EVS24
Stavanger, Norway, May 13-16, 2009

Goods distribution with electric vans in cities: towards an agent-based simulation

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Abstract

Cities being the framework and power of economics, urban goods distribution is essential for the prosperity of urban areas but at the same time it is a source of problems related to the environment, traffic safety and accessibility. To classify and describe different problem-solving options for urban goods distribution, there is a need for a fundamental way of describing the transport process, its actors and its means (equipments and infrastructures). Few works describe methodologies for facing the problem of goods distribution in historical city centers, while taking into account the particular infrastructural restrictions and especially the narrow streets to which such areas are subject.

The main objective of our work is the specification and design of a software tool for the management of an electric vehicle fleet for goods distribution in small and medium sized cities. This is a part of a multimodal urban traffic simulator based on the paradigm of multi agent system (MAS). Agents and interactions are defined from modeling of the system “Goods Transport in City”. The end-user (e.g. city centre Manager) simulates scenarios in agreement with local traffic regulations, the capacity of the fleet and the routing alternatives.

This paper focuses on the modeling of the management process of the parking place sharing between car drivers and dedicated areas of goods deliveries.

Keywords: Simulation, modeling, intelligent infrastructure, van,

1 Introduction

Urban goods distribution is vital for the prosperity of inner cities, especially the shopping areas that fulfill an important role for the city. In fact, about 85% of European Union gross domestic product is done in urban areas and 60% of population lives in urban area having more 10,000 citizens (source Eurostat). Goods transport also causes noise, air pollution, physical hindrance and a decrease in traffic safety; these are important negative side effects. Freight transportation vans with electric power are interesting thanks to energy and polluted emission benefits. But when the fleet management is not optimized very well, problems remain because of congestion created during searching available parking place by goods deliveries.

Reversely, the urban structure and measures that have been taken to limit problems, pose accessibility and logistical efficiency problems to

the urban goods transport system. This results in increased travel delays, lower quality (reliability) and in some cases to inefficient logistical systems using more vehicles (vans) than strictly necessary.
It explains the need to elaborate necessary logistical adaptations and to describe the implementation strategy. No discussion about the urban spatial structure and moreover traffic organization and management, can take place without an overview of urbanization, which has been one of the dominant trends of economic and social changes.
To achieve these objectives, authorities require tools representing, according to a global view, problems associated with city logistics. However, the studies and experimentations conducted so far focused mainly on a too small geographical context (hyper city centre), do not take into account all the factors involved in the urban transport system and not often in a coordinated way which sometimes generated contradictory effects.
The works' main objective is to build prototype tools allowing local authorities of urban transport to optimize the sharing of the whole transportation system between car drivers and freight vans.
This paper is organized as follows: first section treats about the interests and difficulties to manage a goods distribution system. Second section describes the main principles of an agent-based simulator for multimodal urban traffic. Third part consists to describing some of the expected effects of the implementation of this system.
The paper emphasizes the methodology used to determine and describe measures in order to improve efficiency in goods transportation and emphasizes the (changes in) logistical organization that can be used to this end.

2 Goods distribution in small and medium sized cities

2.1 Goods distribution: ELCIDIS

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 in two activity types: delivery of parcels and auxiliary services with electric vehicles.

Fig.1 shows positive results about the number of deliveries and kilometers for 20 months. The average of delivery number is about 320 a month. Electric small vans do about 2,300 km a month on the average.

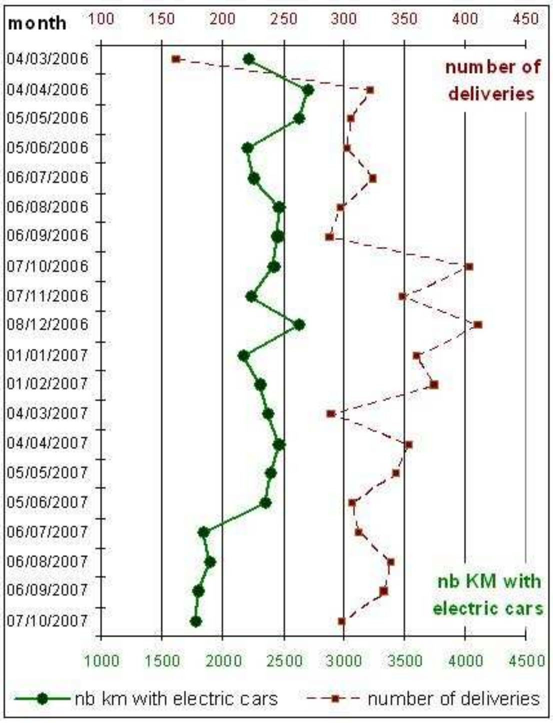


Figure1: Number of deliveries and kilometers a month with electric small vans to deliver parcels

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 in the hypothesis that in the absence of electric cars, deliveries have been done by thermal vehicles (see Fig.2).
The algorithm to compute the fuel economy a month is based on the COPERT III methodology. 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 for several days. The algorithm takes into account the cold emissions because the value of the average distance a trip between the ELCIDIS platform and customers is low (less than 10 km).

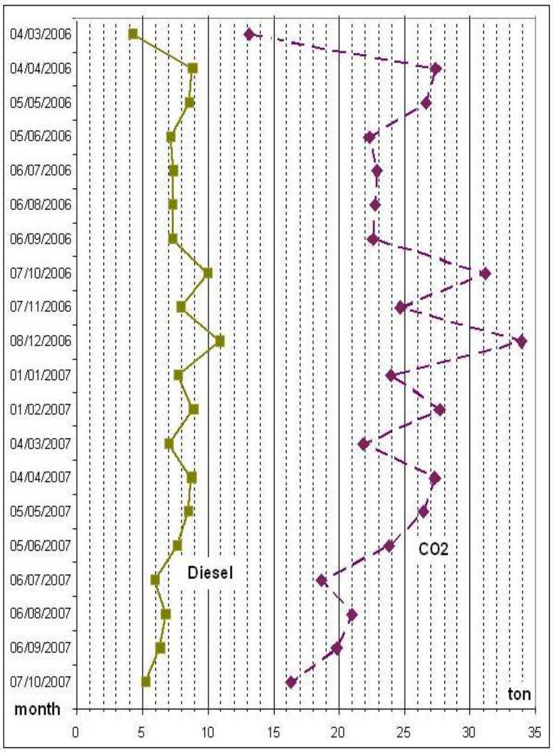


Figure2: Diesel and CO2 economy a month

2.2 Problems to optimize the management and the extension of the system

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. These cities, built around an historical centre, are quite often rich with several types of shops as well as craftsmen and small industries. Generally the average speed of small electric vans is lower than 40 km/h. Even if in absolute terms the time wasted in congestion is less, in these cities it still feels significant. The problem is not a time keeping respect but the lack of dedicated loading places to deliver (or the reserved places blocked by other cars having not found an available parking place). Congestion created by stops of goods vehicles during deliveries (delivery duration is about 10 minutes in the most cases) involves a pollution peak by 5 to 10 cars stopped with running motors (several observations in different urban areas and street during the day and for different days of week and of month).

Urban traffic simulation in the goods distribution framework

State of art concerning analysis and simulation of goods distribution

Generally studies focused on the generation of freight or vehicles trips. Several researchers [1], [2], [3], [4], [5] proposed also other approaches of modeling referred to gravitational model, four-steps model and input-output models. Oppenheim [6] attempted to develop a combined approach considering passenger travel and goods movements with a spatial price equilibrium model. But, once again, this kind of models needs a lot of data.

More recently, Munuzuri [7] proposed a methodology based on entropy maximization in order to build an Origin-Destination (O-D) matrix for freight transport taking into account home deliveries and deliveries within several branches of industry. Thompson and Taniguchi [8] tackle the problem of vehicle routing inside the city. The interest of the development of operational research considering the vehicle routing is increasing because of the improvement of computers and ITS (Intelligent Transport System) technologies.

Yannis [9] investigates the effects of the adoption of restrictions in vehicle movements associated with urban delivery operations on traffic. To generate and to control urban goods transport, simulation tools have been developed. The main functional tools are Freturb© [10] (France), Goodtrip© [11] (Netherlands), Wiver© [12] (Germany) and Distra© [13] (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 to compute complete O-D matrices.

After a literature review, no research work suggests a solution to our problem: congestion created by electric freight vans during the goods delivery. Models computing traffic volume per hour could be interesting but very hard to implement because of the necessity to built one dynamic origin-destination matrix.

2.3 Multi Agent System for the simulation

2.3.1 Our steps of development

The multi agent paradigm is able to define with a lot of realism the behavior of road network users and 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 (see [14] for a good overview), in particular, for designing traffic simulators.

Few works are done for goods transportation simulation [15]. The purpose of the paper, quoted previously, was the architecture development for the simulation based on agent technology concerning the transport of people and goods from their origins to their destinations.

Fig.3 shows the main steps of modeling and simulation approaches to develop our software application.

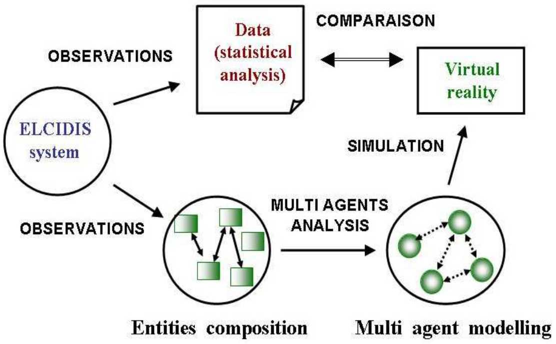


Figure3: Main steps to develop the simulator

The start point of our methodology is the study of the Urban Traffic System (UTS) in order to define the properties then the agents.

2.3.2 Software architecture of simulator

We provide a framework to build easily the model of a system existing or future [16].

The framework depicted in Fig.4 shows the multi agent system (MAS) divided in three subsystems.

The first one concerns the urban traffic simulation. Agents participate to the activity of the city (vehicles, bicycles, pedestrians…).

The second one concerns information system service behaviors. In this part, agents model employees and computing system of the information system itself. Actions of agents belonging to this subsystem are the result of interactions between agents of the simulation of the Urban Traffic System. These interactions may generate new vehicles, new pedestrians… into the system.

The third one is dedicated to decision aid making objective of our tool. The system produces a synthesis of the whole analysis taking into account the statistics wanted by the user and by collecting simulation data from the other subsystems.

Global behavior of the system would emerge from the interactions between all various agents. Because behaviors of agents are formally expressed using finite states machines, structure properties and some functional properties may be verified by using model-checking techniques.

UML (Unified Modeling Language) and Coloured Petri Net formalisms are used to represent states and interrelations between agents.

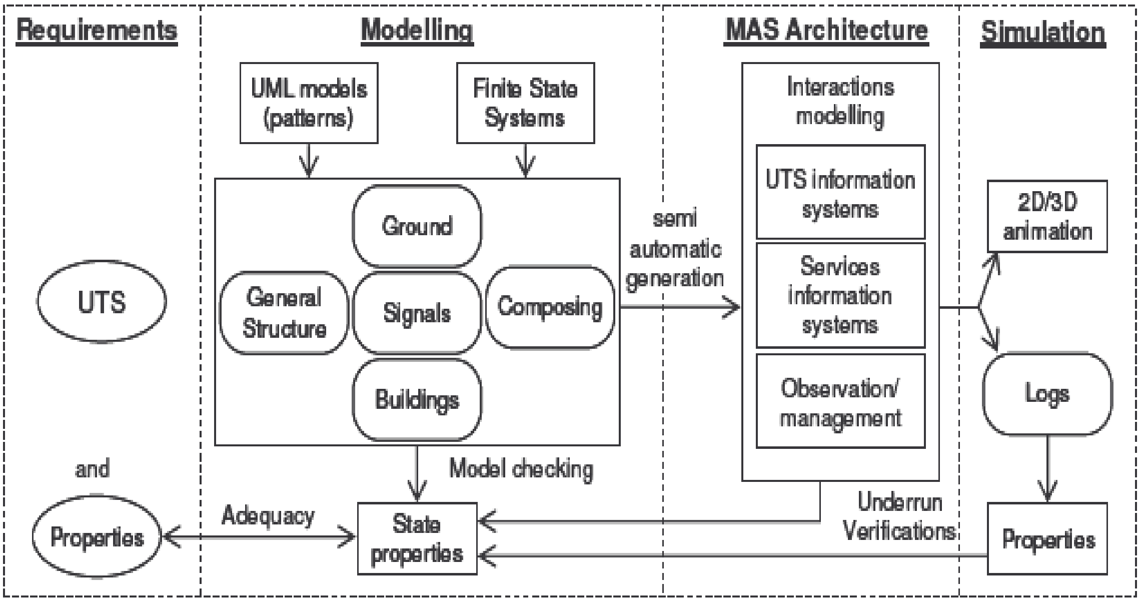


Figure4: The framework of our simulator

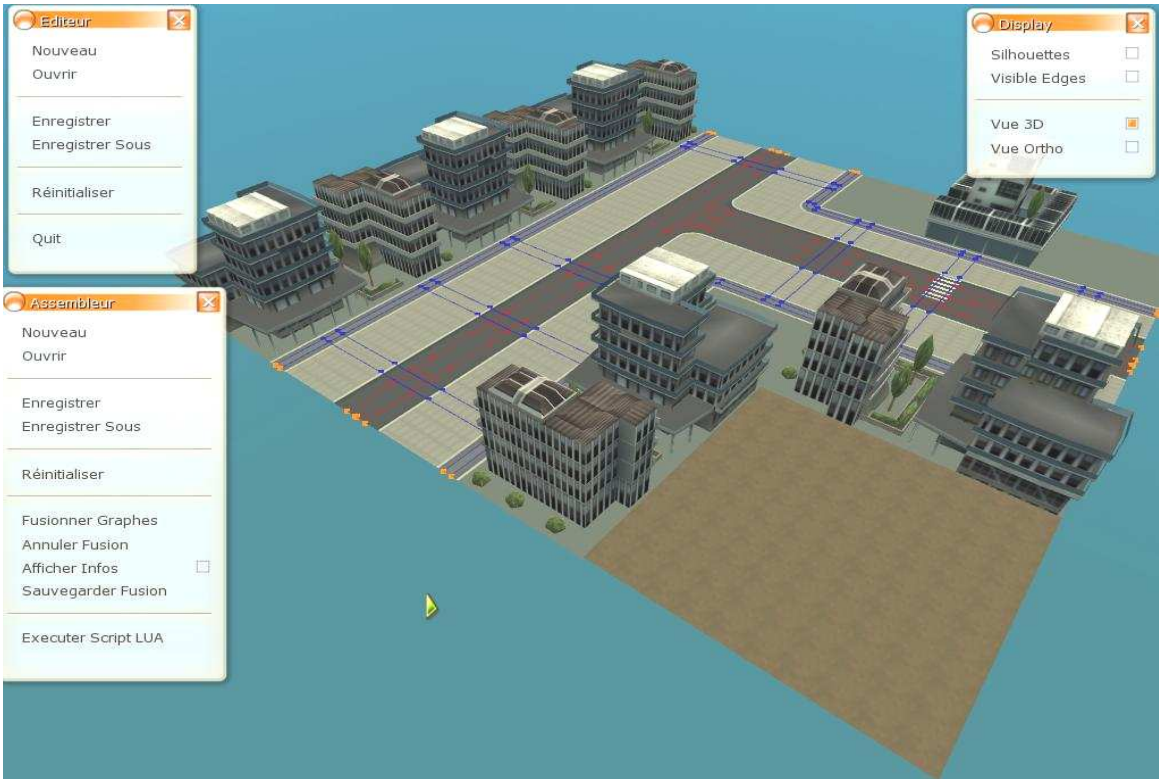


Figure5: Development environment of adaptive city model

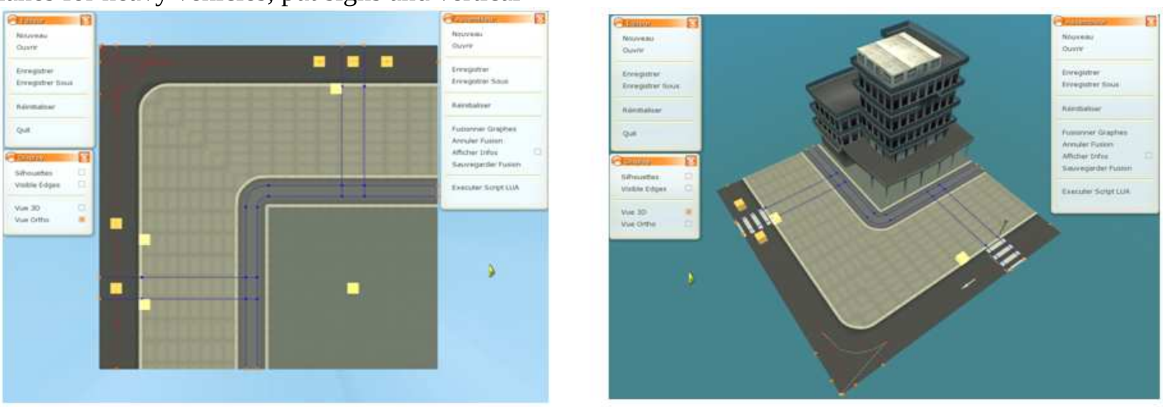
2.3.3 Design of the adaptive ground model

Fig.5 shows the development environment elaborated by the L3i laboratory for building a virtual city used as simulation environment in which different types of vehicles (passenger car, bus, goods vans) move themselves (cruising, accelerating, decelerating) according their diaries or tour planning.

The end-user (e.g. the city centre manager) can instantiate and assemble components in order to model a city and its urban traffic network (Fig.6). He can change infrastructures, create dedicated lanes for heavy vehicles, put signs and vertical signals such as traffic light or road panels, give driving rules and goods distribution rules for the simulated city.

The used structure is based on graphs using a bottom-up approach and an analysis of the domain. We use a particular type of nodes called connection node to connect blocks.

When blocks are assembled, connection nodes disappear because they represent nothing for the urban traffic network. This scheme is applied to nodes of all networks without type differentiation (pedestrian, vehicle…). Blocks are built to be linked in a seamless way.



2D display and editing

3D display and editing

Figure6: Block-based approach to reuse from libraries

There are two types of areas: the area which can be used by moving agents, and the area only displaying scenery. So cars and pedestrians can only move on their dedicated network of the system.
A space is reserved on the block for buildings. They are placed to model real social or economical attractive locations in the city. Buildings can be changed. We consider buildings as agents because they are intelligent. They have their own strategies to produce and consume people, goods and waste.

3 Share the parking places

3.1 Principle

According our point of view, there are two possibilities in order to decrease the congestion level associated to electric vehicles in the proximity of the delivery area: share the street or share parking spaces. But it is well-known within urban areas there 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 reservation of on-street stopping places (to park or to deliver).
In Barcelona (Spain), some on-street places are reserved for deliveries during the night. This solution is not compatible with French regulation because shops and craft men must be delivered during the day.
In Toulouse (France), there are on-street ways on which all types of vehicles can stop during some periods of the day. After, ways are closed for pedestrians. In some streets, parking places have been transformed into spaces for pedestrians without stopping places. This last point poses problem because goods distribution men meet difficulties during deliveries, blocking roads with their vans.
Our proposal is to group the on-street parking places in several units; the unit can be the street or a part of.
Now, on-street parking spaces can be shared as follows.
Each day, before goods distribution begins, on-street delivery places are reserved near the location to be delivered. The length of van is taken into account. It is the spatial reservation.
Reservations are done only for periods of deliveries; each period is computed according the tour planning of each known carriers. It is the temporal reservation.

When on-street stopping places are not reserved, there are available to park individual cars under some conditions.
To avoid conflicts, variable message panels (VPM) display information about the state of each place. Car drivers and freight van drivers know available places to park individual cars and reserved places to deliver goods according the day period. Car drivers know also the duration of authorized parking because places must be available before the beginning of the reservation time slice. If the “pre-reserved” place is not available for the delivery, a system alerts the police office in order to tow the car away.
A similar system running in Poitiers (France) controls a few parking places without booking for goods vans. When the delay is finished and if the vehicle is always parked, the system gives the alarm to police office.
Our solution, with the reservation and more, is interesting for local authorities which want keep parking incomes. Cars can not be parked a long time because of place reservations for goods distribution. It is not sure there is more pollution with parking turn-over than with congestion because of available parking searching.

3.2 Build the Multi agent system of this part

Fig.7 presents the main agents and interactions existing between agents concerned by the occupation of the street during the delivery process.

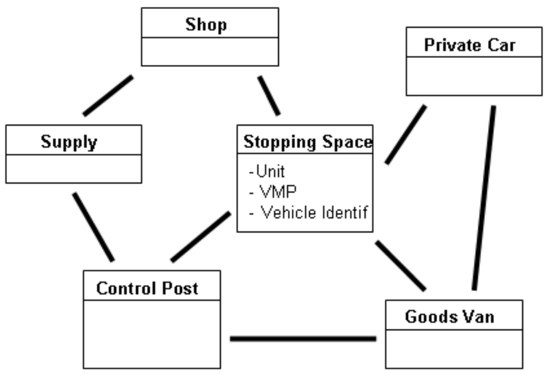


Figure7: Main agents of the studied part: the stopping place sharing

In our simulator, each unit of parking places is driven by one control agent (named Stopping Space). 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.

In fact, we use the same principle than Traffic Signaling Control (e.g. traffic light) of Intelligent Traffic Management already taken into consideration in our simulator.
Each control agent is associated to an object VMP (Variable Message Panel). It indicates the status of the parking space for drivers. In the same time, this agent can recognize the type of vehicles (agents) and alert, if necessary, the "police".
The Control Post agent, having all tour planning of carriers (supply agents), computes time slices and communicates with Stopping Space agents in order to book on-street places for deliveries.
Shop agents interact with Stopping Space agents to define the location and the duration of the delivery.

3.3 The "stopping space" agent

Its role is to manage and to control the set of parking places of a street or a part of.
Fig.8 shows the different states of an agent in the simulator.

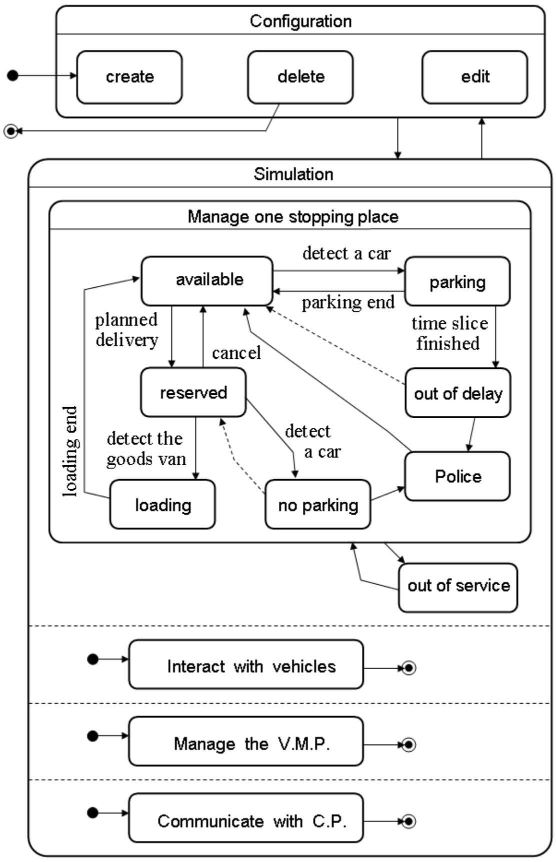


Figure8: State diagram of a "stopping space" agent managing a set of on-street parking places

The agent interacts and detects vehicles stopped on stopping space. According the type of vehicles and conditions to be stopped, the agent reacts and takes decisions.
In parallel, it manages the Variable Message Panel(s) which display information; vehicle agents (one agent a vehicle) decide if they can and/or if they want stop themselves on one on-street place available, reserved or risk being in breach of rules.
The agent must communicate with the Control Post (CP) agent(s) as well. It books places according the actual status of the stopping space and according requests of the CP agent built from different tour planning of carriers.
Moreover, one main task represented by one state of the "Simulation" state in Fig.8 is to manage each place. We can see the different states of a stopping place.

4 Conclusion

Urban goods distribution is vital for the prosperity of inner cities. Especially freight transportation vans with electric power are interesting thanks to energy and polluted emission benefits. ELCIDIS platform in La Rochelle is a very interesting example. But when delivery process can not be optimized, problems remain because of congestion created during searching available parking place for goods deliveries. This problem is very frequent in small and medium sized cities built around historical centre with a very rigid infrastructure.
It explains the need to elaborate necessary logistical adaptations and to simulate impacts of the share between individual cars and freight vehicles on congestion degree. Few works concern those aspects and take into account discussion about urban spatial structure and moreover traffic organization and management.
For it, we provided a framework to build easily the model of a system existing or future. The simulation tool is based on multi agent paradigm. Agents participate to the activity of the city (vehicles, bicycles, pedestrians, freight vehicles, different types of buildings…) built with an adaptive ground model. For a given scenario, the reality is the result of interactions between them. The paper focused on the description of the principle for sharing parking places between passenger cars and freight vehicles. The interest of this part of the simulator occurs on the possibility to simulate impacts of the management of the stopping places in agreement with use rate and time of use. Thanks to our simulator, we can study impacts and benefits to share on-street stopping places in order to park the individual car or to load or unload the goods deliveries with electric vans.

Acknowledgments

The authors are expressing their grateful to Miss Anne Chané, in charge of ELCIDIS platform under authority of La Rochelle Urban Community, for information and data. So, we were able to illustrate this paper and to study the opportunity of our proposal in order to improve the goods distribution.

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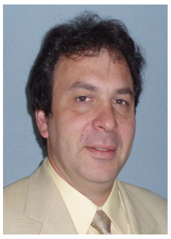
Authors



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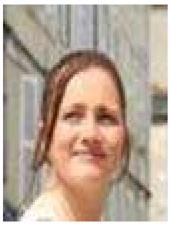

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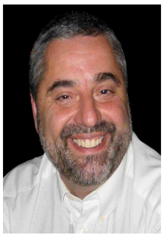
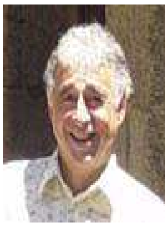


Pascal Estraillier is a full professor in Computer Sciences at the University. His researches concern the architecture of software components in distributed systems. To validate the behavior and interactions, he uses multi-agent paradigm and formal specification theories. He is co-founder of the first French Educational program on Games.



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