THE INTERMITTENT BUS LANE SYSTEM: DEMONSTRATION IN LISBON

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ABSTRACT

The concept of Intermittent Bus Lane (IBL) was introduced by Viegas (1996) as an innovative approach to achieve bus priority. The IBL consists of a lane in which the status of each section changes according to the presence or not of a bus in its spatial domain: when a bus is approaching such a section, the status of that lane is changed to BUS lane, and after the bus moves out of the section it becomes a normal lane again, open to general traffic. Therefore when bus services are not so frequent, general traffic will not suffer much, and bus priority can still be obtained.

The theoretical development of the IBL has already been concluded, establishing the required relationships among bus motion, general traffic flow and the related IBL signals and traffic signals at intersections. Also a simulation of the concept has been developed, and its results suggest that average bus travelling times can be reduced by as much as 30% with small decrease in the general traffic average speeds. Besides these results a real world demonstration was considered necessary to act as a prototype.

This paper describes the demonstration carried out in Lisbon, in cooperation between the University, the Municipality and the urban bus operator (CARRIS), for a period of 6 months starting on September 2005. The main results obtained reveal an overall increase of up to 20% in the bus average speed, with very limited impacts to the general traffic movements.

1. INTRODUCTION

During the last decades many cities developed and implemented several techniques for granting priority to buses. Priority has been given mainly through the definition of lanes or roads in which only Public Transport is allowed to flow or by giving priority at intersections. The traditional bus lane has, since the 1970s, become widely accepted as a means of allowing buses to avoid traffic queues and improve their speed and service, and therefore combat automobile dominated traffic growth and congestion. The priority given at intersections, using signal controls, was made possible by several developments in computer, communications, sensors and Automatic Vehicle Locations (AVL). Despite these developments many road links throughout the cities still don't have any effective priority system and the bus service is significantly affected by congestion.

This paper presents the improvements achieved in the implementation of a demonstration in Lisbon, Portugal of an *Intermittent Bus Lane* (IBL), a concept introduced by Viegas (1996) and theoretically developed by Viegas and Baichuan (2001 and 2004). In those papers, the concept, structure, operations, the movements of buses and other vehicles on IBL, modelling, and optimal control equations, all have been described in detail.

Following that theoretical development a demonstration project of this priority scheme was implemented in Lisbon, as the result of a protocol between the University (where the concept was developed), the Municipality and the urban bus operator (CARRIS). This demonstration project was meant to act as a prototype, and included the preparatory activities to implementation, the preparation of the control logic, the simulation of the experience in a traffic simulation model, a real world application and the evaluation of its results.

This paper synthesises the most important aspects of the IBL Demonstration Project in Lisbon and presents its main results. In Section 2 the IBL concept is presented and its operational system defined, followed by the presentation of the demonstration project in Lisbon (Section 3). Section 4 presents the methodology to evaluate the impacts of the demonstration and in Section 5 the main results obtained with the installation of the IBL are presented; Section 6 presents the simulation of the IBL and Section 7 the conclusions of this experience.

2. THE CONCEPT OF INTERMITTENT BUS LANE (IBL)

The concept of IBL was introduced in 1996 based on a few simple principles:

- Bus commercial speed and reliability are improved whenever buses are able to flow independently from general traffic;
- To provide (permanent) Bus Lanes in road sections where bus frequency is low is rather inefficient, as that lane could be serving a bigger number of travellers if it was also available for general traffic;
- But, if those road sections are congested the few buses using them will suffer significant delays due to congestion, affecting service throughout the lines using them. This could be avoided if one lane was reserved to the bus just for the time enough to allow it to move separately from general traffic.

Thus, an IBL consists of a lane in which the status of each section changes according to the presence or not of a bus in its spatial domain: when a bus is approaching such a section, the status of that lane is changed to Bus Lane, and after the bus moves out of the section it becomes a regular lane again, open to general traffic. Due to this "variable status" an IBL will provide a bus lane for the time strictly necessary for each bus to pass in that road section without being delayed by general traffic. As the restrictions to use the lane are only applied when a bus is coming, one can expect that the efficiency of this kind of bus priority scheme is almost independent from bus frequency (in theory, the lower the bus frequency is the more time the lane is available to general traffic and so less inconvenience is caused). Naturally, as bus frequency increases, the case for a permanent bus lane grows.

The implementation of the IBL is made possible by developments in AVL, which are currently mainly used to control routes and drive passenger information systems (Horbury, 1999). Combining several current technologies fully available in the market, the concept of IBL technique can be realized in several practical ways. The prototype developed in Lisbon lies on the following operational mechanism:

- The IBL controller should be able to monitor traffic conditions in real time; by being connected to local detectors it can receive information about flow, speed and queues in several monitoring points along the axes where the IBL is implemented.
- Also, the IBL controller has to be able to determine bus position within the IBL site and in its approaching area (to estimate the time when a bus is going to arrive in the IBL); this information can be gathered locally by detectors activated by buses and remotely by the reception of data directly from fleet management systems of the bus operators, normally based on GPS.

- When the system estimates that a bus will arrive at the IBL and face traffic conditions that can delay its movement, the IBL should be activated; the activation of the IBL is transmitted to drivers in that area using a combination of vertical Variable Message Signs (VMS) and a set of horizontal LEDs, placed on the line separating the lanes, that will be flashing when the IBL is “on” (the period in which the signalized lane is reserved for buses only).
- When the system determines that no more priority is needed (because traffic conditions are fluid enough or no buses are inside the IBL or approaching it) all signalization should be turned off, and the lane operates as a regular one (being accessible to any kind of vehicle).

It is important to mention that vehicles inside the IBL when it is activated (i.e. when the signalization is turned on) should not move sideways to other lanes, because that would create traffic conflicts, leading to flowing capacity and safety problems: they are supposed to drive on forward, and the system should compute the advance time needed to pre-empt the section from that traffic before the bus enters the section.

3. THE DEMONSTRATION PROJECT IN LISBON

The IBL demonstration project in Lisbon was developed from January 2005 to June 2006. During the first months efforts were concentrated in the preparatory activities to implementation; in September 2005 the IBL started operating. Between September 2005 and June 2006 the main activities were the monitoring and updating of the IBL system and the evaluation of its results.

After reviewing several possible areas for the demonstration in Lisbon, checking the geometry, the real traffic flow situations and bus movements in each area, seven favourite places for IBL application were identified. After discussion with the Municipality and CARRIS (project partners), the site at the “Alameda da Universidade” was selected as the first IBL testing area.

The area of “Alameda da Universidade” is located near the border of Lisbon’s Central Business District, being in the heart of Lisbon’s main university area. Besides being used as access to the universities located around it, it is also used by commuters to avoid other congested roads nearby, leading to a significant level of congestion during peak hours

The installation of the IBL was performed along 800 meters, mostly by eliminating illegal parking in the rightmost lane. In fact, this area was characterized by having many illegally parked cars, which used to cause a reduction from two or three “potential” lanes for traffic flowing to only one. The installation of the IBL was made by the re-arrangement of parking in this area, allowing parking spaces in some of the former illegal parking locations while enforcing the prohibitions in some others, leading to the creation of two lanes for traffic flowing all along the implementation area, with the rightmost lane operating as IBL.

Apart from this traffic engineering intervention, it is important to state that the whole capacity of this road section has not been changed, as the traffic lights at the intersection downstream, which act as major capacity restriction in this area, are still working as they were prior to implementation. This is particularly important to make sure that the results obtained in the evaluation process can be used to assess the potential benefits obtained with the installation of the IBL.

The demonstration period started in September 2005 and lasted for six months. During that period several successive “technological” developments were introduced in the IBL control logic, in the basis of a *continuous improvement* approach:

- During the first 6 weeks of operation the IBL was turned on whenever a bus was detected in its entrance; in this period the system was *inefficient* because it operated independently from traffic conditions (leading to unnecessary activations); and was *ineffective* as it did not apply the information of approaching buses to decide when to turn on and so in cases of severe congestion the IBL signals could not be turned on with the necessary advance to assure that the bus wouldn’t find vehicles queued inside the IBL.
- During the following 8 weeks of operation, the IBL system became more efficient as the activation started to be decided also taking into account the traffic conditions in that area; as the long-range information about the approaching bus was still not available the system was still ineffective in periods of heavier congestion.
- During the last 10 weeks of operation the information about the approaching buses was introduced and the system performed according to specification.

Implementation of the concept was done at relatively low marginal cost: on the detection side, 11 additional magnetic induction loops were installed to monitor traffic conditions, as well as 3 additional detectors of bus presence, all the GPS based AVL system being already available at the time. On the signalling side, one VMS panel at the beginning of each road block (this constitutes the legal element in accordance with the Code of the Road) plus an array of LEDs installed along the line dividing the two lanes of the road, at 3m distance. To connect the detection and the signalling, an additional traffic controller was installed in the traffic lights controller box.

FIGURE 1 Vertical signalization – Variable Message Sign – located at the beginning of IBL section.

FIGURE 2 Horizontal signalization – LED's on the pavement.

4. METHODOLOGICAL APPROACH FOR EVALUATING THE IMPACTS OF THE IBL

Before the demonstration of the IBL in Lisbon started, a detailed methodology to evaluate the impacts of that installation was defined. The main aspects that were monitored and evaluated were the following:

- Impact of the IBL on bus travelling times;
- Impact of the IBL on the general traffic flowing conditions (flow, speed and queues);

Concerning the measurement of the impacts of the IBL on bus travelling times a reference scenario was established, by asking CARRIS (bus operator) to automatically register travelling times of the buses in that area for one month *before* the installation of the IBL. During the 6 months of demonstration every single movement of any bus within this area was automatically registered, using the capabilities of the fleet management system (operated by CARRIS) which monitors bus movement in real time using the GPS based bus location system.

In what regards the measurement of the impacts of the IBL on the general traffic flowing conditions, the main data providers were the loop detectors installed in the pavement to support IBL operations. This was not an efficient data provider to build a reference scenario (that was performed using manual collection of travelling times and flows in some specific days) but it enabled the monitoring of the various traffic attributes during the experience, which can give indications about any impacts due to IBL installation.

In addition to all this data, it has been decided to select two weeks, during the last month of demonstration (March 2006) to act as "special evaluation period". During one of these weeks the system was turned off, while a high level of monitoring effort was performed. The following week the system was re-enacted, and the level of monitoring effort was maintained. The comparison of the various bus travelling times and traffic attributes during these two weeks gives a reliable idea about the impacts of installing the IBL.

5. RESULTS FROM THE REAL WORLD APPLICATION

In this chapter the main results of the evaluation are presented. It is divided in two sections: the first focuses on the impacts on bus movement; while the second discusses the impacts in general traffic movement.

5.1. Impacts on Bus Movement

The following Figure presents the comparison between the average bus speed in the first and second trimester of demonstration and the reference scenario.

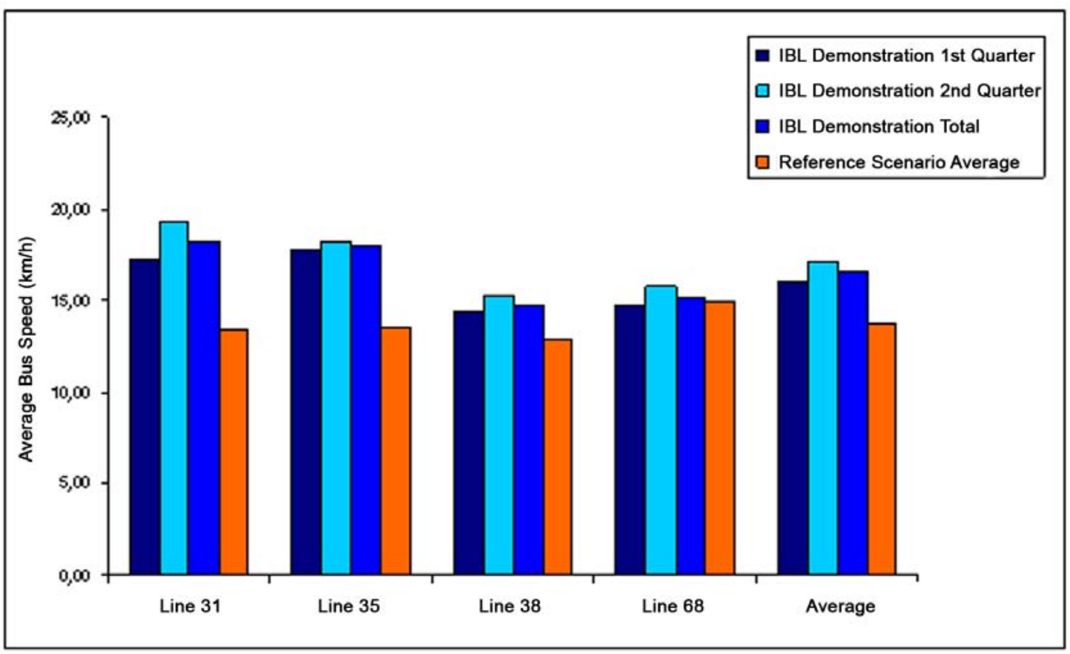

FIGURE 3 Average Bus Speed before the IBL installation and during the demonstration.

The results from this analysis reveal that the average bus speed increased after the installation of the IBL in all the lines that use this road link. The results point to an average increase of 2,8 km/h in bus speed, which represent an improvement of 20%. It is also important to point that the results in the second quarter of the demonstration are considerably better than those of the first trimester, which means that the developments in the continuous improvement of the system had an impact and also that the drivers' acceptance of the system was good (particularly because police enforcement of the system was concentrated in only the first weeks of operation).

The next Figure presents the variation of the average bus speed for the four bus lines in this area throughout the day during the demonstration and in the reference scenario.

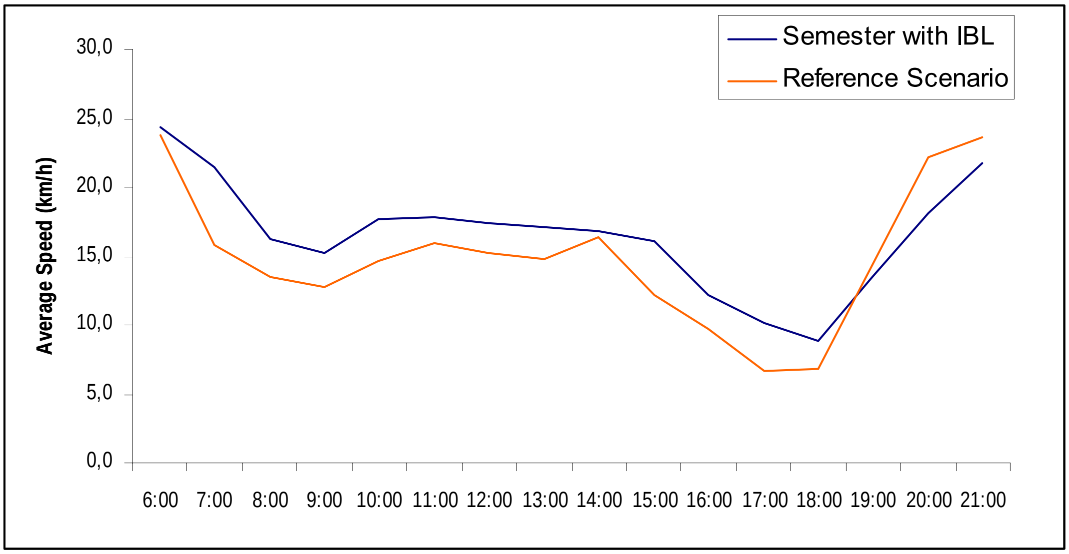

FIGURE 4 Variation of the Average Bus Speed along the hours of the day (in the reference scenario and after implementation of the IBL)

The results show that the improvement in bus speed was achieved during almost all hours of the day, but the relative increases tend to be higher during peak hours. This observation is particularly important because it has a positive consequence in the management of bus operations in this area, as the IBL seems to be contributing for an increased regularity of bus circulation. A possible explanation for the lower speed of the semester with IBL in the evening period is that the reference scenario data was collected in a period with no evening classes, which are the main source of traffic after 19:00 hours.

The comparison of the variations in bus travelling times in the area of the demonstration during the two consecutive weeks in March 2006 (one with the IBL operating and other without IBL) also revealed a significant improvement in bus movement. Results obtained for those weeks present a decrease in bus travelling times in all the four bus lines, ranging from a 5 to 14% decrease in the week the IBL was operating.

This smaller gain suggests that a part of the overall gain (possibly between 5% and 10%) must be attributed to the geometric rearrangements introduced at the outset, with an additional 10% to 15% attributed to the IBL system proper.

Globally, the results of the evaluation procedure suggest a positive impact of the IBL in the bus speed in the installation area, with an order of magnitude ranging from 15% to 25%. It is also important to underline the high consistency of these results, with the improvements being observed in all the bus lines using this road link and in the two methods of evaluation (continuous automatic monitoring of bus movements and the comparison of the two weeks "special evaluation period").

5.2. Impacts on General Traffic

As previously referred the impacts on general traffic are difficult to evaluate, as the construction of a reliable reference scenario was not possible to undertake, but a continuous monitoring of traffic attributes was performed.

The analysis of the traffic flows, vehicle speeds and queues accumulation during the demonstration period did not reveal any significant change in the overall pattern. This leads to the conclusion that the various modifications in the IBL control system didn't create any visible impact in the general traffic movements.

In addition, the comparison of the patterns for the various indicators of general traffic attributes in the two successive weeks in March, with and without the IBL, gave no indication of significant changes. This leads to the conclusion that the IBL in this site is not causing any significant impact on the main attributes of general traffic.

5.3. Drivers Reaction to IBL

Over the first weeks of the demonstration project, a public campaign to alert drivers to this new bus lane concept was carried out. At the same time, the presence of the Municipal Police, acting on an educational level, helped drivers to understand the IBL. The introduction of the VMS panel made a lot easier to understand when the bus lane was working, since the LED signalling had never been used in Lisbon.

In general, compliance with the system was rather good, as drivers understood that road space was being "taken away from them" only when strictly necessary. However, in the last weeks of the demonstration a few problems occurred, possibly as some drivers came to understand that their misdeeds went unpunished, given the very occasional presence of police officers watching over this demonstration after its first weeks. This has raised our awareness that an automatic system for detection of abuses of the Bus Lane (in active condition) would be desirable. This has been developed in the meantime and hopefully included in the second demonstration site, which is to start soon.

Neither car nor bus drivers were formally surveyed.

6. MICRO-SIMULATION OF THE INTERMITTENT BUS LANE

The main objective with the creation of a traffic micro-simulation tool for the IBL is to predict with precision the effects that the introduction of this new type of lane will have in traffic. Whereas in this first demonstration, the on-site installation preceded the simulation, and allowed validation of the software and calibration of many parameters, it is intended that in a subsequent demonstration in a more complex road environment, as well as in subsequent commercial applications, simulation will precede on-site installation, thus minimizing the risk of negative surprises and corresponding remedial actions.

As this is a totally new concept for a bus lane, the available traffic assignment software did not contemplate the use of IBL, thus making necessary the development of an application to reproduce IBL in a simulation environment. AIMSUN NG was the selected software for the development of IBL's simulation, turning out to be very flexible and easy to use. It was developed using the AIMSUN Application Programming Interface and is structured in a set of modules with distinctive functions: one for verifying traffic conditions, another for checking bus location and a decision module for turning on or off the IBL. The data parameters used are the readings from the detectors installed in the model.

6.1. Building the Micro-Simulation Model

A detailed survey of the demonstration site was conducted, thus giving precise knowledge of the site's geometry, signalization, parking and traffic, leading to the construction of two simulation cases: one before the implementation of IBL, and another one with IBL. In each one of them the peak hours of the morning and afternoon were recreated, the major difference between them being the existence of only one lane in the beginning of Alameda for the scenario without IBL (for simulating the suppressed lane due to illegal parking).

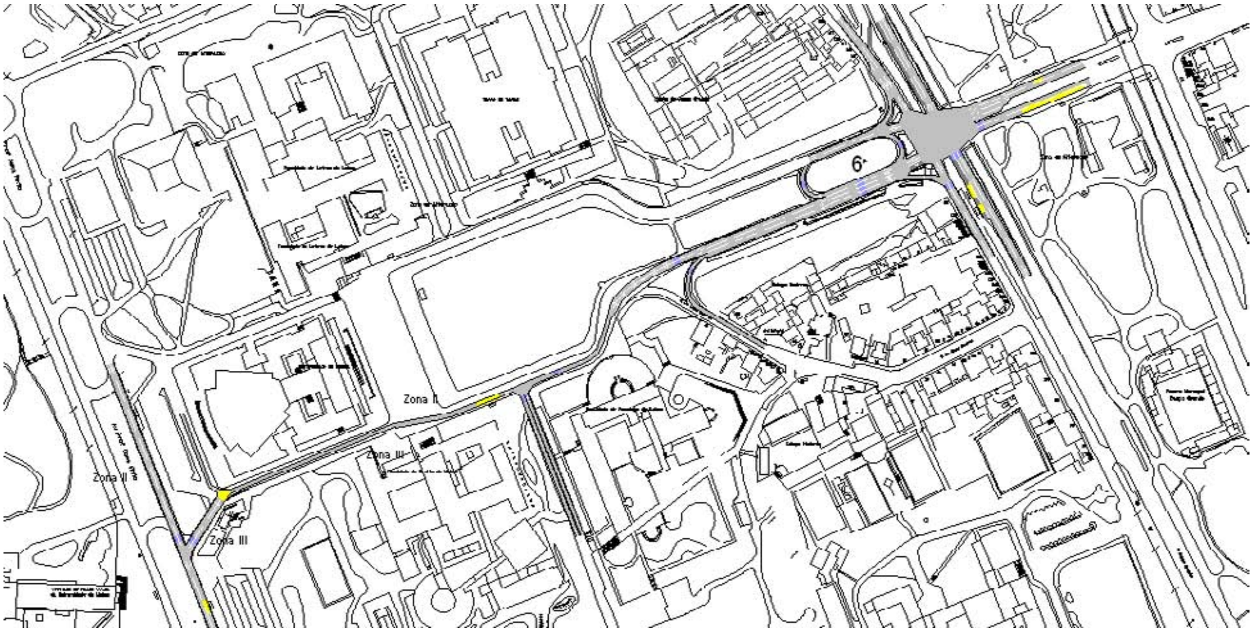

FIGURE 5 An image generated by the micro-simulation model.

6.2. Results and Validation of the Simulation Tool

For simulation purposes, a set of four traffic scenarios based on the values of the traffic survey conducted at Alameda was created. These scenarios recreate growing traffic intensities in order to evaluate the behavior of the model. The results of the simulation were divided in two types: general traffic and bus lines. The flow on an intermediate section of the model, queue lengths and traveling times were observed for general traffic. For bus lines, average speed and traveling times were taken into account. For each one of them, results were presented confronting both cases, with and without IBL, and Figure 6 shows one example for bus lines mean travel time.

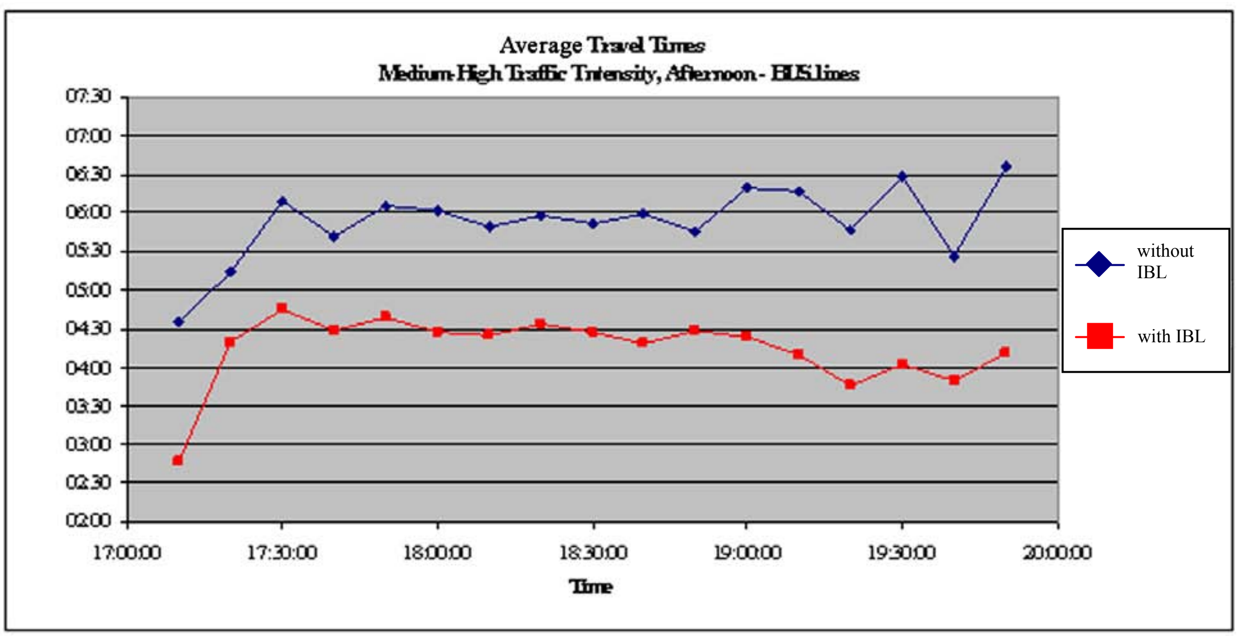

FIGURE 6 Average Travel Times in the Afternoon for the Medium-High Traffic Intensity Scenario.

Results from simulation showed that IBL can improve bus mean travel times up to 30%. For general traffic, queue formation occurred in the same time periods as in real life demonstration, and flows of the same order were obtained in the traffic scenario for which the input data was closest to the traffic survey values.

The results for simulation were validated through the real life demonstration results. Actually they were very close, both showing the gains that the implementation of the IBL in Alameda brought to bus lines, and the very small impact to general traffic, thus proving that the simulation model is a valid tool for predicting the behavior of the IBL in future implementations.

7. CONCLUSIONS

The IBL demonstration project in Lisbon succeeded in preparing a real world application of the system, and with it confirming its usability and value. Based in the theoretical developments defined in several earlier publications by the authors, the prototype for the system was prepared, showing that the technological requirements for this new bus priority system are fully available in the market;

During the six months of demonstration several aspects were evaluated. Firstly, drivers' reaction towards the system was good, having a good level of self-compliance. Second, the quantitative evaluation of the impact of the IBL (including the geometric rearrangement done in the preparatory phase) on bus movement and general traffic flow conditions has shown promising results, namely:

- 15 to 25% increase in bus average speed in all routes that use this road link.
- No significant impact in general traffic main attributes (flow, vehicle speed and queues) was detected.

Considering these results the IBL seems to present a high potential to work as a tool to improve bus movement in cities. The results from the demonstration in Lisbon show that it can contribute to increase bus speed while causing a limited impact to the general traffic. Taking into account all the rationale, and the low marginal cost of its implementation, it can be concluded that the IBL can be a very important mechanism to implement bus priority schemes in congested road sections where bus frequency is low.

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