

Measure title: Implementation of bus priority scheme in Toulouse

City: Toulouse Project: MOBILIS Measure number: 12.2.T

A Introduction

A1

Traffic regulation may optimise the commercial speed and the travel duration for public transport authority. National French studies¹ have shown that bus priority systems save between 20 and 30% of crossroads travel time. The public authority transport of Toulouse (TISSEO) owns around four hundred buses, which cross potentially 500 crossroads. Bus priority systems had already been tested on a small scale within the city centre of Toulouse.

Objectives

The measure objectives were:

- **Objective 1:** to study and implement a new priority system by radio transmission between the regulation system and the junction controllers,
- **Objective 2:** to evaluate the implementation of two different PT priority systems at dedicated junctions, especially at one of the High Quality Bus Corridor, in order to assess each system on the bus travel time and on private vehicle traffic.

A2 Description

This measure aimed to develop bus priority system at the level of the urban area and to adapt the existing traffic control system to integrate bus priority information and secondly to test a radio priority system.

The building of a centralised control system at bus network scale and its integration into the existing road traffic control system to create a multimodal control system need sophisticated tools, which have proved to be too long to develop in MOBILIS time.

The centralised approach has therefore been postponed and the measure focused on the development and the implementation of two different bus priority systems in two different traffic schemes, inline with local concerns.

The aims were to improve bus services (commercial speed, travel times and therefore transport capacity) when they are travelling on dedicated infrastructures (like High Quality Corridors – cf. measure 6.4.T) or on a separated lane and the level of knowledge on decentralised bus priority systems:

- one based on the use of a radio transmission between bus and traffic junction controllers and implemented at classical traffic junctions crossed by busses. This one will be further named “radio priority system”.

¹ STIF, 2001.technical guide for bus priority system at crossroads. STIF Report, Paris.
CERTU, 2001. priority system at traffic light for public transport vehicles. CERTU Report 108.

- the second one based on the use of active detection loops implemented in the High Quality Corridors (HQC) developed within the measure 6.4.T. This one will be named further “loops priority system”

B Measure implementation

1 Innovative aspects

Innovative Aspects:

The innovative aspect of the measure is:

- **Use of new technology** to provide, at the City level, a "tool box" in order to implement different types of PT priority systems at the junctions, according to the type of vehicles concerned (bus or tram), the traffic environment of the crossroads, the traffic strategy applied on the axis concerned, etc. Communication between the PT vehicles may be done, depending of the previous characteristics, directly at the local level (crossroads) or indirectly through communications between the traffic regulation system and the bus management system.

B2 Situation before CIVITAS

Since 1973, the city of Toulouse has developed a road traffic control system. The Automatic Vehicle Location (AVL) system transmits traffic level information at conurbation level. This exploitation system is based on Claire System². In each geographical traffic area, traffic detectors (electromagnetic loops) instantly determine the traffic level situation. The central urban traffic control computer (UTC) located in the central control post (PC) Capitoul compares the instantaneous situation to different traffic types and, determine the best strategy scheme to adopt for managing the traffic light cycles of the covered area and prevent or improve traffic congestion. Its data also feed a public website of traffic information.

The public transports had no specific treatment and the traffic light cycles do not include any bus priority system.

1-Radio priority system experiment

The two junctions chosen to implement this system are located close to the main Toulouse University in the area covered by Capitoul Control Post.

2-Loop priority system

The measure 6.4 of the MOBILIS project contributed to the implementation of high quality bus corridors. Before CIVITAS, the road (RN 113 from A 620 to Castanet Tolosan), on which one of these corridors has been built, was partly composed with three lanes; the speed was limited to 70 km/h and no traffic light signals equipped the crossroads.

² Implementation of CLAIRE, traffic estimation and prediction system, and adaptive traffic control in the U.S, GHAMAN R. S. ⁽¹⁾ ; LIEU H. C. ⁽¹⁾ ; SCEMAMA G. ⁽²⁾ Congrès RTIC 2002 : road transport information and control : (London, 19-21 March 2002) International conference on road transport information and control N°11, London , ROYAUME-UNI (19/03/2002) 2002-, vol. 486, pp. 95-99, [Note(s) : X, 205 p., , IEE conference publication.



Figure n°1: Local bus priority implementation

B3 Actual implementation of the measure

The measure was implemented in the following stages:

Stage 1: Study for the development of bus priority centralised system (March 2005 - March 2006)- The engineering department Amec Spie realized a technical, functional and financial study about the development and implementation of bus priority centralised solution.

The main objectives of the study were:

- The functional and technical definition of a transmission system between the junction controllers and the centralised regulation system of bus network. The functioning hypothesis were that connections between buses and regulation system should satisfy the bus priority demand but also its fulfilment.
- The functional and technical definition of the interface between TISSEO regulation system and Capitoul Control post;
- The cost approach of the financial investment necessary to realize the implementation of centralised bus priority and its integration in Capitoul functioning.

In December 2005, the traffic management department of the city of Toulouse decided to launch the development of a new Automatic Vehicle Location (AVL) system (SITERE) in order to take into account buses and trams (a dedicated AVL will be developed within the tram building project). This new detection system will be implemented in 2009-2010, so out of the MOBILIS scope. A final reason was also the relatively underperformance of the present transmission system, which was too slow to allow a centralised bus priority system.

All developments on the actual urban traffic control (UTC) system have so been suspended. Nevertheless, the study provided some technical specifications for the development of the interface between the UTC and the today AVL systems but their implementation will require the availability of the new AVL system. The functioning will be based on the scheme

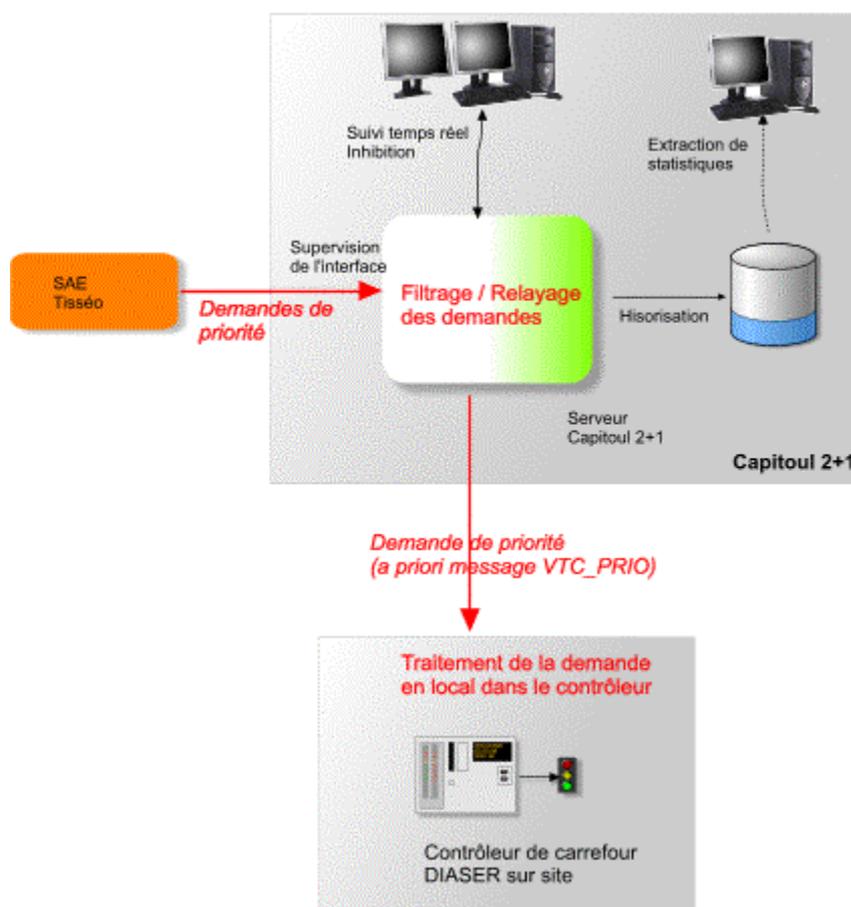


Figure 1 – Functional principle of centralised priority

Due to these conclusions; the local partners decided to put efforts mainly on a decentralised solution that permits to have better results for the bus circulating on a dedicated infrastructure (like High Quality Corridors – cf. measure 6.4.T) or on a separated lane. If the buses are selectively detected and the crossroads not too congested, this technical choice is adaptable at a whole bus network. If the crossroads congestion is too important, a centralised solution could be most effective but is fairly much complex to implement and to manage.

Stage 2: Implementation of local bus priority system

1) -Radio priority system

1. **Invitation for tender** (*October 2006 - January 2007*) – Following an invitation to tender, the COMATIS company together with FARECO and CERYX developed a radio call priority system for busses at traffic light signals and presented the controllers' equipment products on June 22 2006. The on board command box communicates action codes to the traffic light controller but it does not have remote access to the controller cycle data.

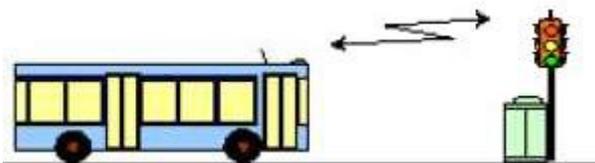


Figure 2. radio priority functioning scheme

The contract prescriptions were defined in September 2006 and the contract signed between the city of Toulouse and the providers in October for an implementation in January 2007.

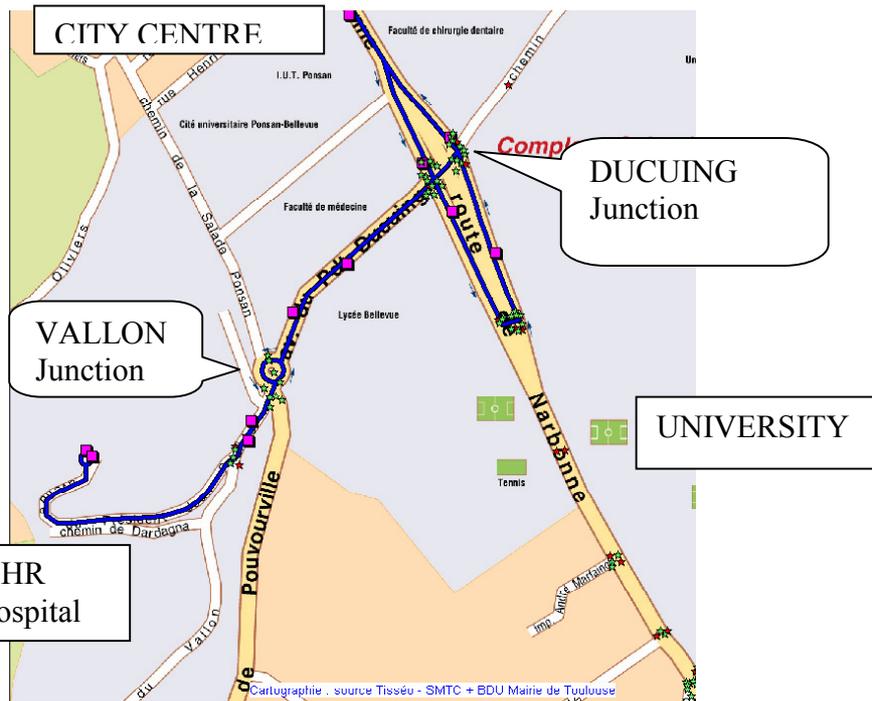
2. **Experimental implementation** (*April 2007- end of June 2007*) – **The priority request test.**

The two junctions chosen for testing the radio priority system between April 2007 and the end of June 2007 are located in the south-east of Toulouse, close to the main Toulouse University.

The main one is Ducuing – Narbonne (N°113) crossroads, and the secondary one "Vallon crossroads" (Ducuing / Salade Ponsan) as described below:



Figure 3: Radio priority system experiment site



Legend: ■ bus stop line 2 ✱ Pole traffic light signals ✱ traffic light signals on overhead traffic posts

The traffic characteristics at these junctions are the following:

- The daily traffic at the first junction is 8600 veh/day from city centre to university, 6 900 veh/day from university to city centre and 7 300 veh/day on Ducuing road.
- The bus line n°2 has two branches: one between the city centre and the university which crosses straight through the main crossroads and the other where buses traveling from city centre towards the hospital turn right at the first junction and cross straight at the « Vallon » junction.
- In each direction, the frequency is one bus every 10 minutes, giving a sample of approximately 200 trips (there or back) per day. The traffic light signals of these two junctions are equipped with “classical” controllers in relation with Capitoul control post as explained in the introduction.

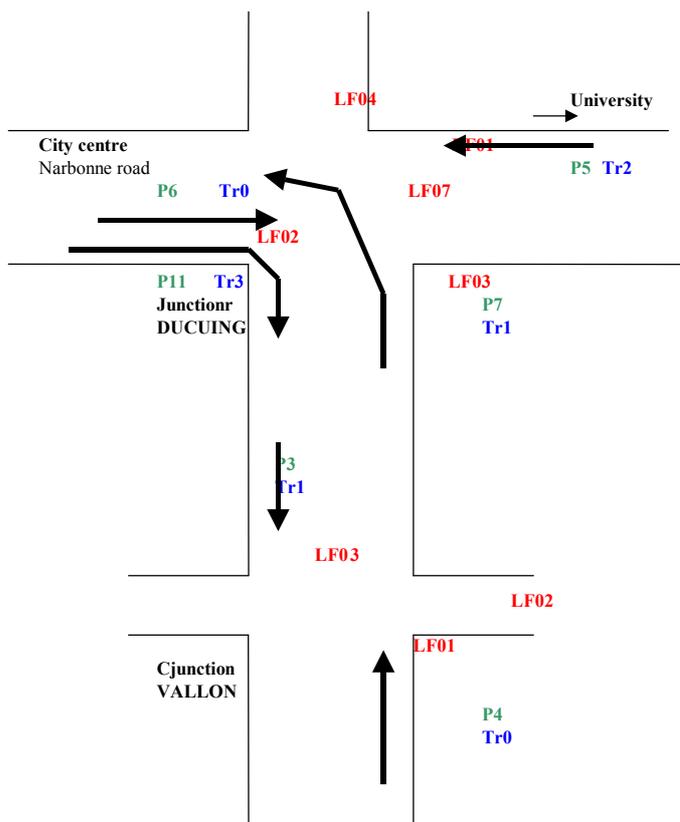
COMATIS supplied on board command boxes and antennas for all the 15 jointed buses (Mercedes O 405 GN) operating on the line N°2, two traffic light controller equipments (DIASER message receiver) and the short wave radio transmission system, which interact between the bus and the controller on one side and between the bus and the control and data collecting central system on the other side.

This priority request system has been tested on the traffic light cycles of the lanes indicated by the black arrows below (figure 4).

To ease understanding, we build a scheme based on the following identification:

Crossroad	Name	Traffic light line	Bus road	Bus procedure	Approach area	Approach area length	Bus Stop
Ducuing	CV-U	LF02	Tr0	6	Z1	350 m	No
Ducuing	CV-CHR	LF02	Tr3	11	Z11	300 m	Yes
Ducuing	CHR-CV	LF03 et LF07	Tr1	7	Z4	300 m	Yes
Ducuing	U-CV	LF01	Tr2	5	Z5	?	no
Vallon	CHR-CV	LF01	Tr0	4	Z3	200 m	yes
Vallon	CV-CHR	LF03	Tr1	3	Z2	250 m	yes

Figure 4: Bus priority scheme at traffic light



Légende :
 LF01 : traf light line
 P1 : Procédure bus
 Tr1 : bus travel

The traffic light cycle organization and functioning scheme were the following:

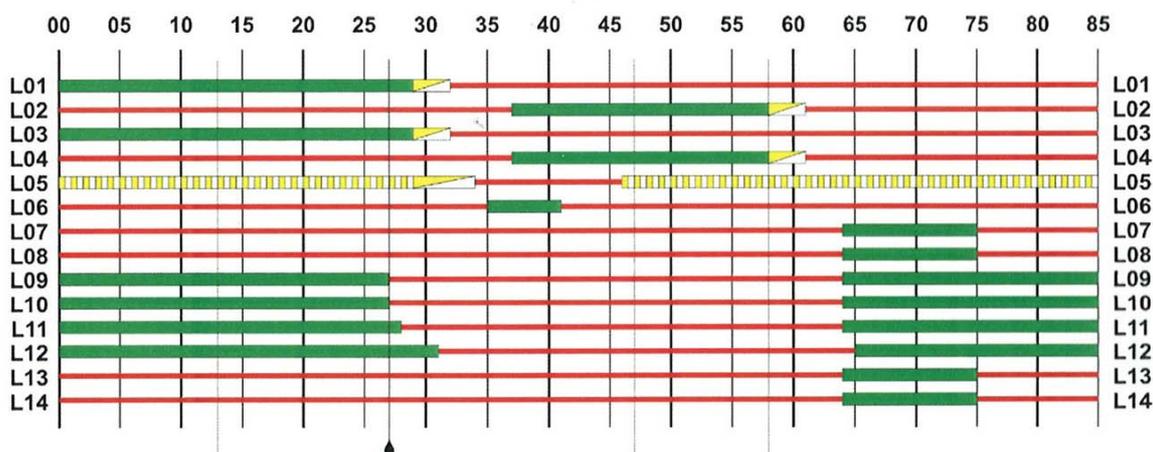
Figure 5: traffic light organisation

Crossroads	Phase 1	Phase 2	Phase 3
Ducuing	LF01 et LF02 With bus	LF03 et LF07 With bus	LF04 Without bus
Vallon	LF01 et LF03 With bus	LF02 et LF04 Without bus	

Figure 6 : traffic light scheme for bus priority at Ducuing and Vallon crossroads.

Désignation des Voies	T/O	L01	L02	L03	L04	L05	L06	L07	L08	L09	L10	L11	L12	L13	L14
Chemin du Vallon	L01	xx	2		2				5						1
Chemin de la Salade Ponsan	L02	2	xx	2					3		3	1			
Avenue du Pr Ducuing	L03		2	xx	1			1							5
Chemin de Pouvoirville	L04	2		2	xx				3	1			4		
Tourne à Droite de Avenue Ducuing vers Ponsan	L05					xx	1								
Piéton du Tourne à Droite Avenue Ducuing	L06					5	xx								
Piéton Avenue Ducuing sens entrant	L07			6				xx							
Piéton Avenue Ducuing sens sortant	L08	2	4		3				xx						
Piéton Ch. de Pouvoirville sens entrant	L09				7					xx					
Piéton Ch. de Pouvoirville sens sortant	L10		9								xx				
Piéton Ch. Salade Ponsan sens entrant	L11		9									xx			
Piéton Ch. Salade Ponsan sens sortant	L12				6								xx		
Piéton Ch. du Vallon sens entrant	L13	10												xx	
Piéton Ch. du Vallon sens sortant	L14			6											xx

2.4. DIAGRAMME DE FONCTIONNEMENT



The buses travelling on the line N°2 CHRroad, from CHR hospital towards the city centre, requested priority when they were arriving at Ducuing crossroads, while turning on the left (the bus stop is located after the exiting crossroads).

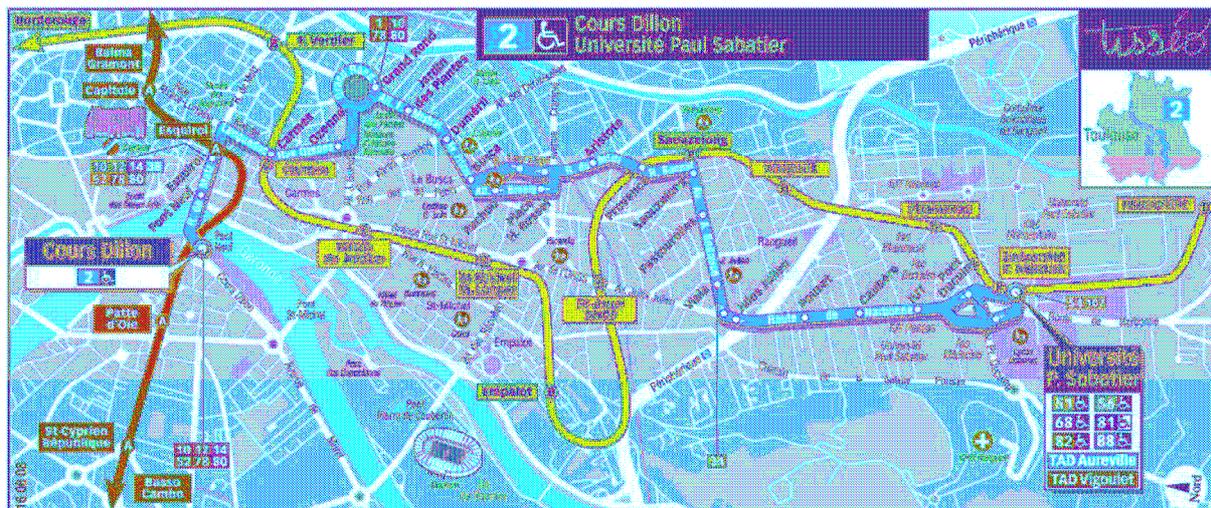
The antagonist traffic flow priorities were requested by the line N°2 buses travelling from the University towards the city centre.

These two simple cases of priority request were completed on the opposite main road by priority requests for buses travelling from the city centre towards the university, or from the university towards the CHR hospital.

3- After the opening of the second underground line in July 2007.

The test ended with the reshaping of the bus network. The line N°2 stops now at the University.

Figure 7: bus line network after June 2007



2) Loop priority system

The bus priority principle is based on the activation of an electromagnetic loop by the buses equipped with adequate beacons. The loop system allows equipped buses to obtain priority at the traffic light signals of the crossroads.

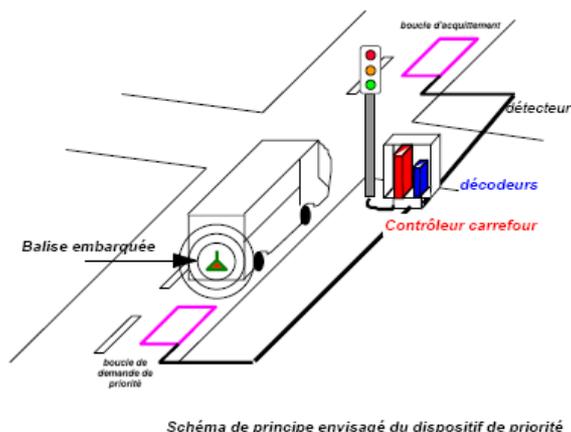


Figure 8: loop priority system scheme

At the end of 2006, the public authority (TISSEO-SMTC) launched a dedicated call for tender to equip with beacons the whole bus fleet that would travel on the High Quality Corridors (HQC, developed within the measure 6.4.T).

The RN126 high quality corridor (HQC) is 10.9 kilometres long completely treated with segregated lanes. It opened in two phases: first section in November 2005 and second section in November 2007. 11 bus stops are located on the corridor.

The RD813 HQC is 6.9 kilometres long; it opened in December 2007. 11 bus stops are located on the line.

At the beginning of 2007, TISSEO signed and notified the contract with the SPIE company. By the end of 2007, SPIE company equipped with beacons the busses travelling on the two high quality corridors (HQC).

At peak hours, the number of buses driving on the corridor and equipped with beacon to request priority varies between 14 and 25 busses per hour on both corridor lanes.

B4 Deviations from the original plan

The deviations by comparison to the original plan are:

Deviation 1 – Abandon of the adaptation of the UTC system (CAPITOUL) to integrate PT priority in the global traffic management.

The results of the study about a bus priority centralised system have highlighted that:

- the development of the necessary interface would be achieved out of the MOBILIS project time,
- it will further be compulsory to modify the defined technical specifications to:
 - integrate the reshaping of the PT network after the 2nd underground line has opened and),
 - adapt them to the new AVL system (Automatic Vehicle Detection) implemented in 2009.

So the partners decided to wait and develop it out of MOBILIS project time.

Deviation 2 ._. Development of a decentralised solution

The Local authorities decided to focus on decentralised solutions

The measure has been re-oriented on the testing of 2 different priority systems: one adapted to the High Quality Corridors (HQC) developed within measure 6.4.T, based on the use of active detection loops, and one for classical traffic junctions crossed by busses, based on the use of a radio transmission between buses and traffic junction controllers.

B5 Inter-relationships with other measures

The measure is related to other measures as follows:

No.	Measure title	Relation
6.4.T	High-quality bus corridors in Toulouse and development of PT segregated and secured lanes in the city centre	Relation is evident: the planning of high quality corridors induces strategies for PT priority.
8.1.T	Improving quality and structure of PT services in Toulouse	Integrate PT priority in the global PT service scheme.
12.1.T	Demonstration of EGNOS/Galileo services use for the control and information system of public transport in Toulouse	These 2 measures relies on the use of a efficient AVL system and are by the way extremely linked together (for 12.3.T measure, we are talking about the 2 nd part of it).
12.3.T	Development of an integrated multimodal traveller information system in Toulouse	
12.4.D	Tramway priority scheme and real-time passenger information system in Debrecen	This measure treats about the same topics.

C Evaluation – methodology and results

C1 Measurement methodology

C1-A Radio priority system -

The evaluation tasks included:

1. Evaluation of functions:

The City of Toulouse and Tiisséo-SEMVAT realised the technical assessment of the system.

The CETE/ZELT verified the transmission and management quality of bus priority requests:

- Are the bus priority request call correctly taken into account by the traffic light signal controllers?
- do the radio receivers integrate the requests in the traffic light cycles and does it really allow buses to obtain priority?

2. Evaluation of the impact on the functioning of equipped crossroads

The purpose was to quantify the modifications of the traffic light cycles, the duration of green light cycles for vehicles travelling in the same direction as the buses, and for the ones travelling on opposite lanes, the duration of green light cycles for buses (if different from parallel ones for private vehicles) and the respect of the traffic light signals. To accomplish this, the crossroads tracking sheets were analysed, as well as the call/message/tracking of buses

3. Evaluation of the impact on waiting times at crossroads:

The purpose was to identify modification in waiting time durations for buses and vehicles (the ones going in the same direction and the ones crossing at right angles), as well as the length of the waiting lines. We employed on-street observations at the crossroads and analysed the bus route tracking sheets.

- ##### **4. Evaluation of acceptability by the bus drivers, bus network managers and bus administrator:** they have been interviewed about the eventual perturbations noticed in comparison to the previous situation.

The experiment has been set up from April to June 2007 in two phases:

1. **First evaluation phase:** during three weeks, between the 23rd of April and the 15th of May, we measured private vehicles (PV) traffic rate, green traffic light cycle length, busses approach travel duration, bus waiting time at traffic light signals, with and without bus priority functioning in order to precise the configuration of the priority request data.

The data collected from the buses between 5 a-m and 10 p-m were:

- procedure numbers
- start and end time of the traffic light cycle process (date and second precise time)
- bus stop time at traffic light
- reduced speed duration
- time spent at commercial stop
- global approach travel duration.

The data collected from all traffic light controllers for both crossroads between 5 a-m and 10 p-m were:

- traffic light cycle number

- green cycle end time (second precise)
- Green phase duration

In order to avoid bias due to differences in exterior traffic conditions, the days with/without bus priority have been alternated.

Measures sample		
Days with priority	Days with priority	Day
23/04/07	14/05/07	Monday
14/05/07	24/04/07	Tuesday
25/04/07	02/05/07	Wednesday
03/05/07	26/04/07	Thursday
27/04/07	04/05/07	Friday

Figure 9: 1rst phase evaluation calendar

The bus travel times were measured in predefined approach areas close to traffic light (200 to 300 meters, depending of the bus direction). Six different directions had been listed. The traces of the bus priority requests were available in the local databases of COMATIS and the traffic light controller data were collected with computers directly at the controllers.

The results of this first phase revealed that it was necessary to slightly modify the geometrical description parameters of the area and specifically the description of the roads for the buses travelling from city centre towards the CHR hospital or towards the university.

Comatis used these results to modify and improve the configuration of the radio priority system before the second phase of measurement.

2. • **Second evaluation phase:** between the 4th and the 19th of June, we did the same measurements and data collection “with and without” bus priority system in operation at peak hours (5 a-m to 10 p-m).

Measures sample		
Days with priority	Days with priority	Day
18/06/07	11/06/07	Monday
12/06/07	19/06/07	Tuesday
06/06/07	13/06/07	Wednesday
14/06/07	07/06/07	Thursday
08/06/07	15/06/07	Friday

Plus, at each site, on-street surveyors were positioned at the opposite traffic signal stop line to record the travelling times of the private vehicles and buses on the approach zones, and the line length of waiting private vehicles. Field data were collected at morning (07.30-09.30) and evening peak hours (16.00-18.00) to determine if the bus priority system was introducing disturbances for private car traffic flows.

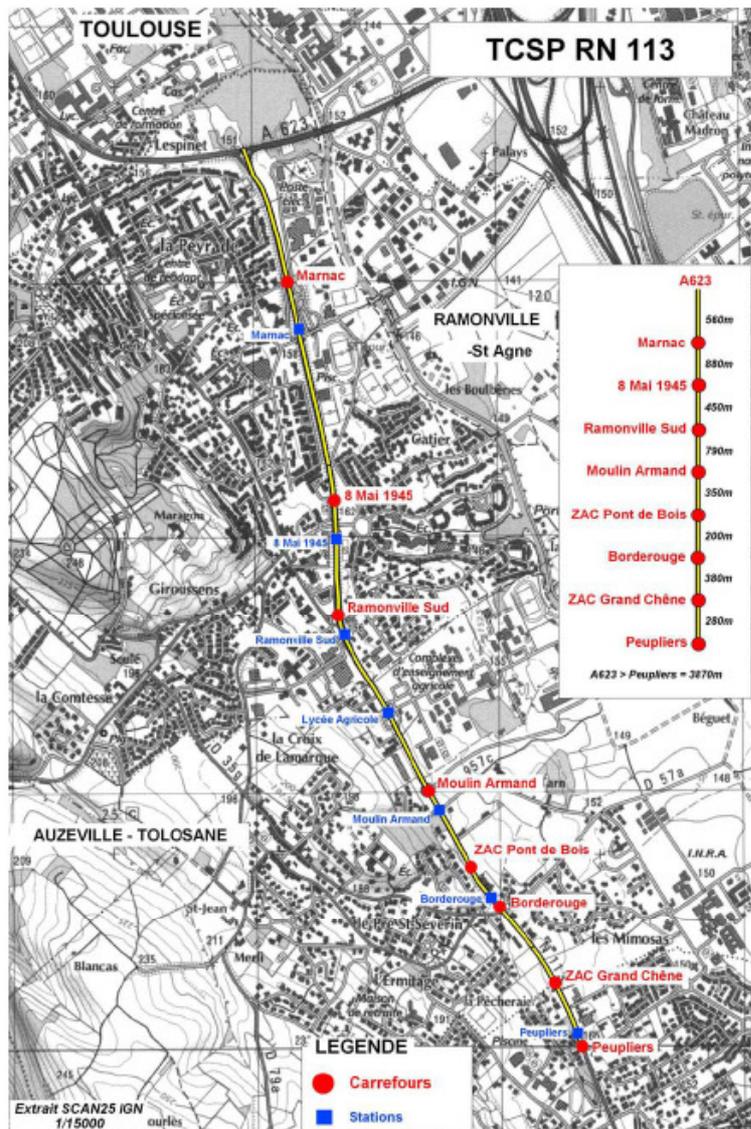
The data sample size for each scenario “with and without” was 1 400 bus journeys (900 at Ducuing, 500 at Vallon crossroads), 3800 traffic light cycles at Ducuing and 5400 at Vallon crossroads.

Loop priority system

The system has been evaluated from May to June 2008.

The evaluation has focused on the measurements of the impacts at two main crossroads of the high quality bus corridor implemented between the terminal station of the underground B line and the suburb city of Castanet. This corridor follows a two-way road and crosses eleven junctions.

Figure 10: High quality corridor in the South-east of Toulouse



The evaluation tasks included, as for the radio priority system:

1. The evaluation of functions:

- a. Do the loops properly detect the buses?
- b. Do the implemented traffic light cycles allow buses to get real priority?
- c. What is the respect rate of the traffic light signals by bus and the private vehicles drivers?

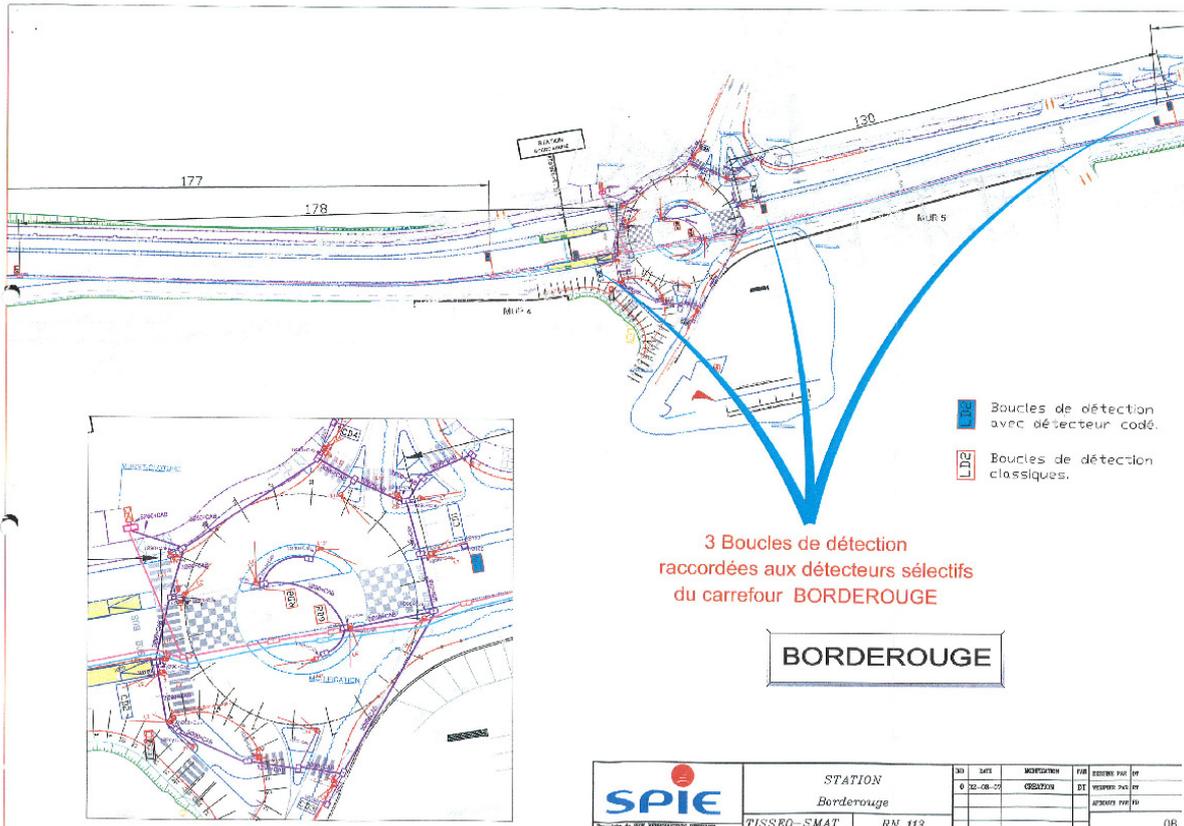
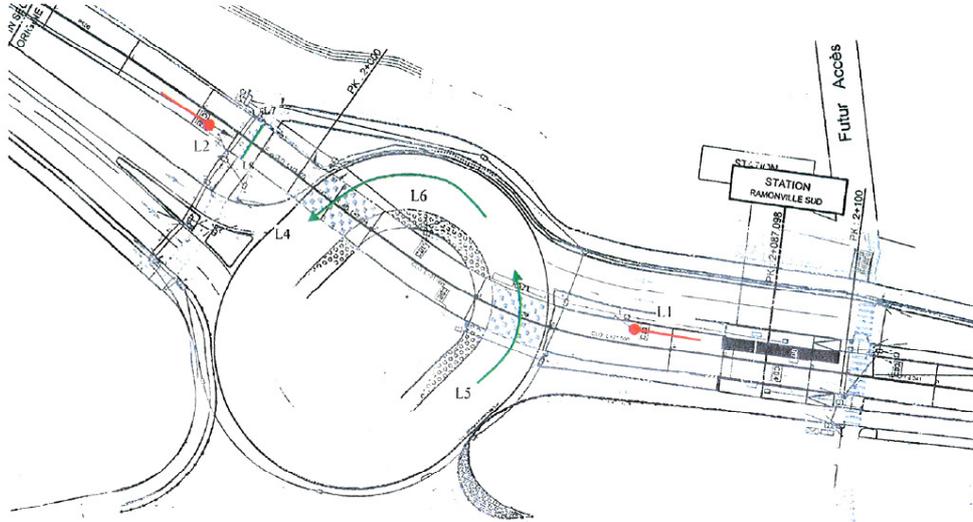
2. The evaluation of the impacts of the bus priority on the private car traffic.

A traffic model based on the present situation studied the impacts on private vehicles traffic of a traffic increase of priority vehicles like emergency vehicles and taxis in the bus corridor.

The selected two main crossroads were those called “Ramonville South” and “Grand Chemin (Borderouge)” according to the close bus stop name; they present important private vehicle traffic (around 4 000 v/h) and different traffic flows. The following maps explain their location.

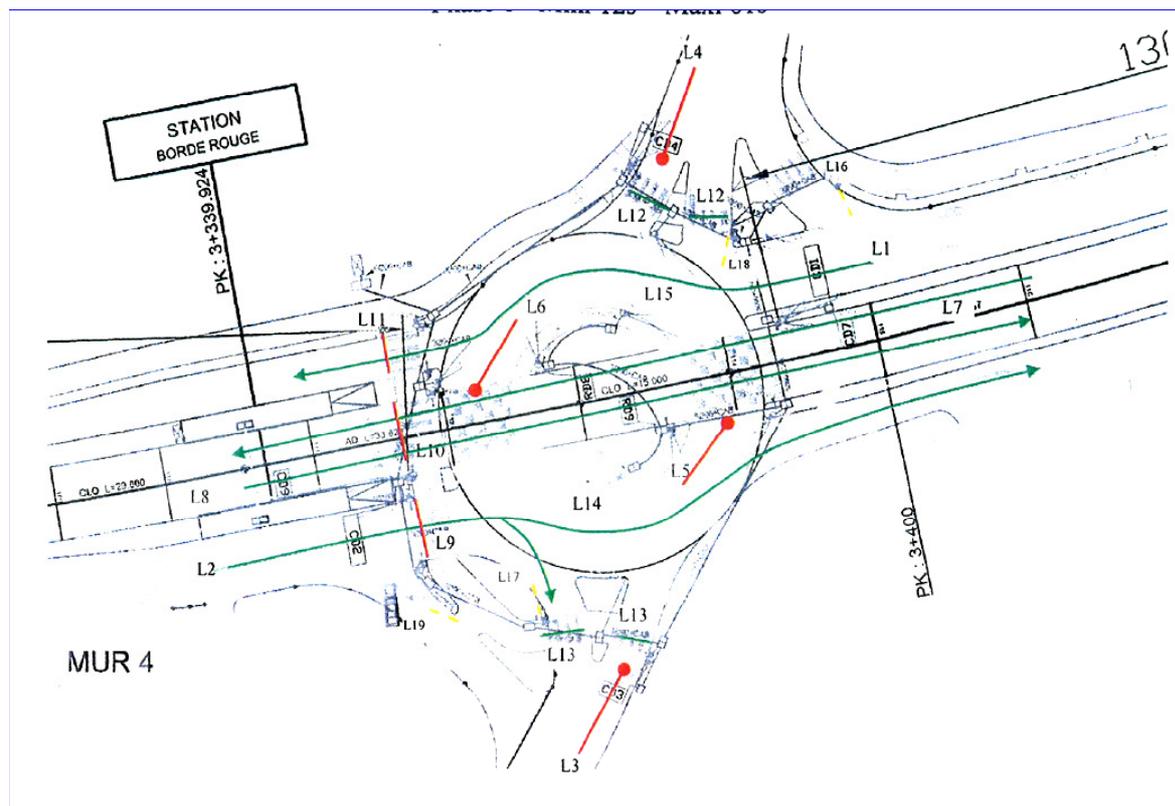
RN113 : Giratoire Sud

Phase 1 : Carrefour N°1 Bus



Ramonville Crossroads

At this junction, the traffic light signals manage only the interferences between buses and private vehicles traffic. The definition of the traffic light cycle algorithm has been difficult because it had to take into account the different bus roads that leave or join the bus corridor at the junction and the bus corridor position in comparison to the private vehicles lanes before and after the cross roads.



Auzeville Grand Chemin Crossroads.

At Auzeville Grand Chemin junction, the bus corridor crosses straight through. The private traffic flows are observed on, or in direction of, both sides of the main roads. The traffic light cycle for each private vehicles access or bus access is antagonist to a traffic light cycle of the ring; they function as different T-junction traffic light signals working one after the others.

It has not been possible to compare the two functioning, with and without bus priority system. So we observed in detail the functioning of the traffic light cycles at each crossroads.

The organization of the data collection focused on the traffic at peak hour period, including the increase and decrease periods, so from 7 a-m to 9.30 a-m and from 4p-m to 6.30 p-m.

No automatic data being available, 5 on-street surveyors at Ramonville crossroads and 4 at Auzeville crossroads collected precise time data on site during 3 days (Tuesday, Wednesday and Thursday) of the second part of May with adequate microcomputers (PSION type). So totally 15 hours of data were collected.

The facts registered were:

- the precise time when bus was passing upon the loop, which is located 150 m before the traffic light,
- second precise stop and start time of bus at commercial bus stop and at traffic light signal line,
- second precise time of traffic light cycle change for private vehicles and buses,
- number of private vehicles waiting at the traffic light signals opposite to the bus traffic light signals.

C1.1 Impacts and Indicators

Table of Indicators.

No.	Evaluation category	Impact	Indicator	Use d	Etc..
19	Transport	Increase in commercial speed of buses	<ul style="list-style-type: none"> Number of buses stopped at the traffic light signals: % Bus stop time length at traffic light signals Crossroads approach time Length of the green phase of the traffic light for buses Respect ratio of the traffic light red signal by buses 	Yes	
23-24		Variation in travelling time of private vehicles	<ul style="list-style-type: none"> Length of the green phases of the traffic light signals Respect rate of the traffic light red cycle by private cars and buses 	Yes	
23-24		Private vehicles traffic reduction	Private vehicles traffic capacity	Yes	
2	Economy	Investment	Investment and operating costs of the measure	Partly	Only investment costs

Detailed description of the indicator methodologies:

- **Indicator 1** (Increase in commercial speed of buses) – variation of the travel time from the approach zone beginning to traffic light line crossing between the two scenarios with and without priority.
- **Indicator 2** (Variation in travelling time of private vehicles) – For the radio transmission systemtest, we used the data of the permanent traffic counters of the city of Toulouse implemented at the two junctions. These data indicated every 3 minutes the traffic flow intensity and the lane occupancy rates. They have been analysed hours by hours with a focus on the peak hours.
- **Indicator 3** (Investment and operating costs of the measure) – the public authority had the investment costs. The systems are new, so no relevant maintenance costs were available. Due to the changes in bus lines and frequencies, it has not been possible to evaluate the benefit costs.

C1.2 Establishing a baseline

Radio priority system

The baseline was established by without priority measurements.

Loop priority system

The bus administrator had chosen to implement this bus priority system on a new bus corridor; the baseline is with the loop system not operating.

C1.3 Building the business-as-usual scenario

Radio priority system

The business as usual scenario is the without priority scenario.

Loop priority system

The business as usual scenario is based on a steady traffic light cycle.

C2 Measure results (attention detailer les resultants)

The results are presented under sub headings corresponding to the indicators categories.

Radio priority system

The results of the evaluation are based on the analysis of the results of the second phase of measurement.

C2.1 Economy

The on board equipment of each bus costs around 2.000 € (tax included)- 1.700 € (without tax). The central data control system costs around 25.700€(tax included)- -21.00€(without tax).

The investment costs of the radio priority system are detailed in Annex N°1.

C2.2 Energy and environment

An approach of these impacts is given at the end of § **C 2.4**

C2.4 Transport

System functioning

96,4% of the bus priority requests are properly received by controllers and integrated in the traffic light cycle, so the functioning of the system and the data collecting system have good performance levels.

Green phase length

At “Vallon” junction, only one of the two phases of green cycle concerns the buses. With the priority, the “green phase length” increases on average by 4,5 % (1 second by phase) and the green phase length for private vehicles on the opposite roads decreases by 2% (6 0,4 s).

At Ducuing junction, the green phase length for private vehicles decreases on average by 1,7 % (0,3 second) on traffic line 4 and by 1,5% (0,4 second) on the main road, where buses request priority for left and right turns.

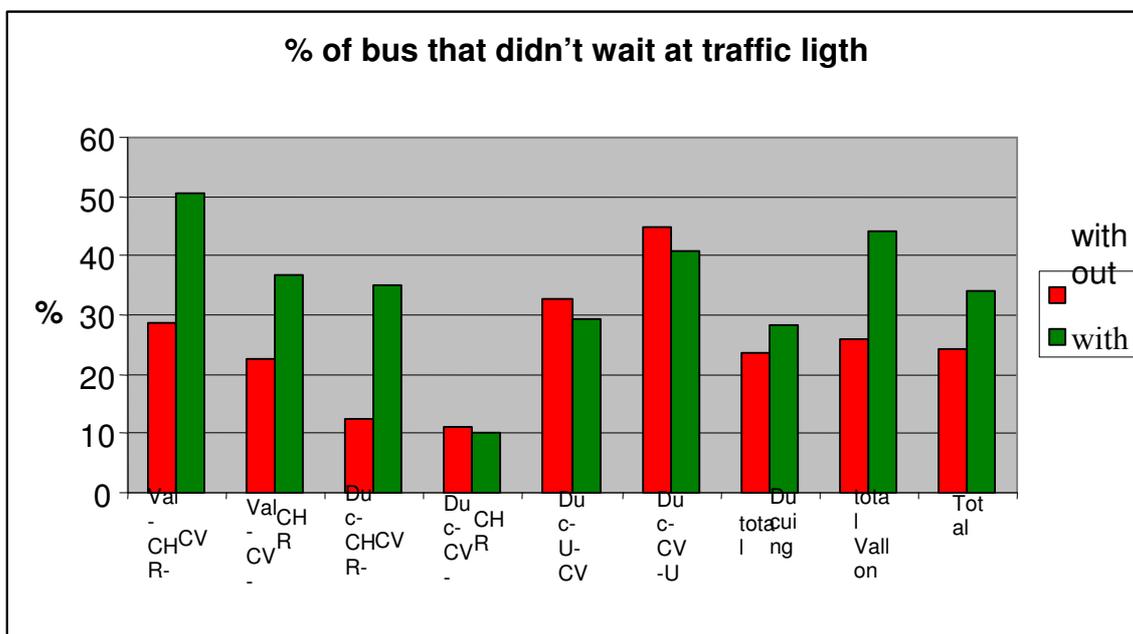
The main green phase time increase is registered for the buses travelling from CHR hospital to city centre (+1,2% or 0,2 second).

The variations of the further values of green phase duration are important.

Bus travel time

The travel time of the buses have been calculated in the predefined approach areas of 200 to 350 m, depending of the six bus roads.

The results of the first measurement phase revealed that the buses, arriving at Ducuing crossroads from university side, had a shorter” green phase duration” and were loingt time.



After Comatis had improved the configuration of the radio priority system, the second phase of measurements has produced the following results:

With bus priority, the waiting time at traffic light signals was reduced on average by 52% (9 seconds), the reduced speed duration increased by 4% and commercial downtimes decreased by 15%. The travel time of bus from the beginning of the approach zone to the traffic line signal line crossing decreased on average by 16% (10seconds).

But the results depend of the “bus procedure” implemented in the traffic light controllers.

- At Ducuing junction, the waiting time of the busses traveling from CHR hospital to the city center fell by 65% (20 seconds), and the total approach travel time by 26%.
- At Vallon junction, the priority system was also very efficient, the waiting time decreased by around 60% and the total approach time by around 19%.

The priority system is less efficient for bus arriving from the city centre at Ducuing junction. The bus priority request is not always properly taken in account for one of the lanes because the two approach zones are parallel and the commercial stop is close to the traffic light signal.

The bus priority system has a low efficiency at Ducuing crossroads for buses arriving from the university because the approach zone is short and very close from the commercial bus stop.

The bus priority system is specifically efficient at peak hours: the waiting time at traffic light signals decreases on average, for all procedures, by 49% (8,3 seconds) when the traffic flow is low, by 51% (8,8 seconds) at morning peak hours and by 59% (11,4 seconds) at evening peak hours.

The ratio of busses, which do not stop at traffic light signals, increases on average for the two junctions by 10 points: from 26% without priority to 36% with priority.

The regularity of bus approach time at traffic light signals

The dispersion³ of the bus global approach travel time for all procedures decreases by 3,5 points.

Approach time dispersion = standard dev/average			
Procedure	Without	With	Dispersion- with In points
3	37,1	28.3	-8.8
4	32.5	30.2	-2.1
5	53.8	55.8	2.1
6	30.9	26.3	-4.6
7	36.1	33.2	-2.7
11	28.7	30.3	1.6
All	43.3	39.8	-3.5

Traffic conditions on the antagonist axis

At Vallon junction where the bus priority impacts only the main road, the analysis of the measures done on the antagonist axis does not reveal any significant impact on private vehicle travel duration and waiting line length in the approach zones of the traffic light signals.

statistical validation of average P V travel time comparison												
à 95%	Entrée	période	Without PRIORITE			With ITy			Gain avec/sans en %	accepter égalité	risque d'erreur en %	
			jour	MOYENNE (s)	Ecart-type	Nombre	MOYENNE (s)	Ecart-type				Nombre
	Pouvourville	matin	lundi/mardi	0:00:30	0:00:19	96	0:00:30	0:00:20	97	0,0	oui	5
	Pouvourville	matin	mercredi	0:00:24	0:00:16	101	0:00:29	0:00:17	88	19,2	oui	49
	Pouvourville	matin	jeudi	0:00:31	0:00:18	80	0:00:26	0:00:18	95	-17,1	oui	49
	Pouvourville	matin	vendredi	0:00:26	0:00:18	95	0:00:25	0:00:19	95	-2,6	oui	6
	Pouvourville	matin	total	0:00:28	0:00:18	372	0:00:28	0:00:19	375	-0,6	oui	5
	Pouvourville	soir	lundi/mardi	0:00:21	0:00:16	94	0:00:20	0:00:16	96	-6,6	oui	10
	Ponsan	soir	lundi/mardi	0:00:27	0:00:14	75	0:00:28	0:00:15	75	3,7	oui	7
	Ponsan	soir	mercredi	0:00:26	0:00:15	82	0:00:28	0:00:15	70	7,9	oui	13
	Ponsan	soir	jeudi	0:00:26	0:00:15	83	0:00:27	0:00:14	81	3,7	oui	7
	Ponsan	soir	vendredi	0:00:27	0:00:13	79	0:00:24	0:00:14	86	-11,1	oui	31
	Ponsan	soir	total	0:00:25	0:00:15	319	0:00:25	0:00:16	312	0,6	oui	5

Figure 11: statistical validation of the comparison of the average PV travel durations

³ the standard deviation in comparison to the average value

The study⁴ “monitoring and evaluation of a public transport priority scheme in Southampton”, prepared by the Southampton University and the University of Portsmouth Transport Research Laboratory for the Hampshire County Council, highlighted that “*the relatively high priority given to buses improved bus performance and reduced bus delay, bus fuel consumption, and bus emissions; however, because such a high level of priority was granted, additional delays were incurred by other vehicles which resulted in an overall increase in fuel consumption and emissions for all listed pollutants except Sulphur (S), Nitrogen oxides (NOx), and particulate matter (PM).*”

The Transport Research Laboratory (TRL) authors noted that the reductions in NOx and PM were important since these compounds were more likely to exceed acceptable levels in urban environments.

IMPACTS OF TRANSIT SIGNAL PRIORITY (TSP)	Buses	Other Traffic	Overall
CO emissions	-24%	9%	8%
CO2 emissions	-13%	6%	3%
HC emissions	-25%	7%	4%
S emissions	-13%	6%	0%
NOx emissions	-16%	-2%	-9%
PM emissions	-22%	3%	-12%
Fuel consumption	-13%	6%	3%
Delay (seconds/vehicle/junction)	-9.5 sec.	3.8 sec.	

(Data excerpted from: TRL 413, Table 19 - Summary of Impacts)

The results obtained are quite close to these of this study, so we can estimate that the conclusions regarding the impacts on energy and environment would be similar. May be better as the impacts on private car traffic are lower

C2.5 Society

The bus drivers notice no difficulties to use the system, which does not change their work conditions. The experiment satisfied the network managers and the system required no special maintenance for the bus administrators.

The improvement of the service regularity and alignment with nominal timetables makes buses a more attractive a transport mode. Furthermore the implementation of bus priority system shows up the clear wiliness of the local authorities to favour the public transport over the private vehicle; the psychological effect on public shall not be underestimated.

4 Monitoring and evaluation of a public transport priority scheme in Southampton

*Published By: Transport Research Laboratory , Source Date: 1999
Other Reference Number: Report No. TRL413*

Loop priority system

C 1 Economy

The on board equipment of each bus costs around 2.000 € (tax included)- 1.700 € (without tax). The cost of the loop supply (8) and road works is around 50.000€ (tax included) for one classical crossroads. It is slightly more expensive than radio transmission system, but less maintenance costs are expected, although the short time since the implementation of the measure has not allowed to determine the average maintenance costs of each system.

C 2.4 Transport

Functionality evaluation

The analysis reveals that the results varies with the approach area characteristics:

Without bus stop (Ramonville south, underground side)

2 on 3 of the buses obtain the bus priority and their average travel time in the approach zone between the loop and the traffic light line is 19 seconds but 1 on 3 do not obtain the priority at the right time and have an average travel time of 25 seconds.

Without bus stop: Grand Chemin, Castanet side

The priority request is properly taken into account for almost all buses, but the implemented traffic light cycles introduce differences in the approach travel time depending of the priority request periods. The priority request collected data are almost equitable between request at red and green traffic light signal phases. They reveal that the average approach travel time is around 9seconds when the request intervenes during a green phase and that the bus crosses the junction in the same phase (46% of the observed cases), 21 seconds if the request intervenes at the red phase (45% of the cases) because the opposite traffic has first to be stopped and 36 seconds (8% of the cases) when the controller hasn't be able to take priority request in account and that the bus traffic light cycle introduces a red phase and therefore a waiting time for the busses.

With bus stop station: Grand Chemin Ramonville side

The bus stop is very close to the traffic light signal (the request loop is at 12 m of the traffic light signal) and half of the buses stop at it.

The assessment is the following:

3. 30 % of the buses obtain the green phase when they arrive at the traffic light signals and their travel time between the bus stop and the traffic light line is 1,2 seconds.
4. 70 % of the buses are delayed after they stop at the bus stop or because the request is not correctly taken in account (distance too short) and their travel time between the bus stop and the traffic light line reaches 2,5 seconds.

With bus stop station: Ramonville Sud Auzeville side1

Almost half of the buses stop during around 14seconds at the bus stop; they wait on average 11seconds before having a green phase after they leave or pass by the bus stop.

70% of the buses wait around 9 seconds at the traffic light signals.

For the whole data sample, the travel time between the bus stop and the traffic light line is 14 seconds whose 8 seconds of waiting time at traffic light signals. That's why 11% of the bus drivers crosses the traffic light line few seconds before the green phase starts.

Priority algorithm performances

The bus priority algorithm should be modified to improve the results.

	Free approach Time (in seconds)	Real average travel time	% of priority performance
Grand Chemin Castanet side	9	165	55
Ramonville Underground side	17	19	89
Grand Chemin Underground side	12	3.7	32
Ramonville Castanet side	6	14	43

Analysis of private vehicles traffic light signals signals functioning

Ramonville Sud

30% of the cycles aren't justified by bus approach.

The bus priority system increases the travel time of private vehicles arriving from the underground side by 28 seconds and of these arriving from Castanet-Auzeville by 34 seconds. The private vehicles traffic flow capacity is reduced by 17% in comparison to a "classical traffic light signals cycle functioning".

Grand chemin

Only the crossing of a bus arriving from Ramonville decreases the green phase duration on the opposite side by 8 seconds. The traffic light cycle is on average 90 s long, 2/3 of the green phases are for the main road and 1/3 for the antagonist one.

The private vehicle traffic flow decreases by 6% on the opposite roads with the bus priority .

Red phase respect by private vehicles

The respect rate of the red phase is almost perfect at Grand Chemin junction for the vehicles arriving from Castanet.

At Ramonville junctions, the private vehicles arriving from the underground side do not respect 1/6 of the red phases and 1/3 of the vehicles arriving from Auzeville. For the vehicles arriving from Auzeville, the red phase offences concern mainly the early beginning or the late end of the phase and this may be explained by the fact that the drivers see the bus stopped at the bus stop.

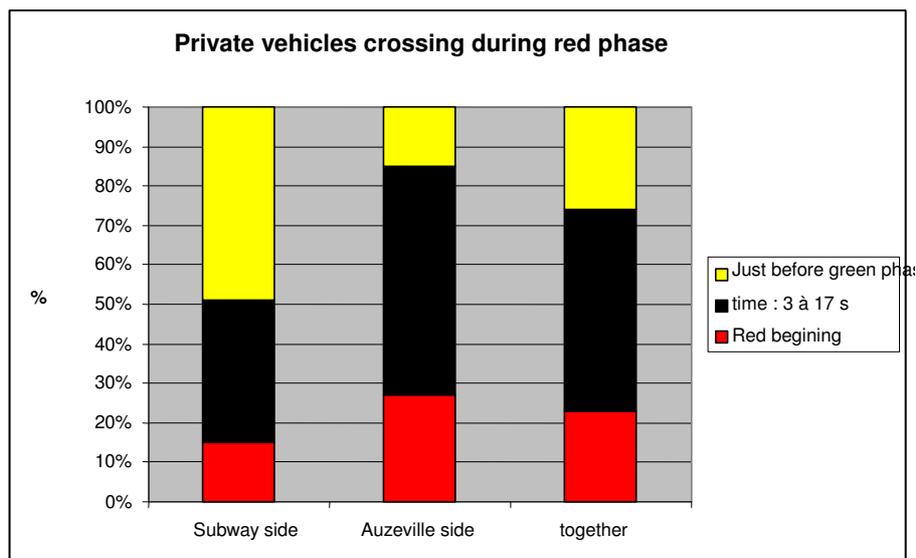


Table 1: % of private vehicles crossing during the red phase

Increase of the traffic on the bus corridor

We have modelled different increases of the traffic flow of priority system equipped vehicles (noted as buses in the following tables) and/or private vehicle. The impacts of these variations are the following:

- at Ramonville junction, at morning peak hours:

Public transport scenario	Indicators	
	PV travel time (s) from Auzeville to underground	Occupation rate at Auzeville Entry on a 200 m zone
Without public transport	24,5 s	11.5%
tc1 Base line	39.2 s	13,5%
tc2 tc1+ 5 bus/h/side	45.4 s	15%
tctaxi tc1 + 5 bus/h/side + 5 veh/h/side	50.2 s	15.9%
tc3 tc1 + 10 bus/h/side	53.2 s	16.9 %)
tc4 tc1+ 15 bus/h/side	69.6 s	21,2%
tc5 tc1 + 30 bus/h/side	125.4 s	34.9 %

Table 2: impacts of the traffic flow variation on the PV travel time and occupation rate at morning peak hours

- at Ramonville junction, at evening peak hours:

Public transport scenario		Indicator	
		Travel time (s) from Auzeville to underground	Occupation rate at Auzeville Entry on a 200 m zone
Without public transport		24,6 s	7,6
tc1	Base line	29,2 s	9,0
tc2	tc1+ 5 bus/h/side	32.8 s	10.6 (+1.6 s)
tctaxi	tc1 + 5 bus/h/side + 5 véh/h/side	37.2 s	12 (+3 s)
tc3	tc1 + 10 bus/h/side	35.9 s	12.3 (+3.3 s)
tc4	tc1+ 15 bus/h/side	45.2 s	14.6 (+5.6 s)
tc5	tc1 + 30 bus/h/side	77.8 s	23.6 (+14.6 s)

Table 3: impacts of the traffic flow variation on the PV travel time and occupation rate at evening peak hours

If, per hour, more than ten vehicles equipped with priority request system would be allowed to drive on the both lanes of the corridor; the algorithm of the traffic light cycles should be overhauled to maintain appropriate private vehicle traffic conditions.

- at “Auzeville Grand Chemin” junction, the main private vehicle traffic is parallel to the bus corridor, so the increase of vehicles equipped with priority request system would not really disturb the traffic on antagonist axes.

C3 Achievement of quantifiable targets

No.	Target	Rating
1	Improvement of bus travel times and regularity.	**
2	Contribution to the high quality of new corridors. Preparation to the tramline development.	**
3	Improvement of the integration between traffic and PT regulation (and of the operators' cooperation).	**
4	Improvement of the quality and effectiveness of control and transmission means.	**
NA = Not Assessed * = Not achieved ** = Achieved in full *** = Exceeded		

C4 Up-scaling of results

Due to these results, the city of Toulouse intend to equip others crossroads with the bus priority systems. The radio transmission priority system will mainly be used for buses travelling through existing crossroads, already equipped with traffic light signals and the loop priority system for new infrastructure and specifically new high quality corridors. To guaranty the efficiency of the priority system, it will be necessary to take in account the crossroads characteristics: bus stop location and approach zone length.

At the end of June, TISSEO decided to implement radio priority system for buses on one whole bus line road implemented on a radial road from city centre towards the suburb. The works have started at the end of 2008.

C5 Appraisal of evaluation approach

The evaluation approach gave precise results and is so satisfying.

C6 Summary of evaluation results

Bus priority system provides substantial benefits in terms of travel times and regularity when the implementation is carefully prepared.

Radio priority system

The evaluation of the radio bus priority system tested on two crossroads reveals successful implementation, impacts and acceptability. The key results are as follows:

- **Key result 1** – The system functioned properly; 96,4% of the priority requests are satisfied.
- **Key results 2** –Bus regularity and journey times were improved. The impact on the global approach travel time in the defined zones is a decrease by 16% (10 seconds). The average bus waiting time at traffic lights was reduced by 52 % (9 seconds); it is specifically efficient at peak hours when a decrease by 51% (8,8 seconds) is observed at morning rush hours and by 59% (11,4 seconds) at evening peak hours. It varies

between 17% and 65% depending of the bus travel route. Reduced speed duration increased on average by 4% and commercial downtimes shortened by 15%. The implementation of such a priority system on a whole line should increase the commercial speed by around 30%.

Nevertheless, the layout of the surrounding crossroads area has a large influence on the bus priority system results. The efficiency of the tested bus priority system varies with the bus directions and the approach line layout. A last bus stop placed near the crossroads, a bus stop placed near a traffic light signal or a short approach line are critical factors for the efficiency.

- **Key result 3** - The bus priority system had no negative impacts on crossing direction traffic flow, neither for the travel time nor waiting lines, but this might be in relation to the low saturation level of the road. The private vehicles traffic rate slightly increase on the roads with bus priority.
- **Key result 4** - The bus drivers appreciated the ease of the system and the others stakeholders are satisfied.

Loop priority system

- **Key result 1** – The bus priority algorithm should be modified to improve the impact on bus travel time, specifically at Grand Chemin junction and at Ramonville on Castanet side.
- **Key result 2** – The implementation of a bus stop close to the traffic light signals introduces disturbances in the priority system.
- **Key result 3**- If other vehicles will be allowed to drive on the both lanes of the corridor with priority request equipment, an increase of more than ten of these vehicles per hour would require to overhaul the algorithm of the traffic light signals cycle to maintain good private vehicle traffic conditions at Ramonville junction.

D Lessons learned

Bus priority, often seen as a very technical measure, can provides substantial benefits in terms of commercial speed, journey times and therefore in transport capacity. It also introduces a reduction of pollution and a more rational use of energy at bus journey level. The improvement of the service regularity and alignment with nominal timetables makes buses a more attractive a transport mode. Furthermore the psychological effect of bus priority should not be underestimated. It shows a clear wiliness to favour the public transport over the private vehicle. The evaluation of the measure highlighted the importance to check the performances of the implemented systems.

D1 Barriers and drivers

D1.1 Barriers

Barrier 1 – A centralised solution could be most effective but requests a big effort of setting and is fairly much complex to manage.

The relatively underperformance of the present transmission system and the decision to renew the AVL system (Automatic Vehicle Detection) hindered the implementation of a centralised bus priority system in the project time.

Barrier 2 – The changes in the public transport network linked to the opening of the second underground line has been an unfavourable context for quick up scaling of the measure.

D1.2 Drivers

- **Driver 1** – The main driver for this measure was the technical insight of the engineers that the bus priority can significantly increase the regularity of the bus services.
- **Driver 2** – The implementation within the required time was of prime importance. After the opening of the second underground line, the bus lines were modified and the implementation of bus priority was felt as the local authorities were clearly committed to improve the bus service quality.

D2 Participation of stakeholders

The demonstration of the radio solution should be realised in May-June 2007, just before the opening of 2nd underground line and the reshaping of the bus network. All partners were aware of these time constraints and developed a dedicated management to apply the critical planning.

- **Stakeholder 1** – For TISSEO SMTC, manager of the measure, the implementation of the bus priority systems within the required time has not created any particular problem.
- **Stakeholder 2** – The city of Toulouse that manages the traffic light control contributed to the radio transmission priority test and met no difficulties.

D3 Recommendations

- **Recommendation 1** – Bus priority systems have to be flexible, i.e. : there is a need to have at disposal a set of solutions which can be applied according to the context and not to apply a same single solution for all junctions, lines and periods. The radio priority system is well adapted to existing infrastructure because it doesn't require civil works, the loop system suits for new infrastructure and when the system does not need to keep track of buses' position and can operate without being connected to an automatic vehicle location system.

- **Recommendation 2** – non-unified traffic light signals equipment complicates the setting of the traffic controllers, in order to take into account bus priority because each junction appears as a specific case.

D4 Future activities relating to the measure

The decision to renew the AVL system (Automatic Vehicle Detection) used on the TISSEO network will require a new interface with the UTC that would be developed out of the MOBILIS framework. In September 2008, the city hall of Toulouse has launched a call for tender to elaborate a priority bus implementation scheme for the next years. It wishes to dispose as fast as possible of a planning for equipment implementation and overhauling of crossroad controllers.