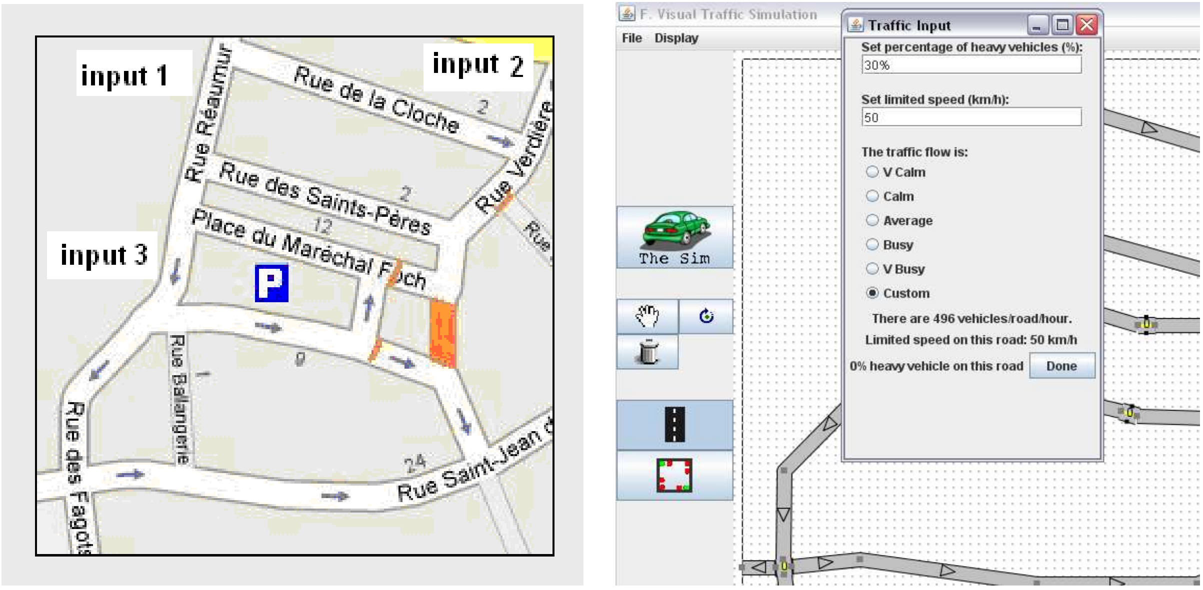

Figure 13 – Map of the studied area and Graphical User Interface of VIS_SIM

Simulations are done even if all behavioural aspects of the agents “drivers of light cars” are not implemented yet.

Agents “drivers of vans” have their destinations, itineraries and information about dedicated places for delivering.

Unfortunately, the normal period and the peak period are the same for the light cars and for the electric vans for goods delivery. The car park is full (table I) and the places for goods delivery booked (sometimes without reason).

Drivers of light cars must perform urgent and flexible activities (how their agendas are organised have been detailed in our previous works [Boussier2005]). For instant, the simulations are done in a randomized manner.

According with the behavioural model obtained using a sample size 186 respondents (private car drivers) by the method presented in section 3, most part of the drivers of light cars would prefer 2 from 4 alternatives presented (do loops, illicit parking, go to another car park, defer the activity) :

- for a “flexible” activity (administrative procedures, recreational activities or shopping) : the agents prefer do loops in the zone (around 8 minutes-this data was obtained by survey). As consequence of this situation, the simulation gives an average value of the speed very low during these periods (15 km/h) due to the congestion created by the research of one available place to park the light cars.

- for an “urgent” activity (work, meeting), agents prefer to park in an illegal manner within the zone. For illustrating the consequence of this choice, the Municipal Police provided us data on parking fines issued in Zone de la Coursive in 2007 (the survey is very rigorously done because the Municipal Police is situated face to this car park).

Table II presents an extract of the data for June 2007 to December 2007.

Table II – Number of fines in the "Coursive" area between June and December 2007

Street name (rue de …)	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Verdière	2	6	11	7	2	1	2
St Pères	0	0	1	0	0	0	0
Cloche	1	0	2	0	0	1	0
Total	3	6	14	7	2	2	2

Another consequence of the cars park activities during these periods are: the fuel consumption and important emissions because of the important number of cars running at low speed and doing loops around the car park for searching an available place or an illicit place. Results obtained by COPERT software (taking into account the length of trips in this area) are presented in figure 14.

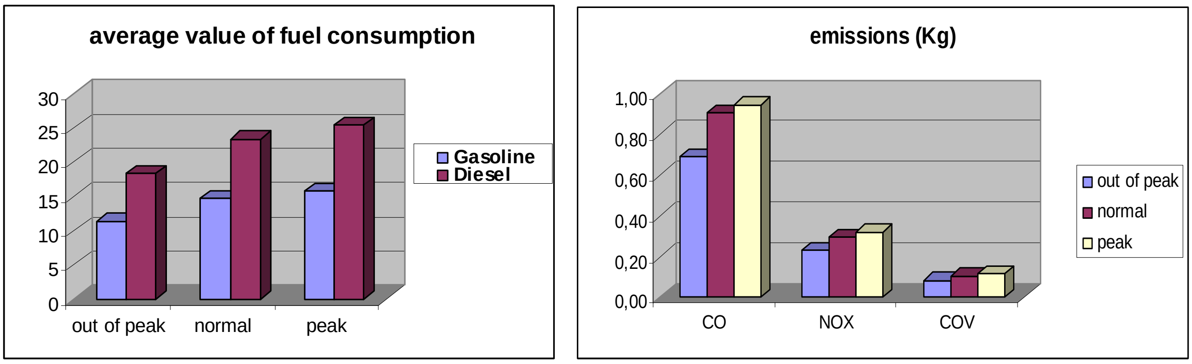

Figure 14 – Fuel consumption (ton) and emissions (kg) in zone Coursive /year

4.2.b-) Expected situation after the sharing of car park places

Now suppose that the booking of the places for goods delivery is shared between the agents "drivers of vans" and "drivers of private cars". We also consider that the durations of deliveries are respected. Simulations have been done only for normal and peak periods by using the same inputs (characteristics of traffic flows, and occupancy rate of the car park, behaviour of agents).
The number of cars using the available places when no delivery is done is not important (only 8 cars can park). What is important in this case is the reduction of the strong congestion level generated by searching of one available place and the decrease of the number of km done in this area by the private cars searching an available place. Figure 15 shows the evolution of fuel consumption and corresponding emissions in this situation (it means a decrease about 5%).

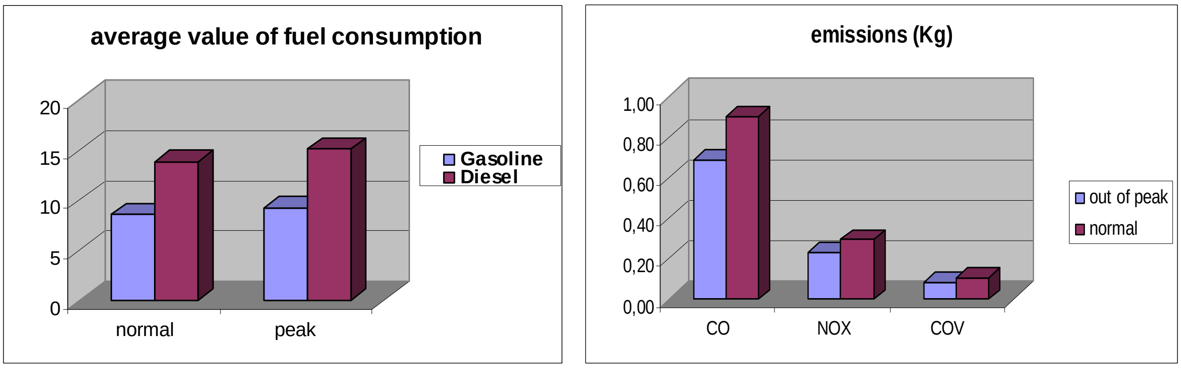

Figure 15 – Expected values of fuel consumption (ton) and emissions (kg) in zone Coursive/year

5. DISCUSSIONS AND IMPROVEMENTS

Our approach coupling behavioural models and simulation tools can be used in several manners by the decision-makers.

- to capture consequences of the interaction between the network users for a real situation (vans and private cars).
- to simulate scenarii by changing the infrastructure, the local regulations, the period for delivering
- to optimize delivery process and strongly decrease the environmental impacts.

This approach has been presented for the sharing of the parking places but other strategies can be tested such as: the implementation of dedicated lanes for freight, changes of delivery period.

But the 2D framework can not capture in real time reactions of individuals in agreement with particular traffic conditions (congestion level, occupancy rate of a road). Laboratory L3I (University La Rochelle) La Rochelle provided a framework to build easily the model of a system existing or future [Augeraud2005a], [Augeraud2005b] The end-user of this tool can instantiate and assemble components in order to model a city and its urban traffic network, in which different types of vehicles (passenger car, bus, goods vans) move themselves according their diaries or tour planning:

- to change easier the infrastructure by assembling blocks, by means of the graphical editor (Figure 16)
- to control better in real time the panels VM ; for it, vertical signals, such as traffic light or road panels are edited for information about the state of a parking place and the duration of the delivery.

Figure 16 – A block for 3D representation and the Development environment of adaptive city model

The approach presented in past sections presents the advantage that is based on a multi – agent paradigm and faithfully can represent the agent behaviour. But in a 2D framework, only the initial choices of a private car driver can be included in a behavioural model, neglecting the real time decisions. In a 3D environment, the behaviour of the agents is more complicated to describe and depends logically on several criteria than presented for a 2D demonstrator (e.g. the possibility to pass on another lane, etc.)

Because the number of variables is important, the same method presented on section 3 is used but the scenarios are presented by coupling the questions with the pictures. One example is presented in Figure 17 which illustrates the scenario 1 : period "peak hours", activity "work", number of lanes "one", light "green", dedicated place for delivering "absent", goods van "partially blocs the way", pedestrian "absent" place to pass "yes", drivers of van "out of danger", visibility "good", position on car following list "first one". Each respondent sanctioned each scenario by a preference which will be converted on score (example: "I'll be very nervous and I'll pass" translated in semantic value (1 for example in a range [1;10]) . We randomized the order of the verbal and visual blocks and the order of the questions within the blocks across respondents.

For each scenario, the average value of all responses is computed and considered like representative for the behaviour of a sample size statistically significant. The Analysis of Variance will allow us to identify the main parameters which affects the perception of one situation and which governs the behaviour of the agents drivers of private cars, in order to reduce the number of information transmitted of each agent.

After the implementation of behavioural models for agents of drivers of private cars, agents "drivers of vans", agents of "stopping space" cars, several scenarios can be simulated. Decision makers will be able to select optimal sites, periods for ensuring a good coexistence between all actors of the urban traffic.

A	B	C	D	E	F	G	H	J	K	L
1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	2	2	2	2	2	2
1	1	2	2	2	1	1	1	2	2	2
1	2	1	2	2	1	2	2	1	1	2
1	2	2	1	2	2	1	2	1	2	1
1	2	2	2	1	2	2	1	2	1	1
2	1	2	2	1	1	2	2	1	2	1
2	1	2	1	2	2	2	1	1	1	2
2	1	1	2	2	2	1	2	2	1	1
2	2	2	1	1	1	1	2	2	1	2
2	2	1	2	1	2	1	1	1	2	2
2	2	1	1	2	1	2	1	2	2	1

Figure 17 – Orthogonal array for collecting perceptions / picture illustrating one scenario [Browne, 2009)

Because the array contents 12 questions (for 11 parameters), more than 2000 scenarios are not tested by questionnaire. In order to predict agents' behaviours for these scenarios one model is built by using the same approach proposed in section 3.

6. CONCLUSIONS AND PERSPECTIVES

The urban goods distribution is vital for the prosperity of inner cities. Especially the freight transportation vans with electric power are very interesting thanks to economies on fuel consumption and on emissions. But when the delivery process can not be optimized, environmental problems remain because of the congestion created during the search of available parking place for goods deliveries. Several private cars must decrease their speed and so the pollution will increase more. This problem is very frequent in small and medium sized cities built around historical centre with a very rigid infrastructure.

The purpose of the paper is the architecture development for the simulation based on agent technology for simulating the impacts of the coexistence of light cars with vans for goods delivery.

Because within urban areas are only limited opportunities to enhance physical capacity of road infrastructure at surface level, the retained idea is to analyze the impacts of a spatial and temporal dynamic booking of on-street stopping places (to park or to deliver).

This paper focuses on the modelling of the management process of the sharing of the parking places between private car drivers and vans for goods deliveries. For it, we have provided a framework to build easily the model of a system existing or future. The simulation tool is based on the multi agent paradigm. For a given scenario, the reality is the result of interactions between them. The drivers of private cars are agents able to decide and negotiate, in agreement with a behavioural model. Their behaviour is strongly dependent on the period of the day (peak or out-of-peak), of the type of activity to perform (work, shopping, etc). The method for the design of behavioural model is based on stated preferences.

One application is presented in order to propose the optimisation of goods delivery process in particular zones of La Rochelle. We present the environmental interest of this type of distribution (fuel consumption and emissions) and the benefits of the management process of the sharing of the parking places between private car drivers and vans drivers goods deliveries.

Several aspects are under development: a 3D ground for simulation which is able to capture perception of the agents in spatial scale and a more exhaustive behavioural model. For it, scenarios are built by using verbal terms and also pictures for visualizing the attributes of the road.

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