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Corporative Parking Location Choice and Route Guidance: The case of Urban Area of Tunis

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ABSTRACT: Cruising for parking angers drivers, increases traffic congestion and pollution, and wastes fuel and time. This paper proposes and studies new strategies for parking guidance based on a network of intelligent agents which can helps drivers to find a parking place, before or during their travel at anytime and anywhere. With reference to the objective that is interested to bring vehicles to vacant parking place with the aim to reduce the traveling time and to ensure efficient use of available parking capacities, this study offer three services: the search for a vacant parking place, directions to that parking place and booking the place for parking. This study takes on optimal route guidance algorithm, which is simulated and analyzed by the platform MATSim transport simulation.

KEYWORDS: Intelligent car parking management; Multi-agent system; Benefit evaluation; Urban transportation; parking guidance.

1 INTRODUCTION

Parking problems are a great challenge to facilitate traffic and ensure the quality of urban life. For a long time, looking for a place to park was neglected because of its invisibility, even though its negative externalities have been identified. The severity of impacts caused by the problem of finding a parking place motivates researchers to study the parking management problem and to come up with solutions to solve problems met by drivers and to reduce impacts on traffic, environment, and society. Vehicles in search of a parking space represent a share that cannot be ignored in urban traffic. At the end of the trip, the driver shall park his vehicle, but in the absence of parking, it will look for another car or an illegal site, or turn around the parking lot, or postpone its activity. As it seeks a place, the motorist gradually widens its circle of research. Studies have shown that a small search time by car can create a surprising amount of extra traffic which is source of urban traffic congestion [1]. Finding a place is still responsible for the causes of accidents, waste fuel and time, air pollution, and degradation of the pedestrian environment [2] [3]. Reducing of the traffic externalities is one of several objectives of good parking policy. There are other goals such as ameliorating accessibility, maximizing turn-over for shops to develop the local economy, reducing the congestion, encouraging the using of public transport. Generally, the establishment of an optimal parking is often difficult because these objectives are in conflict [4].

The good parking policy is then which taking into account the maximum of economic, social and environmental constraints. It needs the evaluation of its numerous effects as many other urban policies (urban transport policy, land-use policy). The literature showed that numerous tools have been used to achieve one or more of these objectives. Some of them are economic as parking pricing [5], fiscal as parking taxing, and technological as intelligent parking management.

In this paper we propose the application of Technologies of Information and Communication (TIC) to elaborate an intelligent parking system. These studies proposed parking system which are based on technologies as especially on Cellular Automata (CA) and Multi-Agent System (MAS). Contrarily to traditional regional models, these new models have permitted to pass from macroscopic to microscopic parking modeling approach throughout the simulation models [6]. Particularly, Traditional models aggregate all origin and destination points of traffic flows in zones of the considered area to “average points” namely “centroids” and all drivers to the “average driver”. However, new models disaggregate all variables in areas and can studding the behavior of every driver taking into account the variety of parking’s, links, origins, destinations, and real traffic and parking environment. Search time for finding parking place, walking time, traffic flow, traveled distance gain and associated energy consumption and pollutants emission are the main impacts measured by these studies.

A lot of information and communication technologies are likely to set up a promising smart parking such as the website, staking systems dynamics parking lots, mobile phones, the multi-agent and ad hoc networks without son. Vehicular Ad Hoc Networks (VANETs) is a new technology that has mostly gained the attention of researchers in road traffic management. Safety and efficiency of transportation system are the two essential problems where it is applied. Dynamic staking systems of parking lots try to bring the flow of vehicles heading to saturate parking and to less busy areas. They display the name of the car park, the direction and the filling of the parking lot. The search strategy, based on dynamic staking systems of parking lots, is unassisted. Indeed, the driver turns into a search radius where the node information on the availability of parking places and it can get as close to parking places. Nevertheless, it’s to be noted that ad hoc network without a son is an opportunistic assisted research strategy. Thanks to standard interfaces without son, the information on the availability of vacant parking place is provided to all motorists who are in the coverage area. Vehicular Ad-hoc Networks based real-time navigation of parking was studied recently [7]. The basic idea consists to use of restricted stock units for monitoring and management of the entire parking lot. These units are activated by communication among vehicles and RSUs (Road Side Units: units across the road) in an ad-hoc network.

Mobile phones, the Web site and multi-agent systems represent a centralized assisted research strategy. In this case, it is a central server or a central unit responsible for the dissemination of data on vacant parking place. Once the reservation is made, the driver simply moves to the designated place. The Internet can be the best way to help drivers find a place to park, online in an occupied city. Motorists can also use their cell phones to check available space, make a reservation and get directions. Furthermore, the multi-agent artificial intelligence is one of the new technologies of information and communication that are now applied to parking. Numerous existing studies have created a multi-agent platform for several objectives and with a variety of constraints. [8] proposed a platform which correspond to an implementation of a dynamic system of negotiations parking place. They used a system of intelligent agents, and given that the price of parking is negotiable, it selects the best car for the driver. [6] presented a parking model, PARKAGENT, which simulates the behavior of drivers capture the complex self-organizing dynamics of a large collective of parking agents within a non-homogeneous (road) space. Authors applied their multi-agent model to residential parking in Tel Aviv city and aimed to determine if the additional parking supply can reduce the search time of parking place. Along similar lines, [9] created a system of information and guidance for parking by the alliance of GIS (Geographic Information System) with GPS (global positioning system) and 3G (wireless system).

The objective of our work is then to reduce the traveling time and to ensure efficient use of available parking capacities. This study integrates a multi-agent network. In fact, with rapid technological advancement in computing and telecommunications, Multi-Agent approach may be appropriate to minimize wasted time and fuel, to improve traffic flow, to optimize the use of parking lots and to reduce the negative effects on society and the environment. To emphasize our goal, a comparison among two methods is imposed. For the first method, the cars travel randomly in the hope of finding a vacant place. Here, the strategy adopted by the driver during his research depends on both the urban context in which they are searched and the individual characters. Gradually, as he seeks a place, the driver gradually widening its circle of research and can sometimes give up its activity. For the second method, the cars will be guided to a parking space around their destinations through our system.

After presenting the various methods and technologies to solve the problem of finding a place or park in section 2, the architecture of our proposed system is described in section 3. A section 4 deal with the implementation of the architecture proposed in the simulation model MATSim, presents the results and their analysis, and describes the algorithms used in the system. Conclusions are drawn in section 5.

2 SYSTEM ARCHITECTURE

The conceptual model of our system is based on Multi-Agent network.

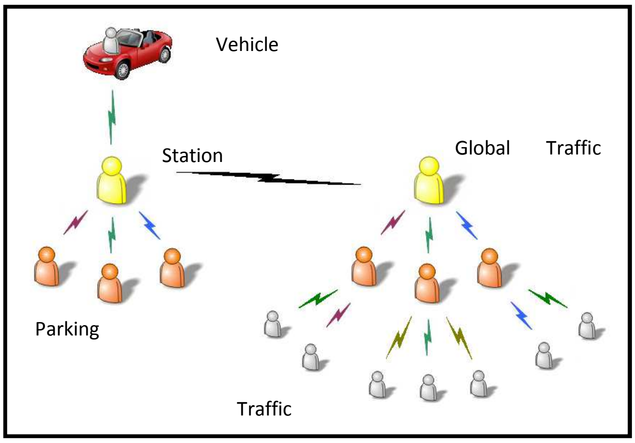


Fig. 1. Hierarchical structure between agents

This model is a way of representing our real world. This allows us to represent the dynamics of resource parking use, namely the interactions regarding the use of parking resources among vehicles which are the main actors of our system. Here, we assume that all cars and parking places are fully connected to the information network.

The basic organizational structure of our system is a hierarchical structure. The hierarchical organization of agents allows a default message routing which facilitates the development of agents. There are five types of agents having each one characteristic that distinguish it from others: vehicle agent, traffic agent, global traffic agent, parking agent and station agent.

2.1 VEHICLE AGENT

This is the only dynamic component that drives the road network. Each vehicle is equipped with sensor allowing the agent to perceive information from its environment. They produce information contributing to knowledge in real time, traffic conditions or to predict traffic conditions. Indeed, all the parameters such as: average speed, travel time, inter-vehicular time ... will be calculated by the agent on board the vehicle to determine the approximate state traffic: fluid or dense traffic..

Each disturbance in traffic conditions observed by the vehicle during its movement must be transmitted to other vehicles, which transmit this message to the nearest traffic agent. Generally the exchanged data are intended to produce alerts and inform drivers so as to be more attentive.

2.2 TRAFFIC AGENT

This is a static component that represents a specific point of the transport network: at each intersection (or node), we introduce a traffic agent. It produces, in real time, information about the current state of traffic within the road segments that it manages.

The traffic agent must first handle messages emitted by vehicles in the first place to inform the global traffic agent of disruptions to normal traffic situation. Second, he warns motorists on their way to the place of accident for example. The average speeds, the inter-vehicle distance ... can be exploited by the traffic agent as information on the status of traffic: fluid, dense or saturated.

2.3 GLOBAL TRAFFIC AGENT

The vehicle-to-vehicle communication and the vehicle-to-infrastructure communication are used to exchange a wealth of accurate information on traffic conditions. Following these exchanges, the global traffic agent will have a global vision on the road network of the area it oversees. The main goal of this supervision is to maximize road safety and minimize the time spent on the roads to make them friendlier.

The global traffic agent collects the information on road conditions from traffic agents then synthesizes the data. Once the global traffic agent has a more complete view of the road network, it broadcasts information to traffic agents. For example, the agent tries to reduce road congestion by seeking alternative routes for vehicles aware of traffic conditions: it produces a path map that guides them to alternative routes more secure.

2.4 PARKING AGENT

For each parking lot, one parking agent is installed (parking, sidewalks). Their role is to follow in every moment the state of occupation of parking places. They get information on the availability of parking space through sensors installed throughout the car park on-Street, or through the automatic gates installed at the Off-street parking. Each park agent must in turn report to the station agent, in real-time, the number of parking places available compared to the total capacity of the park.

In fact, the parking agent provides to the station agent two data types: static and dynamic. When it comes to static data, it represent an invariable data such as the name of the park, the maximum capacity, the price (sometimes variable), the coordinates of the car, type of parking (to determine if this is a car park on-Street or off-street) parking time. With respect to the dynamic data they stand for the number of reserved places and the number of available parking places.

2.5 STATION AGENT

The station agent has a global view on all car parks in the area**.** It acts as a central supervisory entity through direct interaction with parking agents**.** He is responsible for acquiring and managing in a real-time a set of information**.** This information may come from different parking agents as they may stem from the global traffic agent**.** In a more explanatory**,** The station agent is a central location for storage of information detailing the state of parking places in the area it manages. At each time**,** he gathers the list of vacant parking and with the collaboration of the global traffic agent coordinates with motorists to guide them to open space.

2.6 COMMUNICATION PROTOCOLS

The vehicle agent acquires information in the form of observed events, either by itself, or through exchange of information with other vehicles, or whether through an infrastructure. Similarly to the traffic agent who acquires information by the vehicle agents, or through the global traffic, or by other traffic agents in control of the global traffic agent. Each vehicle is equipped with a sensor (eg antennas) to generate data and with an agent to deal with them. At each intersection and we install a post in charge of collecting information and an agent responsible for processing information. With the 802.11 communication protocol information can flow in real time between the different agents in the same area. In this study, we assume that all of cars and parking places are fully connected to the information network.

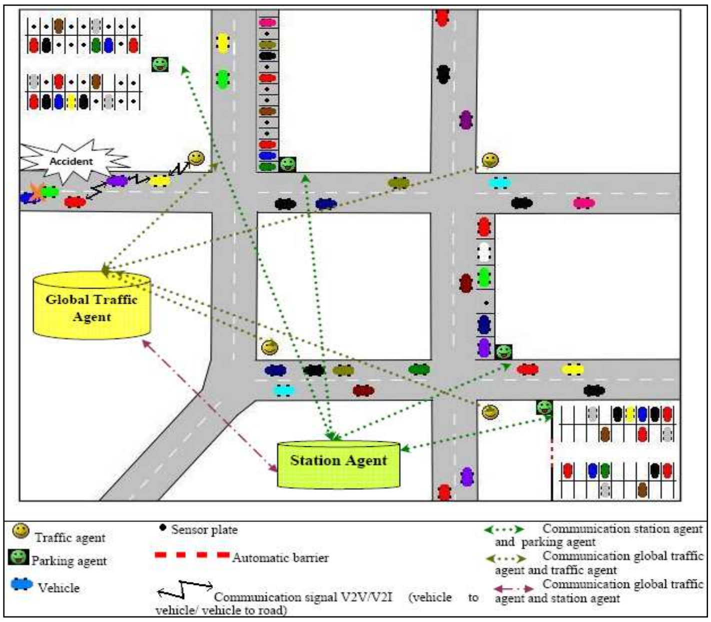


Fig. 2. Scenario of communication between different agents

The parking agent collects information from plates installed in the ground for each parking place or through the automated gates installed at the entrance of the park. In addition, it receives information from the station agent. The latter has two sources of information: the parking agents and the global traffic agent (Fig. 1). The plates are sensors powered by an onboard battery. The signals from these small devices will be transmitted in real time, to parking agents installed on sidewalks. Signals from the sensors contain information on seat availability.

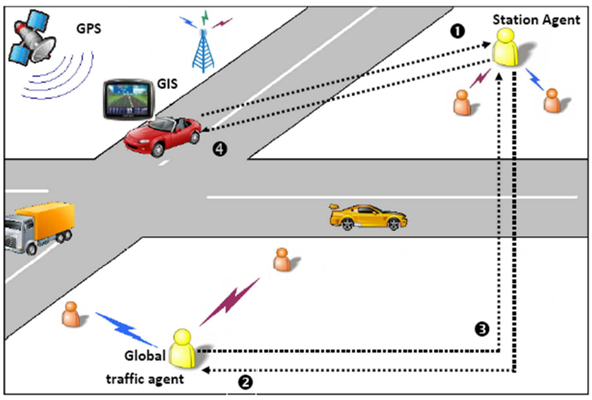
Sometimes during the existence of traffic lights, different agents can cooperate to minimize the waiting time of vehicles at intersections. Agents of highest priority vehicles such as ambulance vehicle [10], inform the parking agent of their attentions to park. The parking agent on his part communicates with the global traffic agent for information. And the latter under the action of the agent traffic, will try to reduce the waiting time of the vehicle by adjusting the next sequence of each traffic light.

3 THE FUNCTIONING OF THE SOLUTION

The idea of our smart parking system is to develop a procedure which coordinates road between driver and car parks in order to solve the problem of finding a parking place and then provide more convenience and comfort in terms of conduct. New information technologies such as GPS and GIS are used to facilitate the process of parking (Fig. 2).

Our system will enable pilots to:

- Search free parking places, quickly, at anytime and anywhere.
- Acquire a lot of information, among others, as prices, locations of parks around their destinations.
- Search for the optimal path to reach the destination quickly and avoid traffic jams (the algorithm of the shortest path applied in our study is the A * algorithm).
- Ensure the principle of seat reservation.



(1) The vehicle requires the station agent a parking place.
(2) The station agent sends the list of car parks available to the global traffic agent.
(3) The global traffic agent returns the shortest path for each car.
(4) The station agent calculates the cost of parking (C) and returns to the driver a dataset.

Fig. 3. General Design of the Solution

3.1 THE SEARCH FOR PARKING PLACE

Once the driver reaches the air in "D" where he wants to park, it must register with the station agent by entering its destination: the GPS accurately measures the coordinates of the current location of driver [9]. Through the GIS, the positioning of this point will be located on a map displayed in the GUI man-machine. The user can then view its destination and highlight it. The vehicle is the agent responsible for transmitting all information to the station agent. It's worth noting that the station agent, who has, in real time, the list of car parks with open place, interacts with the global traffic agent and asked him to find the shortest path associated with each parking place. The global traffic agent refers to the current location of the driver and contact information for each parking place contained in the list.

The idea of seeking for the shortest path can lead to beneficial results not only in terms of reducing time spent on the road but also in terms of improving traffic efficiency and reduced consumption of fuel (energy saving).

Based on the information transmitted by the global traffic agent and on the price and duration of parking, the agent assigns a cost to each parking place. Indeed, the cost (*C*) is the combination of three elements. The first element is the multiplication between the travel time of the shortest path (*K*) leading to the parking and fuel consumption (*F*). The second element is the multiplication between the parking price (*P*) and the parking duration (*D*) of the driver. Finally, a multiplication of the length of the distance in feet to walk (M: distance between parking and destination) and the time's value of the driver and his companions (R). Afterwards, all costs will be sorted in ascending order from minimum to maximum, which is likely to allow the solicitor the opportunity to choose the most convenient parking.

$$C = (K \times F) + (P \times D) + (M \times R) \qquad (1)$$

Where *C* is the cost evaluated with Tunisian dinar (TND), *K* is the travel time by car (*h*: hours), *F* is the fuel consumption (TND/h: dinars/hour), *P* is the price of parking (TND/h: dinars/hour), *D* is the parking time (h: hours), *M* is the travel time to work in feet (h: hours), *R* is the time value of the driver and the number of people in the car (TND/h: dinars/hour).

3.2 THE GUIDANCE TO A PARKING PLACE

As soon as the calculations are completed, the list of free parking places (unoccupied) appears instantly on the screen of the dashboard: the GIS produced a map that illustrates consulting geographical positioning of each parking place compared to the driver's location and destination. Several information associated with each parking are also displayed: name parking, type of parking (on-street or off-street ...), cost (*C*), parking price (*P*)…

Once all information at the disposal of the user, it must take the initiative to decide which parking place he wants?

The driver can select the parking that suits him on the basis of the cost function calculated by the station agent, or according to its time value, calculated on the basis of the distance of walking. This latter is between the parking and the chosen destination target. This factor reflects the time value of driver that can be solved at its selection of the location of the parking lot.

A simple touch of the screen and the selected car park is designated by the user. Following this choice will start two steps: (1) The GIS produces a path map that guides the driver's current location to the desired parking location (display the shortest path already computed by the global traffic agent). (2) The station agent must sign a seat booking contract with the vehicle agent.

3.3 THE RESERVATION

The system ensures, through the principle of reservation, a parking space available for the driver. Indeed, the station agent must provide to the vehicle agent a reservation guarantee, if we fall back into the same conflict of lost time due to the search for a place. In a simpler way, once the driver manages to have the reservation, it will go straight to the chosen car park. While the concept of reservation is not guaranteed by our system, there are certainly other cars currently looking for a place to park. When the driver reaches the target location, it will most likely find its space already occupied by another vehicle. Subsequently, our driver must try to do another search [11] [12].

Once the order booking is confirmed by the station agent, the vehicle agent and the parking agent must inform each other to follow the progress of the vehicle. The follow up of the car as it moves towards the car park, gives information on exceptional events that may hinder the progress of the vehicle. When the space detects the presence of a vehicle, the parking agent must check the identity of the agent vehicle. If the identity is not confused, the agent must warn the car driver through the vehicle agent, that this place is reserved.

4 SIMULATION AND RESULTE

The network created in our system is an extract from Open Street Map (Fig. 3) containing only roads in the region of interest, Tunis city center.

This sample contains about 50,000 vehicles / day (randomly generated). This network includes only roads with cars of 2500 links and 1000 nodes.

Fig. 4. Tunis city center according to Open Street Map

According to the municipality of Tunis, the selected area has a capacity of 11.201 parking spaces divided into two categories: off-street parking and on-street parking (fig4).

The municipality of Tunis attempted to increase the capacity of the off-street parking by the construction of car parks intended primarily to capture migrants (merchants and employees), residents and partly those who have a need for long-term parking. Off-street parking of Tunis offers 6001 seats.

To reduce the on-street parking, the center of Tunis has several parks with capacity reached 5200 seats. The on-street parking offer the paid parking or Parking in the blue zone (tab .II.) Following the creation of a blue area, the municipality of Tunis has made the generalization of short-term parking in the street, this type of paid parking and limited in duration. Parking in the blue zone of Tunis offers 5200 seats including parking time shall not exceed two hours and this is what allowed from 8:00 until 20:00. The unit price of a place to park is 0.500 TND per hour.

The generalization of paid parking policy with short-term parking in the city center is implemented to improve the management of the supply of available parking on public highway this is by setting the rotary parking with the installation of parking meters. The objective of this new technique of payment in the blue areas is to facilitate the process of paid parking allowing drivers to have a simple method, faster and more secure.

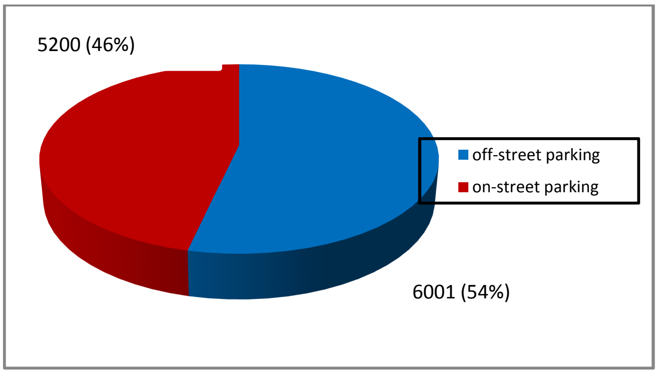


Fig. 5. Parking supply of Tunis city center

We have developed a simulation's environment in the software simulation MATSim (Multi-Agent Transport Simulation). As a matter of fact this software provides a toolbox to implement large-scale transport simulations based agents.

Moreover, for the project described, two methods were highlighted. For the first method, people can move randomly in the hope of finding places to park their vehicles in the area of their destinations. However, in the second method, drivers are guided to parking places. Thus, a comparison between the two methods was established. Figure 4 provides an overview of the data structure.

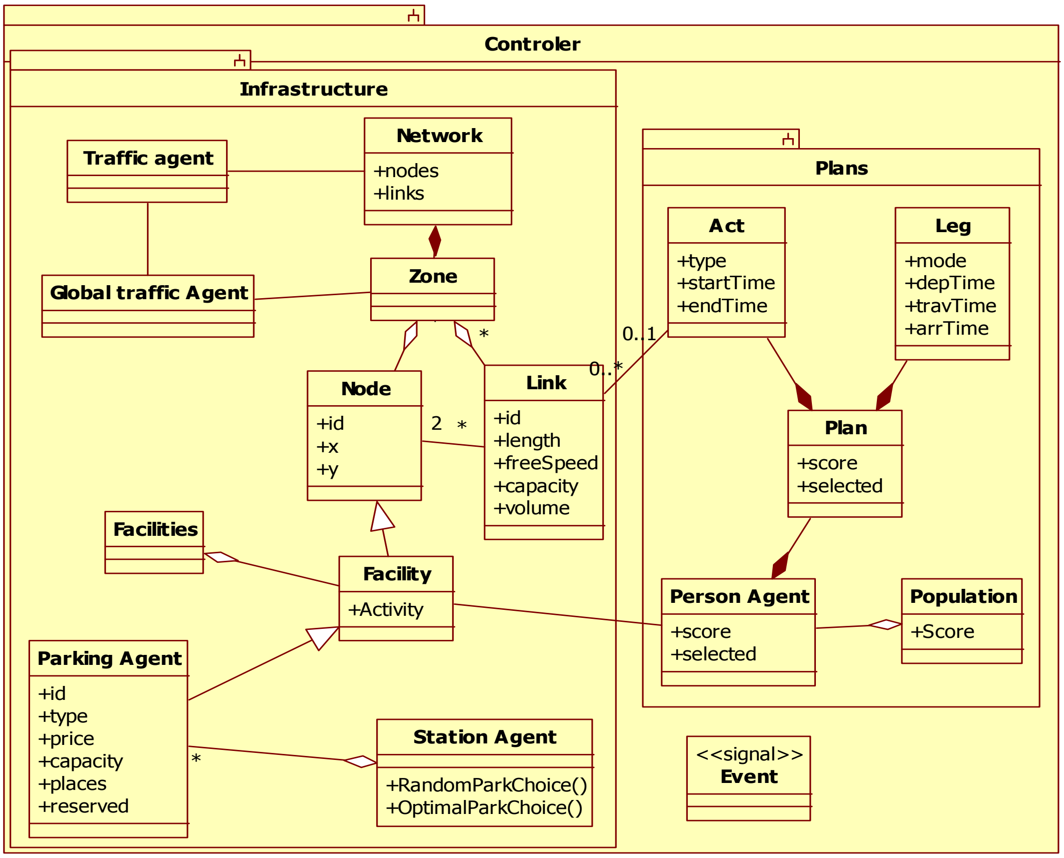


Fig. 6. The data network-based activity data

Network:

1) Node: each node is identified by a unique id and has *x*, *y* attributes which are converted from geographical location.

2) Link: each link has a unique id and is defined by a start and end node. Further important link attributes are length, capacity (vehicles per hour), free-flow speed and number of lanes.

Plan:

3) Agent person: each agent person refers to a citizen.

4) Itinerary: each itinerary contains the trips and activities done by the agent throughout a given time period. Within that period, each agent only has one itinerary. Each agent should and only have one itinerary for one day.

5) Trip: each trip contains multiple nodes and has distance, start and end time attributes. Hence the exact location of an agent at certain time can be retrieved.

6) Activity: each activity is what the agent is doing at a given time. It contains the activity type, such as shopping and education, location, start and end time attributes. Activity can also be considered as a trip with an event type and no change in the location.

4.1 CHANGES IN THE NUMBER OF VEHICLES IN CIRCULATION OVER TIME

After each simulation, MATSim generates a set of curves representing departures and arrivals of vehicles agents and the number of those on the roads. Figures 5 and 6 show the traffic for one day during the week by the two different methods.

These are curves that reflect the number of staff vehicles arriving, departing or moving every hour of the day. By doing so the red symbolizes the number of vehicles that have left their places of origin, the green curve represents the number of cars circulating in the street, whereas the blue curve shows the number of vehicles that have reached their destinations.

In order to compare the results of both methods, we proceed by comparing the curves. Table 1 can summarize the main results distinguished. Then we can notice that:

- With the method 2, the green curve is lower and the red curve is higher than of method 1. This implies that if drivers are guided to parking places, first the number of cars circulating in the street is fewer, and second the number of vehicles which have reached their destinations is higher despite that the number of vehicles which have left their places of origin is more important than if drivers are moved randomly in the hope of finding places to park their vehicles. The blue curves show that the number of vehicles that have led to their destinations on the 24 hours studied is higher in the case of method 2.
- The curves have two peaks: a first peak in the morning, which peaked at 8.00 and a second peak at the end of the day which peaked at 18:00. In fact, the morning peak reflects the number of vehicles that gets to the desktop. While the evening peak reflects the vehicles leaving work and returning home. In the morning, the maximum number of car (pic) is 12100 cars for method 1 against 11100 cars for method 2. It can be concluded that first, the traffic for method 2 is proportionally more fluid than the traffic of method 1. Second, the 2% of vehicles or 1000 cars reduced for method 2 represent the proportion of motorists who were looking for places to park. Therefore less time to find a parking place represents a reduction of travel time. This reduction has positive repercussions on the psychology of drivers, especially in the morning. The evening was recorded by more than 14.250 cars for method 1 against 13.900 cars for method 2. The traffic is fluid in the evening and compared to method 2, the percentage of reduced vehicle traffic is currently equal to 0.7%. It's lower than that found in the morning because the conductive agents who broke away from their workstations will move toward the periphery of the city center (away) or they will move downtown to a pattern of leisure or purchase; they are more likely to find vacancies. Similarly, for people arriving from the outskirts of the city center will be guided to parking places unoccupied.
- The number of vehicles in circulation is damped to 22:00 for Method 1 and to 21:00 for the method 2. One hour of traffic accounts for 4.17% of road traffic or 2084 vehicles. This is explained by traffic that has become more fluid and by lessening the time to find a parking place.

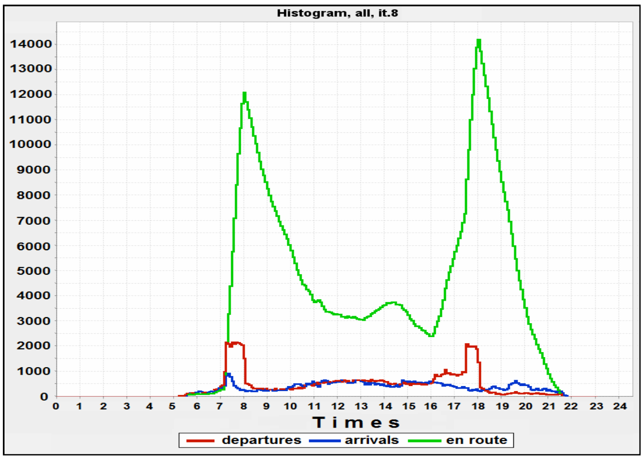


Fig. 7. Simulation of 50000 vehicles (Method 1)

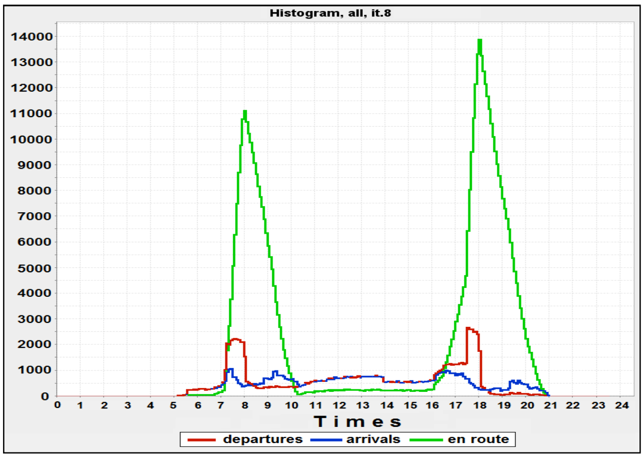


Fig. 8. Simulation of 50000 vehicles (Method 2)

Results obtained from method 2 imply that an intelligent management of parking demand could have several positive impacts on the environment (pollution, noise, energy ...), and the society (health, comfort, lower gas evolution ...).

4.2 Study of Statistical Scores according to MATsim

Three types of statistics are available for eight iterations generated in simulation: the best plan, the average plan and the worst plan as curves. Thus, the score function according to MATsim is defined as:

$$U_{plan}=\sum_{i=1}^{n}\left(U_{act,i}+U_{wait,i}+U_{lat,i}+U_{travel,i}\right) \quad (2)$$

Where, *i* denotes the activity, *n* the number of activities, the utility of a plan (U_{plan}) is the sum of four components: the total utility due to the implementation of the plan of activity *i* ($U_{act,i}$), the positive utility due to the establishment of the activity *i* ($U_{wait,i}$), the negative utility following a delay to achieve the activity *i* ($U_{lat,i}$), and the negative value due to the effect of the distance traveled to arrive at the *i* acitivity ($U_{travel,i}$).

Results of statistical scores (Table 1), show that method 2 is more efficient and more effective than Method 1.

4.3 Statistics Distance Travel

Figures 7 and 8 show the evolution of the total distance traveled by the 50000 vehicles for each iteration.

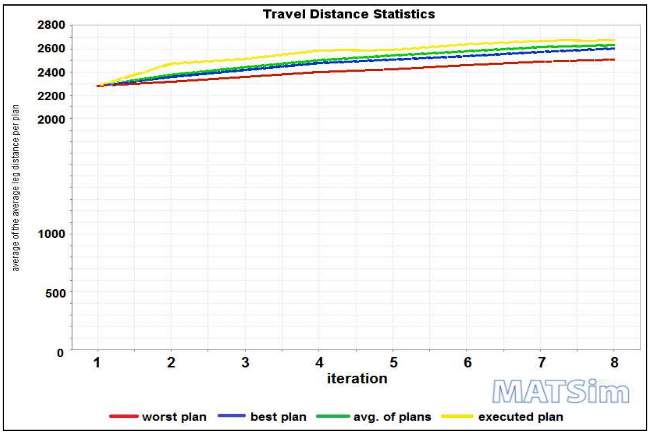


Fig. 9. Statistics on Distance Travel (Method1)

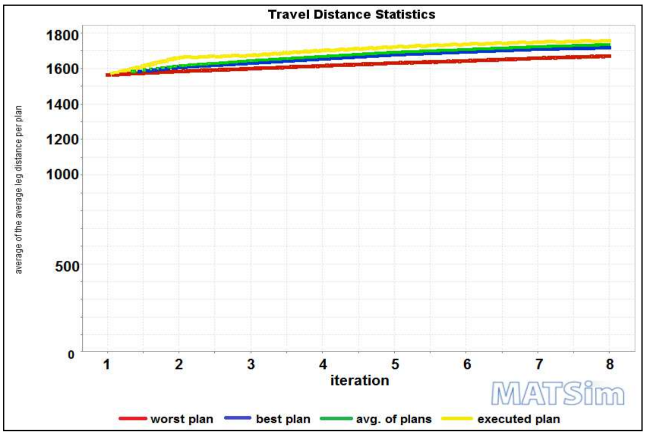


Fig. 10. Statistics on Distance Travel (Method2)

Table 2 presents the main differences between the two methods in term of the best distance traveled, the worst distance traveled, the average distance traveled, and the associated average saving of energy consumption.

Results of statistics distance traveled (Table 2) show also that method2 is more efficient and more effective than Method1.

Depending on the distance traveled, the average saving of energy consumption can be measured as:

$$ASEC = NV \times AFC \times D \times APD \quad (3)$$

Where, *ASEC* is the Average Saving of Energy Consumption, *NV* is the number of vehicles (50000), *AEC* is the average fuel consumption per 100 km (7 liters/100 km = 7%), *DT* is the distance traveled, and *APD* is the average price of fuel (1.250 TND). According the method 1, the average saving of energy consumption is:

$$1.09375\times10^{10} = (50000\times7\%\times2500\times1.250).$$

However, according method 2, it's:

$$0.74375\times10^{10} = (50000\times1700\times1.250).$$

A decrease in daily distance traveled by the resulting method 2 causes a reduction in average savings of energy consumption of 0.35×10^{10} .

Table 1. Statistical scores

	Method 1	*Method 2*
Score of the best plan	-55	23
Score of worst plan	-310	-103
Average score	-187.5	-47
Score of implementation	-160	-37.5
Score of start	-305	-92

Table 2. Comparative statistics

	Method 1	*Method 2*
Best distance traveled	2500 km	1700 km
Worst distance traveled	2400 km	1680 km
Average distance traveled	2520 km	1710 km
ASEC	1.09375×10^{10}	0.74375×10^{10}

Therefore, vehicles of a method 1 began with a distance of -305 km. While at iteration 1, vehicles reached a distance of 1570 km in method 2. The results of the travel distances reinforce the idea that method 2 is more efficient and more effective than Method 1.

The results show that finding a parking place is now guided. It can also provide a time saving, less congestion, less mileage, less movement and energy consumption and therefore less pollution. Then, it is possible to calculate for instance the average saving of energy consumption on the study area (table 2).

An impressive difference between the two proposed methods appears in the average distance traveled. Indeed, the best distance traveled by vehicles is 2500 km by method 2 against 1700 km by method 1, so there's been down for 800 km through the park during the 24 hours studied, making a decrease of 292000 km throughout the year. This decrease is synonymous with significant decrease energy consumption.

However, the Tunisian fleet consists of 40% of gasoline vehicles, diesel vehicles of 42% and 18% of diesel-50 vehicles (National Agency for Energy Conservation, 2009). Light vehicles, rolling months of 50 km-h average consume 7.17%, making 20936.4 liters of energy for all the vehicles and over a period of one year.

$$EE = 209364 \ \ liters \times AEP \qquad (4)$$

Where *AEP* is the average price of all energy types $((1.25 + 1.200 + 1.350 + 1.380)/4)$. So, with this intelligent parking management energy consumption expenditures can be reduced by 27112.638 (TND).

4.4 Changes In The Occupied Parking Over Time

The parking occupancy study involves field observations. It helps to determine the number of parking spaces occupied at different times of the day. We are interested in a first step, to all the car parks (on-street and off-street). Then we focus on the variation of the occupancy of two examples of parking: an on-street parking and another off-street parking. This study will observe the distribution of flows discounted vehicles through method 2.

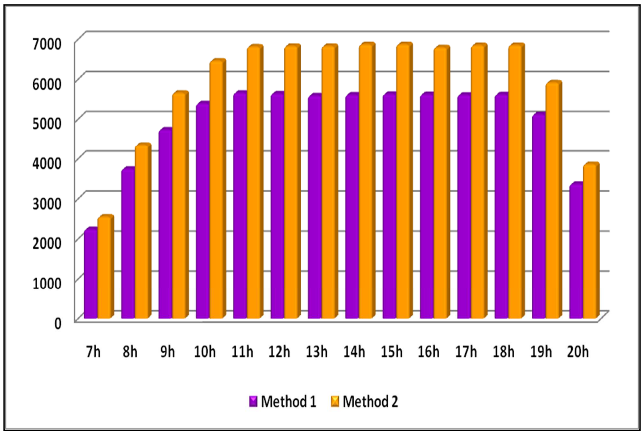


Fig. 11. Changes in the occupation of the parking space

The graph below is a comparison between the parking occupancy rate for method 1 and the occupancy rate of parking for method 2. It was found that using the method 2, we could better allocate vehicles looking for a parking spot, over all existing parking in downtown Tunis (cited above). This graph shows that the maximum vehicle accumulation is reached at 14h and 15h 6900 with parked cars.

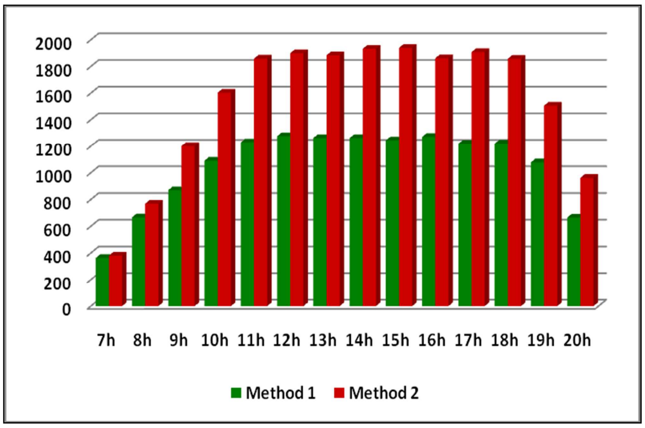


Fig. 12. Changes in the occupied of off-street parking

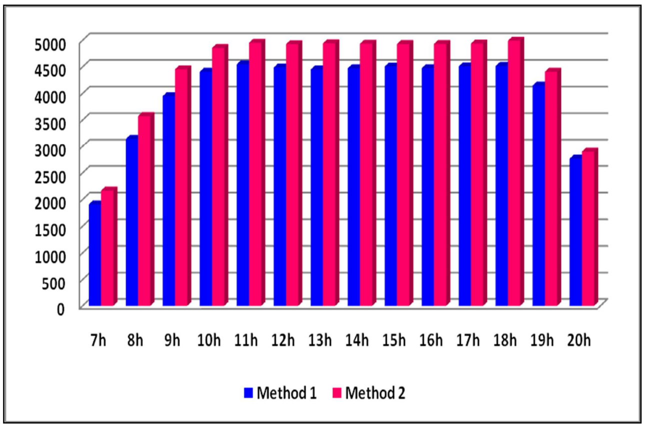


Fig. 13. Changes in the occupied of on-street parking

A comparison of Figure 12 and Figure 13 approves the method 2 is more efficient compared to Method 1. We also note that the on-street parking occupancy rate resulting from the method 1 and 2, is almost equal to the maximum occupancy of on-street parking rates. However, the occupancy rate gained by method 1 and 2, is less than the maximum occupancy rate of off-street parking. This can be explained by the behavior of drivers over at walking distance. Indeed, the drivers prefer the on-street parking rather than off-street parking, as parking is on-street located near the various activities while off-street car parks are more or less distant from the center of Tunis.

5 CONCLUSION

In order to research an intelligent car parking management system, this paper proposed a multi-agent system for minimizing the time spent in search of a location in a parking place. It starts with the description of the considered system organization in order to arrange the interactions, communications and coordination between agents. The coordination between them implies to find a vacant parking place, guide the driver to this area, and guarantee the reservation of the targeted area. Faced with all the possibilities that are available, the agents try to optimize the choice of driver for convenience and comfort.

Simulations established in this work show firstly the importance of our model of multi-agent in organization parking in a town center and secondly the differences between two methods, the first involving that people can move randomly in the hope of finding places to park vehicles and the second supposes however that our people are guided to park places. The results of the simulations from downtown Tunis are considered quite satisfactory in terms of reducing the search space for parking. Indeed, one could improve circulation by reducing the number of cars in the morning of 2% and 0.7% of the evening. In addition, the traffic per hour per day was reduced by approximately 4.17%. These results are due to the minimization of time looking for a parking place. The consequences of this minimization of search time has resulted in a reduction of the distance traveled, energy consumption, pollution, noise and other benefits such as an increase in the average age of the infrastructure, improving the psychology of drivers...

REFERENCES

[1] D.C., Shoup, "Cruising for parking". Transport Policy, 2006, 13, 479-486.

[2] A. Tofani, G. Dipoppa, G., "Report on available infrastructure simulators. Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (ENEA), DIESIS ; Design of an Interoperable European federated Simulation network for critical Infrastructures, 23 octobre 2008. Available in http://www.diesis-project.eu/include/Documents/Deliverable2.3.pdf

[3] R. Mraihi, "Transport Intensity and Energy Efficiency: Analysis of Policy Implications of Coupling and Decoupling. In M. Eissa (Ed.), *Energy Efficiency - The Innovative Ways for Smart Energy, the Future Towards Modern Utilities*. Chapter 13 (pp. 271-288), InTech, 2012.

[4] G. Marsden, "The evidence base for parking policies-A review". *Transport Policy: Special Issue on Parking*, 13(6), 2006, 447–457.

[5] W. Fan, M. K. Babar "Modeling the parking pricing of multiple parking facilities under different operation regimes".*Journal of Transportation Technologies*, 2, 2012, pp. 260-266.

[6] I. Benenson, K. Martens, S. "PARKAGENT: An agent-based model of parking in the city. *Computers, Environment and Urban Systems*, 32, 2008, pp. 430-439.

[7] R. Lu, H. Zhu, "An Intelligent Secure and Privacy-Preserving Parking Scheme Through Vehicular Communications. *IEEE Transactions on vehicular*, 59, 2010, pp. 2773-2784.

[8] S.Y. Chou, S.W. Lin, C.C. Li, "Dynamic parking negotiation and guidance using an agent-based platform. *Expert Systems with Applications*, 35 (3), 2008, pp. 805-817.

[9] Y.C. Shiue, J. Lin, S.C. Chen, "A Study of Geographic Information System Combining with GPS and 3G for Parking Guidance and Information System. *World Academy of Science, Engineering and Technology*, 2010, pp. 418-423.

[10] F. Baumarius, "A multi-agent approach towards modeling urbain trafic scenarios. *The Research report RR- 92-47*, Deutsches Forschungszentrum fOr KOnstliche Intelligenz GmbH, 1992, pp. 2-16.

[11] H. Wang, W. He, "A reservation-based smart parking system. In Proc. 5th International Workshop on Cyber-Physical Networking Systems (colocated with IEEE INFOCOM), April 2011.

[12] M.T. Tsai, C.P. Chu, "Evaluating parking reservation policy in urban areas: An environmental perspective. *Transportation Research*, *Part D*, 17, 2012, pp. 145-148.