FLEXIBLE BUS LANES IN BOLOGNA

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ABSTRACT

In busy urban areas, bus lanes are becoming a luxury as their design capacity is hardly used. The Flexible Bus Lane application, as part of the European research project CVIS, is a cooperative application that aims at using bus lanes more efficiently. New cooperative technology, in particular vehicle-to-infrastructure communication, enables specific vehicles to enter a bus lane through a negotiation process that increases the overall efficiency of the infrastructure while ensuring an undisturbed passage of public transport vehicles. This paper presents the concept of the Flexible Bus Lane application and an analysis of its potential by means of the Bologna test site implementation.

KEYWORDS
Public transport, CVIS, Cooperative, Vehicle-to-Infrastructure, Simulation, Roadside application, Test site, Bus lane, Dynamic routing

INTRODUCTION

The Integrated Project CVIS (Cooperative Vehicle Infrastructure Systems) of the 6th European Framework Program was launched in February 2006. The consortium comprises 60 partners from 12 countries, representing car manufacturers, road operators, traffic solution providers, research institutes and universities. The aim of CVIS is to enable flexible, harmonised and open communication between vehicles, roadside equipment and management centres to improve existing services and develop new ones. Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication will improve the quality and reliability of information throughout the cooperative systems network, enabling improved driving conditions which lead to enhanced safety and mobility efficiency [1]. Within CVIS three subprojects develop applications, providing new services to demonstrate the efficiency of cooperative technology.

More specifically, one of the sub-projects aims at developing Cooperative URBan applications (CURB) to improve the efficient use of the urban road network. The CURB applications are divided over three areas of interest: local traffic control, traffic management and public transport [2]. A total of eight applications will be demonstrated at test sites in Italy, Germany and the Netherlands.

There is one application specified within the public transport area: the Flexible Bus Lane application. The objective of this application is to increase the road capacity of certain origin-destination relations or on certain road sections by providing temporary access to bus lanes to selected vehicles, while ensuring an undisturbed passage of public transport vehicles. By making better use of the design capacity of bus lanes, the high investments for such lanes can be more effective as other vehicles can also benefit from the extra infrastructure. The application consists of two elements. One element enables the distribution of licenses to use the bus lane, while the other element monitors the bus lane and guarantees a smooth passage of public transport vehicles. Besides the technical aspects, one of the most challenging aspects is to determine the switching point from enabling to disabling the distribution of licenses.

This paper provides a more detailed introduction to the concept of the Flexible Bus Lane application, the test site location in Bologna, and an analysis of its potential based on the results of a simulation study.

FLEXIBLE BUS LANE APPLICATION

The application concept is to allow CVIS equipped vehicles, of a certain type or class, to use the spare bus lane capacity in urban areas in order to shorten their journey times, while ensuring an undisturbed passage of public transport vehicles. Two types of bus lanes are considered: physically separated bus lanes, sometimes even constructed as dedicated streets (see Bologna test site), and bus lanes constructed as an extra lane alongside normal lanes for private traffic (see Figure 1). The Flexible Bus Lane application can be applied to both.

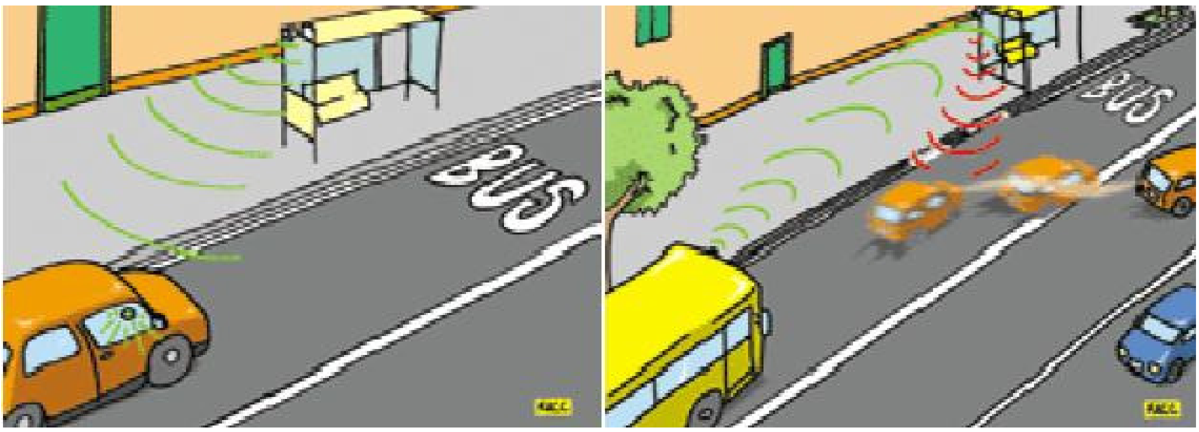

Figure 1 - Illustration of Flexible Bus Lane application

With two complementary parts, one installed on the vehicle platform and one installed on the roadside system, the Flexible Bus Lane application is a so called ‘cooperative system’. The sequence of activities performed by the two parts is described below and depicted in Figure 2.

A roadside unit (RSU) at a bus lane section continuously monitors the traffic situation on the bus lane and at the controlled intersection at the end of the bus lane. This concerns traffic flows, traffic densities, vehicles delays, queues and intersection saturation. Added to these is information from a public transport management centre on the positions of buses to estimate delays and arrival times at the bus lane and the exit(s) of the bus lane. For instance the traffic lights at the end or halfway the bus lane. As a result, the RSU can calculate the traffic state on the bus lane and predict how this state will evolve, both for buses and other vehicles.

When a vehicle with a subscription to the 'Bus Lane Service' is approaching a bus lane, it can apply for a license either automatically or manually. In case of the latter, the driver is made aware of the presence of the bus lane by the in-vehicle client and asked if he or she wants to use the bus lane and thus the system should apply for a license. The alternative is that the bus lane service is integrated in an enabled routing engine which selects the optimal route for the driver and automatically applies for a license if a bus lane is part of that route. It is important to note that the license acquisition process should be fulfilled before the vehicle arrives at the last logical route decision point. In case the request is denied the driver should always be able to a chose the second best route.

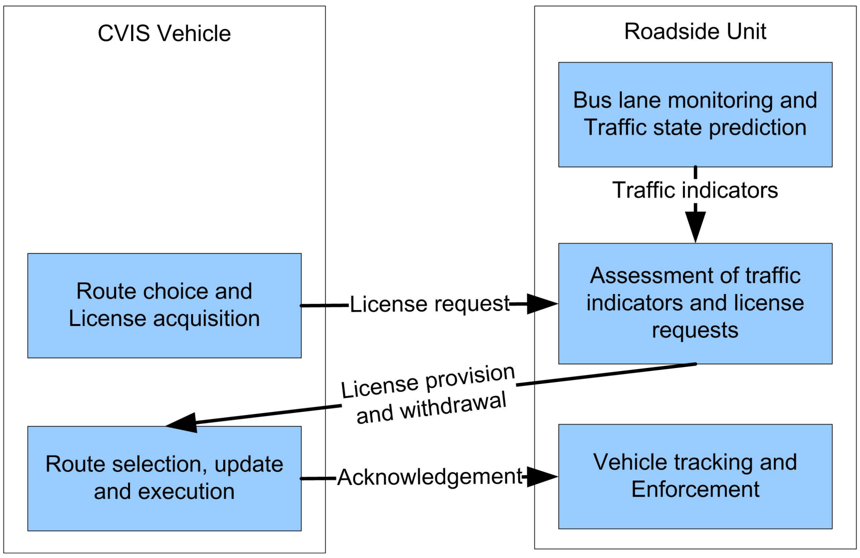

Figure 2 - Activity flow diagram Flexible Bus Lane application

The RSU determines if the bus lane can be used at the time the applying vehicle arrives at the bus lane using the traffic indicators mentioned above. If the traffic situation permits, the RSU gives permission to use the bus lane. In that case, the driver will be informed and guided to the shorter bus lane route. As long as the vehicle, together with the other CVIS equipped vehicles, does not disturb the public transport services the license will be renewed for the next bus lane by the next RSU.

In case of incidents or sudden serious delays that disturb the public transport services, the RSU will instruct the licensed vehicles to leave the bus lane as soon as possible. On physically separated bus lanes, the vehicle will receive a route update with an appropriate solution where to leave the bus lane and how to proceed to the desired destination. On bus lanes constructed as extra lanes alongside normal lanes, vehicles will be instructed to change lanes and merge with the other traffic. All messages from the RSU will be acknowledged by the vehicles to enable vehicle tracking and have insight to what extend the instructions of the Flexible Bus Lane application are followed up.

Unauthorised vehicles which use the bus lane will be detected by an enforcement system and automatically fined for their violation. To do so, the enforcement system refers to a ‘white list’ that contains registration numbers of vehicles that are allowed to use the bus lane. This list can be defined by the road operator and will automatically be updated by the Flexible Bus Lane application when a license to use the bus lane is distributed.

BOLOGNA TEST SITE

The Bologna test site is located in Via Giacomo Matteotti which is an important road that directly connects the north of Bologna to the city centre. Currently the street in the direction of the city centre is completely dedicated to buses. People travelling by car from the north to the city centre have to drive significantly longer routes to reach their destination. With a license to use the bus lane, vehicles can shorten their trip up to 5 minutes.

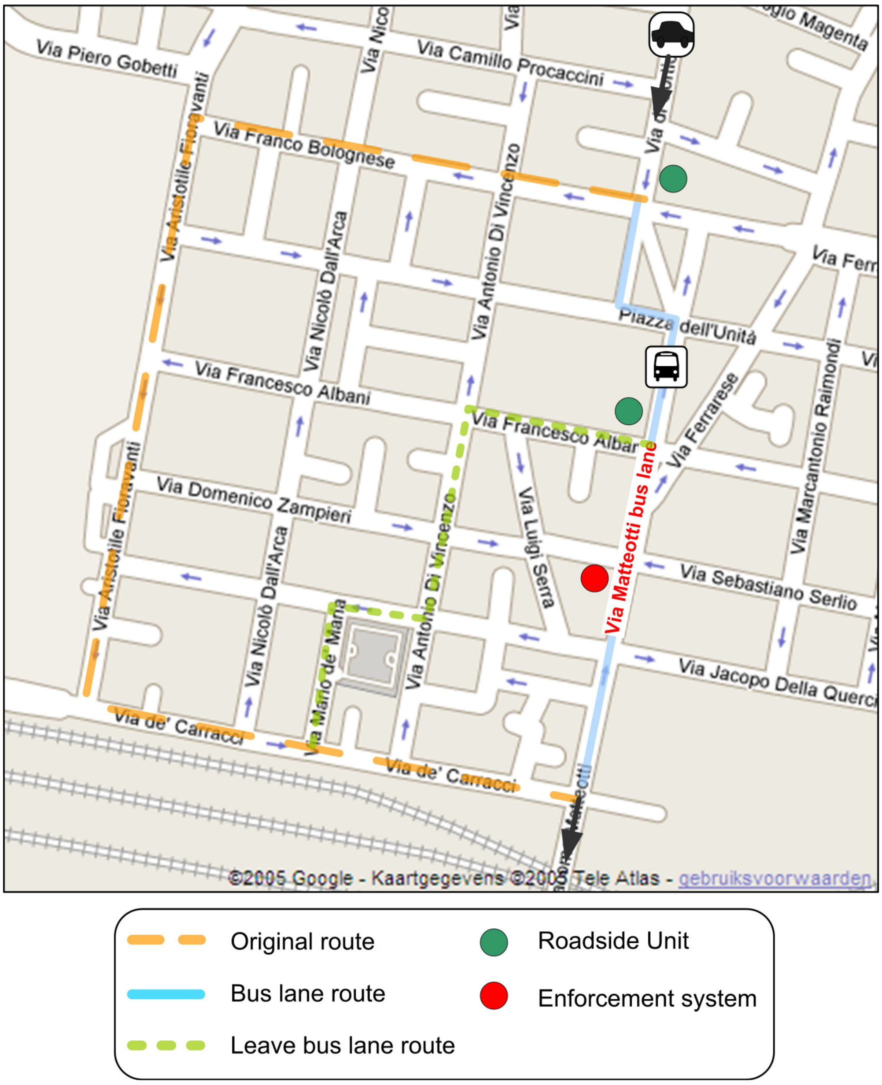

Figure 3 - Explanation of the test site location

Now, the original route to reach the city centre is through Via di Corticella, Via Franco Bolognese, Via Aristotile Fioravanti and Via de' Carracci. Licensed vehicles can travel along the alternative route through Via Giacomo Matteotti. At the intersection of the Via Giacomo Matteotti with the Via Francesco Albani, the licensed vehicles have the possibility to leave the bus lane when this is instructed by the Flexible Bus Lane application. In Figure 3 these routes are highlighted as respectively; 'original route', 'bus lane route' and 'leave bus lane route'.

In more detail, Figure 3 also indicates where the roadside equipment will be installed. In total, two roadside unites and two vehicles will be equipped with CVIS equipment. Additionally, an already existing monitoring system for public transport systems and a video enforcement system will be used. The Bologna public transport fleet is managed through an Automatic Vehicle Monitoring system (AVM) with GPRS localization (see Figure 4). This system allows to monitor buses on the whole area covered by urban and suburban services and to know the real time positions of vehicles.

Figure 4 - Bologna AVM (left) and RITA (right) systems

Many bus lanes in Bologna are equipped with an automatic video enforcement system named RITA that allows detection of unauthorised vehicles driving on the bus lane. RITA consists of a local network of detector stations connected to a control centre. The detection station includes: a loop detector for the detection of passing vehicles, a digital infrared camera (see Figure 4) to detect the license plate of the vehicle and a local unit for decoding the license plates and check whether a vehicle belongs to the 'white list' of authorised vehicles. If not authorised, the images are recorded from the camera and forwarded to the control centre for further verification.

Both the AVM system and RITA enforcement system are essential for the Flexible Bus Lane application. The AVM provides the positions of buses to estimate delays and arrival times at the bus lane and the traffic lights at the end of the bus lane. The enforcement system enables the detection of unauthorised vehicles on the bus lane. Test site demonstrations are planned for spring 2009.

SIMULATION STUDY

The purpose of this simulation study is to support the implementation activities and validate the application concept. Generally four objectives can be defined:

- To perform a more systematic and extensive analysis of applications and their possible variants.
- To explore and estimate the timing of applications and derive the optimal parameter settings, in an early stage of specification and development.
- To analyse the potential impact of applications if validation in the real world is not possible. For instance due to a low availability of equipped vehicles.
- To create clear and comprehensive demonstrations of cooperative systems and their applications in a controlled environment.

As described in the CVIS validation plan [3], the simulation study should minimally prove that more than ninety-five percent of the participating vehicles, which have received a bus lane license and have not been instructed to leave the bus lane, experience a decrease in travel time. The public transport's travel time must not be affected by this. Therefore, the following five indicators to measure the impact of the Flexible Bus Lane application have been defined:

- Number of vehicles on created route; only licensed vehicles.
- Travel time on original route; in seconds and for all vehicle types.
- Travel time on created route; in seconds and for all licensed vehicles.
- Travel time on bus routes; in seconds and for buses only.
- Travel time on bus lane segment; in seconds and for buses only.
- Total network performance; in hours and for all vehicle types.

On the basis of first simulation results it became clear that the effectiveness of the Flexible Bus Lane application is very case sensitive as various factors determine the impact of the application. The following four factors are encountered in the simulation study.

- Type of bus lane: a physically separated bus lane has only few possibilities to leave the bus lane once a vehicle has entered compared to a bus lane alongside normal lanes for private traffic.
- Type of bus stops: curb side stops have a huge disadvantage over turnouts that the bus lane is fully blocked as long as the bus halts.
- Traffic situation in the vicinity of the start of the bus lane: traffic lights, right of way rules and changes in the volumes and manoeuvres of traffic flows can influence the delay of vehicles significantly, even before entering the bus lane.
- Traffic situation in the vicinity of the end of the bus lane: traffic lights, right of way rules and changes in the volumes and manoeuvres of traffic flows can influence the delay of private vehicles and buses significantly, even after leaving the bus lane.

In total 6 scenarios were simulated using the VISSIM traffic simulation model. The network is modelled as depicted in Figure 6. Apart from the reference scenario, 5 scenarios were defined in which a number of vehicles used the created route. The exact number is defined as a percentage of the vehicles normally using the original route. No random variance was applied to the other variables. Based on the results in Table 1, the 6 scenarios are compared.

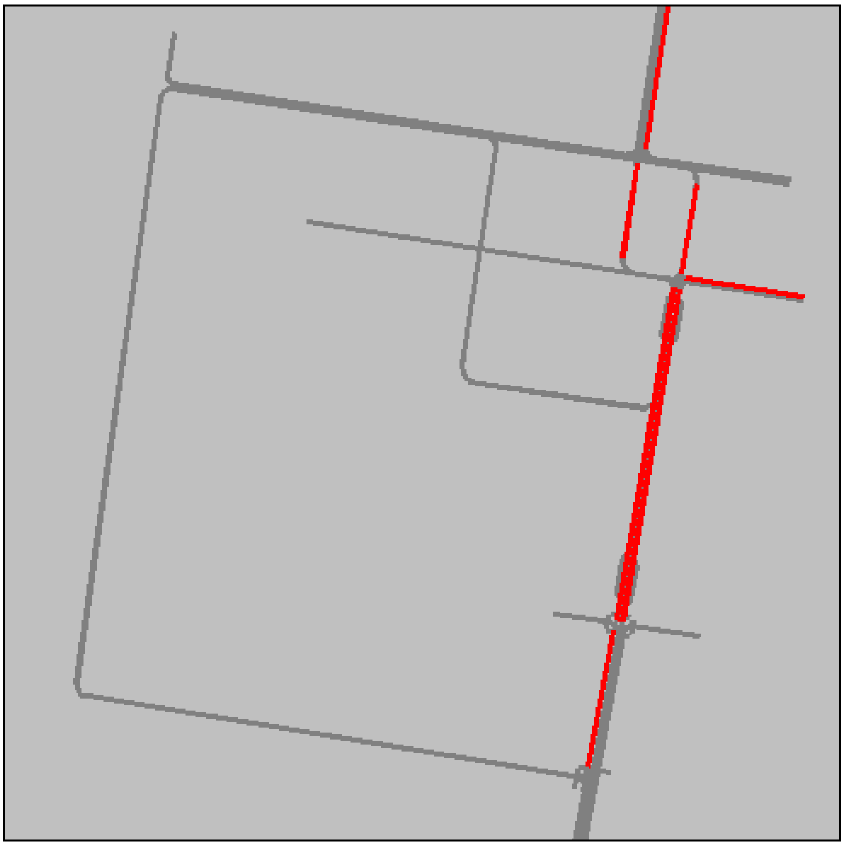

Figure 6 - Bologna network as modelled in VISSIM

Table 1 - Results from the simulation study

	Ref.	Run 1	Run 2	Run 3	Run 4	Run 5
Vehicles on created route [#]	n/a	83	175	238	336	420
Travel time original route [s.]	425	329	213	185	181	174
Travel time created route [s.]	n/a	94	95	96	100	102
Travel time bus route north [s.]	139	140	142	144	145	146
Travel time bus route east [s.]	143	145	153	154	165	169
Travel time bus lane segment [s.]	123	123	125	126	129	129
Network performance [h.]	135	93	64	57	54	53
Travel time original route [s.]	425	-23%	-50%	-56%	-57%	-59%
Travel time created route [s.]	n/a	-	+4%	+6%	+15%	+21%
Travel time bus route north [s.]	139	+1%	+2%	+3%	+4%	+5%
Travel time bus route east [s.]	143	+2%	+7%	+8%	+15%	+18%
Travel time bus on bus lane [s.]	123	+0%	+2%	+3%	+5%	+5%
Network performance [h.]	135	-31%	-53%	-58%	-60%	-61%

The above results indicate that spare bus lane capacity can be used without serious negative impact on public transport vehicle. With around 200 additional vehicles per hour on the bus lane, public transport is delayed by only 3 percent, which equals 2-3 seconds. Using the spare bus lane capacity the network performance increases dramatically. Again with around 200 additional vehicles per hour on the bus lane, the average travel time for private vehicles decreases with more than 50 percent.

It has to be noted that it is questionable if the bus stops at Via Matteotti should be modelled as curb side stops or turnouts. The street is wide enough for vehicles to pass halting buses, but to do so they have to use (part of) a bicycle lane that is located in the middle of the road. Although this is not allowed, vehicles frequently make this manoeuvre in practice due to the low amount of cyclists. Above results are based on a simulation where bus stops are modelled as turnouts. When the bus stops are modelled as curb side stops, the necessity of cooperative technology becomes clear: with random insertion of vehicles on the bus lane, public transport will be disturbed significantly.

CONCLUSIONS

Cooperative technology enables the development of new systems and services to improve the efficient use of the urban road network. Utilisation on bus lanes, by means of the Flexible Bus Lane application, has a high potential with regard to network performance and optimal use of road capacity. Simulation has proven to be very useful in an early stage of specification and development for more systematic and extensive analysis of possible variants, optimal parameter settings and the potential impact. The simulation results showed that the effectiveness of the Flexible Bus Lane application is very dependent on the type of bus lane and the type of bus stops. Besides, the traffic situation in the vicinity of the start and end of a bus lane and the way this situation is affected by the application is also very relevant. In the Bologna case, spare bus lane capacity can be used without serious negative impact on public transport services, whereas the network performance increases significantly. With 175 additional vehicles on the bus lane per hour, public transport services are delayed by only 3 seconds. Facing that is a dramatic decrease in the average travel-time for private vehicles: 53 percent. Cooperative technology is essential: with random insertion of vehicles on the bus lane, public transport will be disturbed significantly. Demonstrations in real-life traffic are planned for spring 2009.

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