Use of Dynamic Individual Traffic Lanes

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Abstract

This paper focuses on regular traffic-jams in intersections and in the use of intelligent traffic control systems in the solution of this type of problems. It is also studied the use of dynamic individual traffic lanes to solve regular traffic-jams in problematic intersections as it is considered that this method can reduce travelling times and accidents associated with the crossing of traffic streams.

To study the benefits of dynamic individual traffic lanes, it was chosen an intersection with characteristics appropriated to the implementation of this traffic control system. First, a model of the intersection was made and validated, to simulate real intersection with accuracy. After the model was calibrated, several options using dynamic individual traffic lanes where simulated. The results obtained where then compared regarding travelling time and mean velocities.

After this studied it was concluded that the use of dynamic individual traffic lanes can bring advantages when used in intersections with particular characteristics of design and flow.

1 Introduction

A traffic control system is defined by fixed installations, flows and by control systems who allows safety and efficient circulation.

In the last few years there has been a great increase in the use of this type of systems, especially in individual transportation. Increases in traffic originate several problems regarding traffic-jams, safety and pollution. To cope with this problem, there has been a great evolution in traffic systems control.

In this paper a new approach for intelligent traffic control is presented. It is studied the use of dynamic individual traffic lanes to improve traffic conditions in intersections where regular traffic-jams occur. It is believed that such kind of system can diminish traffic perturbations due to vehicle lane change and in consequence the reduction of travelling time. It is also expected that avoiding some streams crossings, unconstrained flows will stop being perturbed by congested ones, once more with reductions in travelling times.

The use of dynamic individual traffic lanes has been tested in micro-simulation using CubeDynasim. It has been applied to an intersection which was modeled and simulated.

In a first phase, an intersection with characteristics though to be adequate in the use of lane individualization has been chosen. This intersection has been modeled, trying to simulate the real intersection with accuracy. Flows have been measured in critical hours.

In a second phase, changes to the model have been done to simulate several options involving lane individualizations. This results where then compared to conclude if the adoption of such kind of system can bring advantages to this particular intersection.

2 Road Traffic Simulation

In order to understand traffic dynamics, the problem was deeply studied in the last 50 years and techniques regarding traffic engineer suffered great evolution [Hoogendoorn & Bovy,2001].

Simulation appeared as a way to predict consequences of an action in a particular system, without submitting that system to changes. Simulation is particular important in traffic engineering because this science interacts not only with road physical issues but also with social issues. This way, changes need to be deeply studied before implementation.

Nowadays, a great variety of commercial simulation software is available. It is now easy to simulate changes in traffic with simplicity, low-cost and little time consuming. In opposition to the situation several years ago, simulation is gaining importance in traffic planning, in the study of new solutions and in optimization of intelligent traffic control systems.

Acording to [Akçelik & Besley,2001; Taplin,2000] simulation can be divided in three major groups: macrosmulation, mesosimulation and microsimulation.

Macrosmulation is used to simulate at regional level and does not take into account every vehicle individually. [cube,2007]

To describe traffic flow with medium detail level it is used mesosimulation. Vehicle performance is not evaluated individually but in groups.

Microsimulation describes vehicles and drivers with a high level of detail. Due to it's level of detail it can only be used in small areas. This is the simulation type used in this work.

Cubedynasim was the software used. It is a commercial microsimulation stochastic package, based on events.

3 Intelligent Traffic Control

There are several emerging technologies related to traffic control. Although there are several kinds of traffic control systems, there is still a lack of knowledge in certain fields. Increases in computer technologies are leading to the development of better calculation software. Nowadays it is also possible to have real-time communication, leading to extensive development in traffic control systems. These types of systems are very efficient in preventing traffic-jams and incidents. [Chowdhury & Sadek,2003; IHT,1987]

The main goals of traffic control are: increasing roads efficiency, safety increases and pollution reduction [Papacostas & Prevedouros,1993]. These systems can be divided in four categories: highway incident management, urban traffic regulation, public transportations management and information systems to intermodal-systems users. [USDT,1997]

The use of dynamic individual traffic lanes is part of intelligent traffic control. It is composed of physical elements (sensors and actuators) and a computational system where data is processed. It is intended an automatic adaptation of lane characteristics to the traffic conditions, leading to a more efficient circulation.

4 Dynamic Individual Traffic Lanes

The work presented in this paper is the implementation of a system that can individualise or not traffic lanes according to traffic conditions, with increases in road efficiency, accident and pollution reduction.

To the present, when a lane is separated from others using pavement markings or physical separation, the individualization was permanent, regardless of traffic conditions. In this paper is proposed the use of dynamic individual traffic lanes and discussed the influence of that procedure in traffic flow conditions. This system is based in the use of a kind of lane separation which can be active or not, taking in account traffic conditions in the area.

The use of individual lanes makes a separation in streams of traffic, preventing stream crossings. Separation of traffic streams can be done by destination, origin or vehicle category. The destination choice is based on the final destination of each vehicle. The origin separation is used to mix streams of traffic in a predetermined matter to avoid traffic congestions. Finally, type separation is used to give priority to certain types of vehicles, for example, public transportation.

The use of dynamic individual lanes instead of simple lane individualization has the advantage of being adaptable to traffic conditions, allowing them to have the advantages of lane individualization without their disadvantages. One example of the disadvantages of permanent individual lanes is the impossibility of overtaking slow vehicles.

Another advantage of this traffic control mechanism is the possibility of monitoring traffic conditions. This way, it is possible to connect this system to other traffic control systems, giving users real-time information of expected traveling times or alternative routes.

The system can also alert about accidents. In one hand, it can warn users of potential risk and, in other, it can alert authorities.

Although the system has a wide range of possibilities, in this paper it is only studied the influence in traffic conditions, namely, variations in traveling times and average speed.

The dynamic aspect is related with the fact that lane individualization will occur only when traffic conditions are propitious.

One option for lane individualization is the use of lights (or LED's) on the pavement in the area between lanes which would change colour according to lane desired characteristics. The disadvantage of this option is the reduced visibility in shining conditions. The system also needs some kind of sensorial equipment (inductive sensors or cameras) to determine flow characteristics. The sensors would then send information to the processing unit which would decide whether or not to individualize traffic lanes.

Great advantages of such kind of system are the possibility to be implemented in existent roads without major works and at low costs.

5 Case Study

The studied intersection is a cloverleaf type. One of the main axis is A2 highway and the other is IC20. North to the intersection is “Ponte 25 de Abril” and South from it is A2 towards Setubal and South. To the West is IC20 towards Caparica and to the East is IC20 towards “Rotunda Centro-Sul” (access to Almada).

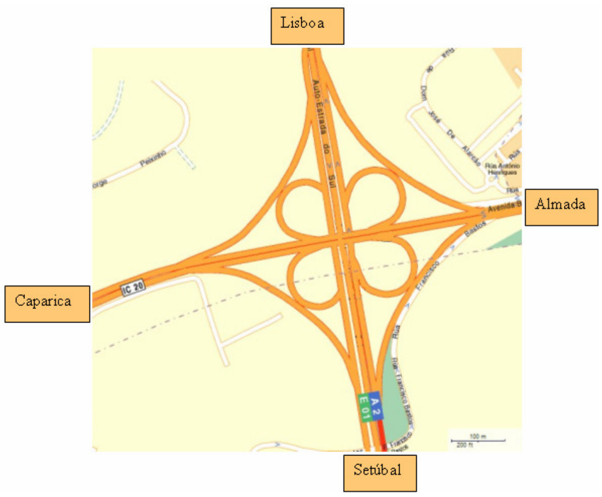

Fig. 1 – Studied Intersection.

Due to its location, next to one of the major entrances to Lisbon, this intersection suffers from congestion problems, especially during the morning peak hours. At this critical hours three main flows cross this intersection. One from South, one from the West and other from the East, all of them heading to the bridge’s toll before entering Lisbon originating huge traffic congestions.

At morning peak-hour, most of the traffic is due to daily movements from these areas to Lisbon. In the rest of the day the intersection is characterized by a high level of traffic, although without congestions.

This intersection has been chosen because it is believed that adoption of dynamic individual traffic lanes can diminish traffic problems in the area. In the direction West-East of IC20 there are two streams of traffic which are constrained due to the streams heading Lisbon. One is the stream going straight to Almada and the other is the one going South to A2. This problem occurs because at the moment, the stream from West heading Lisbon is occupying all the lanes (3 lanes) in IC20, blocking the other two streams.

Another problem, easily seen, is that the stream heading Almada is using secondary roads, not prepared to this level of flow, passing the Hospital and train station areas or via the shopping area (Almada Forum). It is desirable that those streams would be redirect to IC20, allowing better traffic conditions in Hospital, train station and commercial areas (Fig. 2).

Fig. 2 – Alternative routes to Caparica-Almada flow.

It is also believed that lane individualization can also benefit traffic heading Lisbon, because it stops perturbations due to car lane changing.

5.1 Modelling in “CubeDynasim”

The zone in study was modelled and then simulated using micro-simulation software “*CubeDynasim*”, with the following assumptions:

- One way roads were modelled as “*speed percent lanes*”. In this kind of lanes, it is defined the maximum speed allowed to vehicles according to their category. This road types are used in ramp access where the maximum speed allowed is 50 km/h. Although 50km/h is the real value, 65km/h is a better approximation for what really happens, so the lanes where modelled with this value;

- For two or more lane roads was used the option *"speed percent multilanes"*, which has the same basis of "speed percent lanes". The major characteristic of this road type is associated with lane changes. The lane change is made as soon as possible, taking into account the final destination of each vehicle. It is predetermined a limit point which, if reached, obliges the car to force lane change even if that implies stopping to achieve that goal. The valued assigned as maximum speed to this roads was 100km/h;
- Road marks were modelled using the option "*invalid path"*, where it is defined which vehicle type (based on destination or category) can use or not certain lane;
- The only traffic signs used were yield signs at the ramp's exits, but after running the model those signs were removed because it can be verified on site that when congestion occurs vehicles pass alternatively regardless of traffic signs;
- To assure that queues never reach system entrances, a stage with 10000 vehicles capacity was added near each entrance;
- Toll zone modelling was made taking in account the maximum number of vehicles which can actually pass that area. This limitation is due not only to tolls but also by bridge's capacity and is 7000 vehicles per hour. This value was supplied by "Lusoponte" which has automatic measures of vehicles passing the bridge.

5.2 Model Validation

Model validation is an important aspect to any simulation of a real process. It is necessary to assure that the model is as similar to reality as it is desired. To validate model, several measures were take into account:

- The mean time for some routes was measured and compared to real ones. The differences obtained where around 2 minutes, being sometimes the simulation time for the same route minor and others greater. This results were considered fine taking in account the randomness of the process;
- The queue length was also compared, although, in this case, not measured but only observed. This parameter seemed in accordance in both models;
- The number of cars passing bridge's toll was also measured to be around 6810 vehicles per hour, being this value in accordance with the 7000 used ("Lusoponte" measure).

6 Alternative options

As already said, it is intended to study the effect of dynamic lane individualization in traffic conditions. Three options where proposed and studied. All the options involve separation of streams with Caparica origin.

The first option is to separate the right lane (lane 3), corresponding to traffic heading Setúbal and South.

The second option is to separate the left lane (lane 1), corresponding to the traffic heading Almada.

Finally, a combination of the first two, simultaneously separation of left and right lanes. In this option all streams with origin Caparica are separated. A scheme of this option is show in Fig. 3.

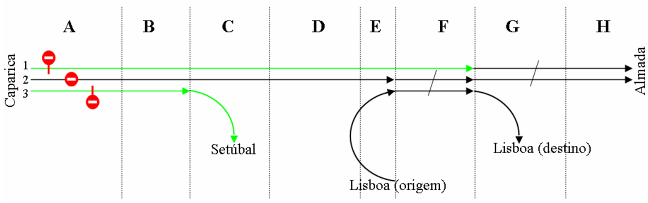

Fig. 3 - Modeling of lanes 1 and 3 individualization.

In every option lanes were modeled as totally separated because the used software didn't allowed the use of dynamic lanes. This is not a particular problem to this study as in this case all flows correspond to peak-hour. In this condition there are queues and for that reason, totally separation of lanes is a reasonable approximation.

7 Results

7.1 Introduction

An analysis was made to each option and to original situation to determine the effects off lane individualization. Three flows were varied: Caparica-

Lisboa Setúbal-Lisboa and Lisboa-Lisboa. The variations were made considering a flow of 50%, 75%, 125% and 150% of the real value. The flows with origins in Lisboa and Caparica heading Almada were not varied because their values are low compared with others.

To each variation, the effect was studied in 5 distinct flows; Caparica-Lisboa, Caparica-Alamda, Caparica-Setúbal, Setúbal-Lisboa and Lisboa-Almada.

Because the software used is based on stochastic processes it is necessary to make multiple simulations to each situation. Although 3 is the minimum number advised by *CubeDynasim* publisher the value used was 5. This number was obtained after some tests, it was noticed that in this particular case stabilization only occurred after 5 simulations.

After some tests, the simulation duration was set to be 30minutes of stabilization followed by a 1 hour simulation.

Results were then processed using *MatLab* programming in order to obtain graphics representing mean time and average speed for every studied situation.

7.2 Actual Situation

Graphics showing the results of the simulation of the real situation are showed in figures 4 throw 7. Although graphics showing mean velocity were also obtained, only graphics showing traveling times are presented in this paper.

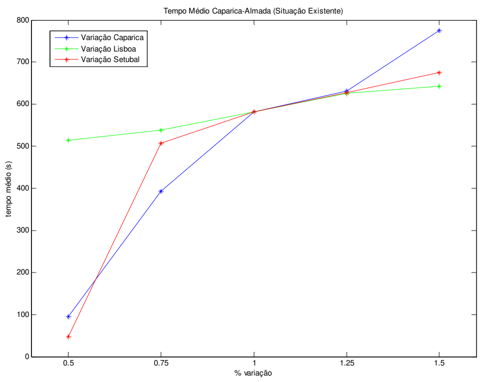

Fig. 4 – Traveling time for Caparica-Almada route.

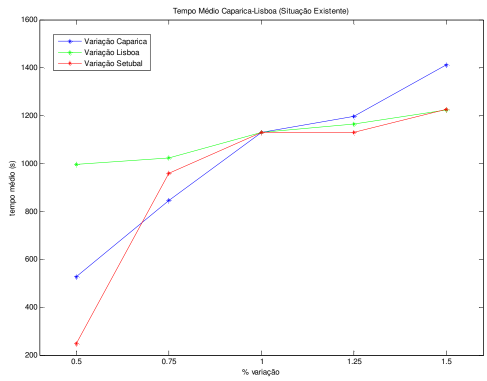

Fig. 5 - Traveling time for Caparica-Lisboa route.

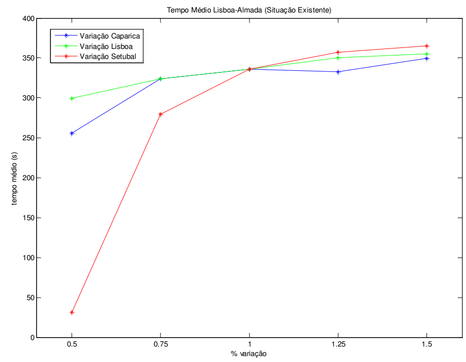

Fig. 6 - Traveling time for Lisboa-Almada route.

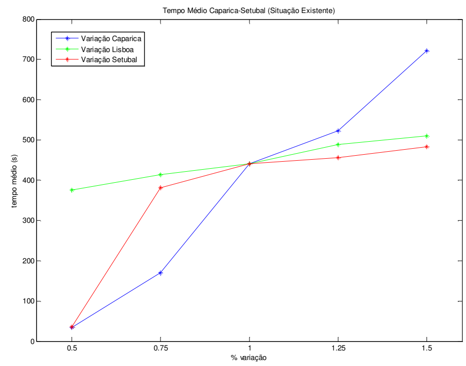

Fig. 7 - Traveling time for Caparica-Setúbal route.

It can be concluded that for flows greater than 3000 vehicles per hour traveling in the route Setúbal – Lisboa the queues due to bridge toll's get to the intersection between IC20 and A2. This way, an increase in the flow Setúbal – Lisboa does not take great effect in the studied intersection, because queues will form in A2 south to the intersection.

Linear increases in the flow from Caparica have the effect of linear increases in traveling times with origin Caparica. This increase is due to IC20's queue increase.

Flow with origin Lisboa has small effect in all the streams.

In the routes Caparica-Almada, Lisboa-Almada and Caparica-Setúbal minimum traveling times are very similar to 50% variation of flows Caparica and Setúbal. These results mean that in that cases road condition is very similar to totally uncongestioned situation.

7.3 Option 1

The comparison between option 1 (individualization of the right lane – Caparica-Setúbal stream) and the real situation leads to the following conclusions:

- Caparica – Setúbal: this stream stopped being influenced by others leading to travelling times 7 minutes faster than originally to the real flow; to higher flows this value is up to 11.5 minutes; it is also noticed that travelling times in this situation are almost independent from the flows.
- Lisboa – Lisboa and Lisboa – Almada: travelling times approximately equal in both cases, this situation is normal because the area where these streams pass is in a area where lane individualization is far and consequently with low effect;
- Caparica – Lisboa: general increase in travelling times, around 4 minutes for real flow;

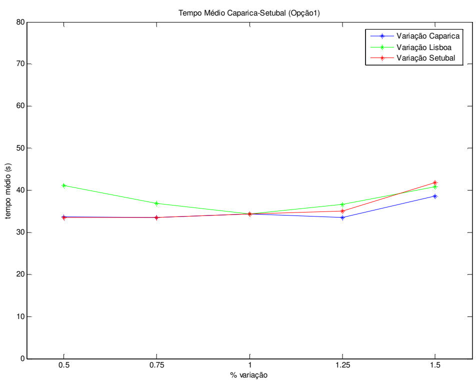

Fig. 8 - Traveling time for Caparica-Setúbal route.

- Caparica – Almada: graphics are similar, but there is a increase around 6 minutes in travelling time (at real flow) with this option; this increase is greater for greater values of flow;

The increases in Caparica – Almada and Caparica – Lisboa were not expected but can be explained by increases in left and centre lanes. It was expected that the lack of perturbations due to car lane change would lead to smaller/equal travelling times in those routes also. This increase can also been explained by the fact that vehicles which made this route using the right lane had smaller travelling times than the others. This way, they contributed to an overall mean time reduction in this route. This explanation can only be confirmed with more detailed simulations, including intermediate time readings. Since this was not the option with the best results this detail was not studied deeply.

7.4 Option 2

In this case, the left lane was individualized, corresponding to the stream Caparica – Almada. Comparing these results to real situations leads to the following conclusions:

- Caparica – Almada: travelling time reduction of more than 8 minutes at real flow conditions, from 9 minutes to 45 seconds.

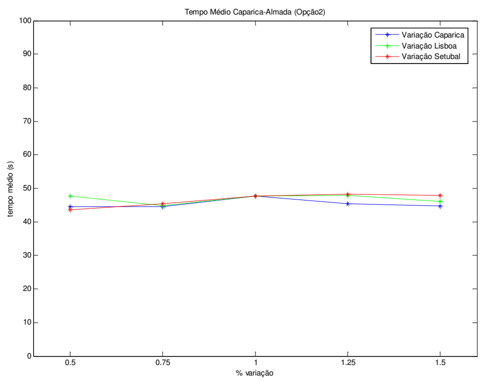

Fig. 9 - Traveling time for Caparica-Almada route.

- Caparica – Lisboa and Caparica – Setúbal: slightly diminution in travelling times, around 1.5minutes in the first case and 1 minute in the second for real flow;
- Lisboa – Almada and Lisboa – Lisboa: slightly increase in travelling times, from 5.5 minutes to 6.5 minutes in the first case and less than 20 seconds in the second;

The Caparica – Almada difference is according to what was expected due to its stream individualization. The other results were of minor importance as the difference (increase/decrease) is of small value. The best performance in routes Caparica – Lisboa and Caparica – Setúbal may be due to the absence of perturbations due to car lane change.

7.5 Option 3

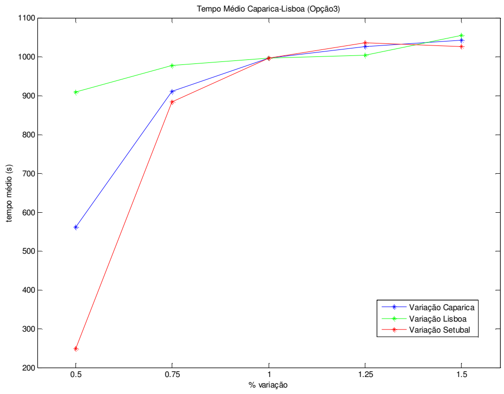

Fig. 10 - Traveling time for Caparica-Lisboa route.

This option is the individualization of both the left lane (Caparica - Almada) and the right one (Caparica – Setúbal). As a result, all the three streams in IC20 become separated. The conclusions in this case are:

- Caparica – Almada: similar results as in option 2, travelling times dropping of a maximum of 13 minutes to approximately constant travelling time around 45 seconds regardless of traffic conditions;
- Caparica – Setúbal: as expected, these results were similar to option 1, corresponding to decreases is travelling times around 7 minutes for the real situation up to 11.5 minutes in the worst scenario;
- Caparica – Lisboa: travelling time diminution, passing from 19 minutes to 17 minutes in real flow conditions. This difference is up to 6 minutes in the worst simulated conditions. It is noticed that it's difficult to improve this route because it's impossible to eliminate the conflict between Lisboa - Lisboa and Lisboa – Almada streams. Other problem in this stream is that it is heading a very congested area (bridge's toll zone);
- Lisboa – Lisboa and Lisboa – Almada: for both routes there is an increase in traveling time of 1 minute in real flow conditions. This difference may be due to randomness associated with the simulation process.

In Tables 1 and 2 the values of mean speeds and traveling times for the several simulated options are summarized. The results shown are for the real flow conditions.

Table 1 – Travelling mean times

	Mean Time (minutes)			
	Actual Situation	**Option 1**	**Option 2**	**Option 3**
Caparica-Almada	9,72	15,20	0,75 (45s)	0,75 (45s)
Caparica-Lisboa	18,83	21,53	16,97	16,60
Caparica-Setúbal	7,35	0,58 (35s)	5,37	0,58 (35s)
Lisboa-Lisboa	12,48	12,52	12,67	13,73
Lisboa-Almada	5,60	5,50	6,58	6,50

Table 2 – Travelling mean speeds

	Mean Speed (Km/h)			
	Actual Situation	**Option 1**	**Option 2**	**Option 3**
Caparica-Almada	6,7	3,9	72,0	73,5
Caparica-Lisboa	5,2	4,6	5,6	5,6
Caparica-Setúbal	5,6	65,0	7,0	65,8
Lisboa-Lisboa	5,8	5,7	5,6	2,6
Lisboa-Almada	5,4	5,5	5,0	5,0

By analysing Tables 1 and 2, it can be observed that some routes suffered significant reductions in travelling times after the adoption of individualized lanes.

Routes Caparica-Almada and Caparica-Setúbal were the ones with the best improvements. This is due to the fact that, in these cases, the low flow corresponding to these routes has been separated from the higher flows and the perturbations ceased.

A small improvement can also be observed in the route Caparica-Lisboa for Options 2 and 3, expected due to conflict points reduction. The weaving section for the Caparica-Lisboa flow circulating in the right lane is bigger than the weaving section for the Caparica-Lisboa flow circulating in the left lane. It is also known that in this second weaving section two more flows converge: Lisboa – Almada e Lisboa – Lisboa. This way, individualization of the left lane gave best results than right lane individualization.

Routes Lisboa-Lisboa and Lisboa-Almada have identical values in all the options simulated.

8 Conclusions

The study of dynamic characteristics of traffic flows led to the conclusion that traffic streams individualization carried by lane individualization can be benefit in several situations. The referred individualization stop traffic flows with relatively low values to be perturbed by high intensity flows. It is also known that some perturbations, like changing lanes in congested situations by certain vehicles can create shock-waves and be prejudicial to overall performance of the traffic system.

The chosen intersection, due to it's characteristics is a good example of a situation where lane individualization can be benefice.

The use of micro-simulation software to test lane individualization appeared to be a good option. After modelling the intersection and the calibration done, it was possible to test various situations, namely flow variations and signalling changes which were used to simulate lane individualization. The use of simulation allowed to obtain data of several combinations without affecting the real intersection.

Some conclusions were found after analysing the results. The individualization of a low value flow which is not heading to a heavily congested zone represents major reductions in travelling times to that route. This time reduction is up to 12 times the travelling time at real flow conditions and greater when greater flows are involved.

As expected, when all the streams (three) with the same origin were individualized, the traveling time values for the low flow routes suffered great improvements. The higher flow route, which is heading to a congested zone as also suffered a time reduction. This reduction is not so notorious (about 10%) and is due to absence of perturbation motivated by car lane changes.

Lane individualization was only simulated in congested situations, where total individualization of lanes was desirable. It is expected that in the congestion situations the results of dynamic individualization would be similar to those obtained. The great advantage of dynamic lanes is the possibility of slow vehicles overtakes by fast ones in low congestion situations. This kind of system can also benefit in preventing traffic accidents by warning drivers about dangerous situations.

There is still a great amount of work to be done before real implementation of such a kind of system. The system should be tested in other intersections with characteristics thought adequate to the use of dynamic lane individualization.

To make a real implementation of the system it is necessary to develop the sensorial, command and actuation system. It is necessary to decide the best sensor scheme for this system. The processing algorithm has to be deeply studied, to decide what are the conditions to individualize, or not certain zones. At last, it is needed to decide what is the best process to individualize the lanes, because the process should be automatic. A horizontal light signaling solution is probably the best option.

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