VEHICULAR TRAFFIC LIGHTS PRIORITY SYSTEM BASED ON A GEO-REFERENCE ANALYS

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ABSTRACT

Globally, and as a result of increased population and its concentration in large cities is essential to improve mobility and promote the use of public transport, therefore, priority intelligent vehicle is one of the paths that leads to sustainable mobility in cities.

We read or hear in the media is necessary to encourage public transport use to the detriment of private cars to reduce air pollution, applying technological innovation and engineering, we can state that promotes the use of urban surface transport ensuring citizen timeliness, quality and reliability of service, therefore, based on experience in implementation of different systems for vehicular priority, we define the Geo-referential analysis is the most effective method to achieve this.

The introduction of vehicle priority system geo-referencing, allows not only prioritize urban transport on the surface, but uses the infrastructure to get the fire engines, ambulance and police, have right of way at certain intersections in the city.

The data were obtained in Spanish cities like San Sebastian and Albacete demonstrate the effectiveness of this system.

Specifically in this document we highlight the implementation of the priority system in the city of San Sebastián, it is the head of Spain in bus use, since it has the highest ratio of travelers per capita: each person makes 152.9 [1] trips per year

1. THE RIGHT WAY FOR INTELLIGENT MOBILITY IN CITIES

The data obtained in different cities where the geo-referencing bus priority system has be implemented, let be optimistic in the way this system improves the mobility in cities.

In our case we propose the cases of Albacete and Donostia-San Sebastian in Spain but we can talk about other examples of priority geo-referencing in other European cities such as Aalborg, Denmark [2], Glasgow and Cardiff in the UK [2]

Analysis times achieved in cities like San Sebastian (Spain) using the bus priority system in certain areas of the city, show that the system improves the trade speed, and punctuality of the buses is approximately 98% [3] using this system.

1.1. Engineering value applied to sustainable mobility

The system of geo-referencial analysis is the name of a complex system of traffic engineering using current technologies, and the description refers to the first link of the chain of a priority vehicular system

It is much more than a device that analyze and break down the GPS information, it is an engineering technique that allows the following:

- Explore all routes passing vehicles to prioritize.
- Identify critical intersections for priority.
- Identify optimal points to improve travel times.
- Define the best appropriate actions at each cross linking them to previously defined green wave routes.

- Consider the real needs of priority for each vehicle.

This system can be used for any transportation that requires priority on its way either immediate or controlled, such as public transportation, trams, ambulance, police, fire, etc.

Geo-referencing system consider in addition to public transportation passing through each intersection, other important parameters as to know in advance if the bus requires priority actions or it is on time.

This system would reduce travel time, increasing speed, tending to match the best tram, and making shorter routes time.

1.1.1 *Sinergy between public transport companies and mobility management departments in cities*

To find the way to intelligent mobility we must get the sinergy between public transport companies and urban mobility area in cities.

The way to see and develop it, depends on the position where you are, different in the transport company that in the urban mobility area:

- Urban transport company "*Win time as much as possible in each cross, and improve speed*"
- Mobility area. "*To maintain current traffic lights at crosses that are designed to kinetic characteristics of private vehicles.*".

Engineering applied to geo-referencing bus priority system can maintain the balance between the two entities envolved, thanks to promptly request the priority using the least possible impact on the kinetic properties designed for each cross and route.

1.1.2 *Urban traffic engineering applied to vehicle priority systems*

In the implementation of a vehicle priority system is critical and priority the detailed study of each route, each cross and each traffic lights involved in the prioritization of vehicles.

The companies that can provide this work of “engineering” are those that for years have worked with prioritization systems, positioning systems or passing vehicles detection technology.

The data used to define priority engineering are:

- “Crosses”. Study of phases diagrams defined and definition of approach, pass and confirmaton control points.
- “Sub-routes and routes study”. Effect on each stage considering the priority actions.
- “Vehicles”. Type of vehicle, bus line and number of vehicles simultaneously.
- “Type of priority”. Prioritization demand, approaching confirmation, stop confirmation and pass confirmation.
- Detailed study of traffic congestion in areas to implement priority system. It identifies sections of the city where the impact on congestion is minimal.
- Implementation of bus priority especially at areas with bus lanes.
- Priority criteria of buses when they intersect. The criterion is based on the level of delay for each bus that coincide in the intersection. Also priority bus lines are defined as prevailing over the others.

It is also important in engineering applied to bus priority to configure the delay levels to consider for each line and of course taking into account the differents slots of the day.

The data provided in the historicals of pass-time of buses over virtual passing control points defined in the city, will set the criteria to allow priority actions only if the bus has a delay level over the configured threshold.

2. GEO-REFERENTIAL VEHICULAR PRIORITY SYSTEM DESCRIPTION

GPBI (instant vehicular priority manager), management of vehicular priority system, is based on criteria of geo-referential location, this information is obtained from GPS module, it identifies it, it validates the virtual position and sends data via radio to traffic lihgts controller and/or management center, showing the geo-referential position, instantaneous speed, the vehicle identification code and some additional parameters that provide to system all necessary information to controll the traffic.

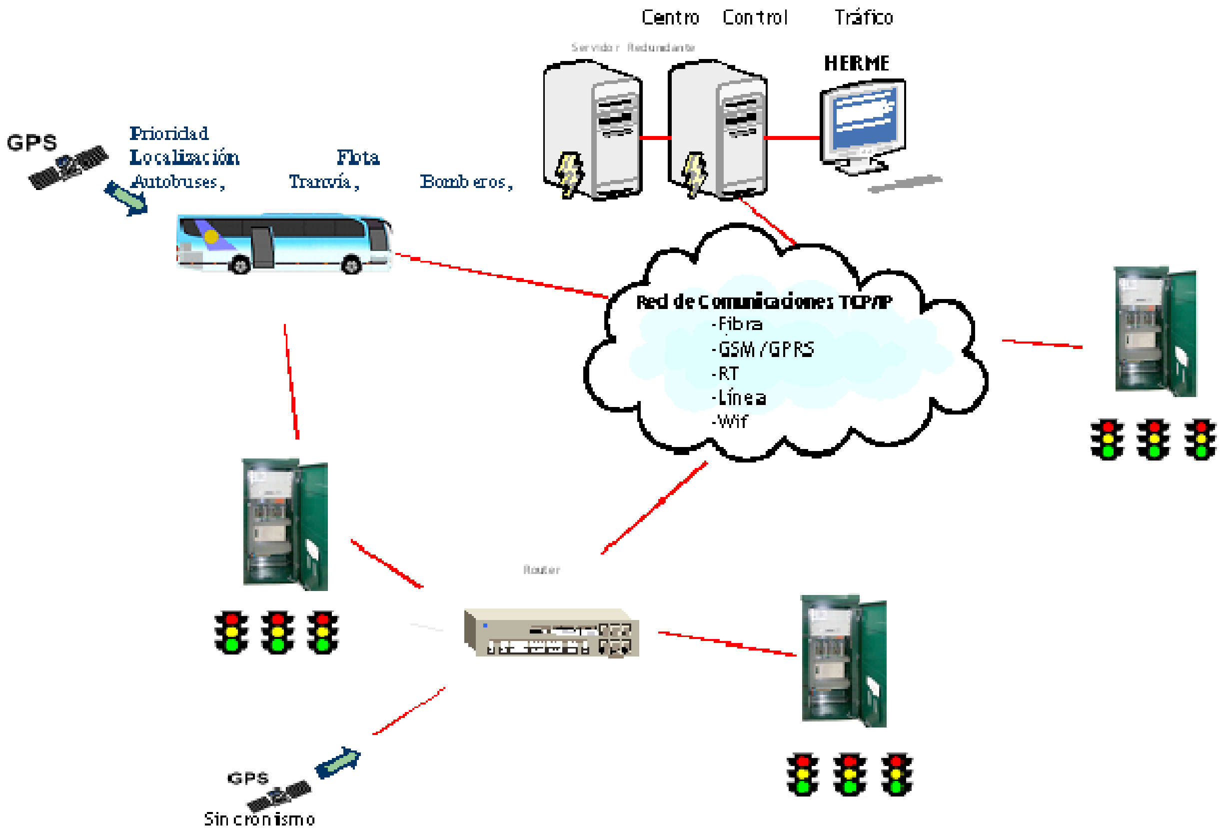

Figure 1 – General diagram of vehicle priority traffic lights system

2.1. Basic description and concepts of vehicle priority.

After several years of development, research and taking part of the business community involved in public transport and mobility management in cities, we have defined that the combination of technologies is the ideal way for vehicular prioritization urban traffic.

Combination of different technologies

- On board equipment, base on PC platform.
- Application of GPS positioning module.
- Radio communication between on board priority bus module and traffic lights controller.
- GPRS/3G communication between on board module and traffic management center.
- Centralized management system of mobility.
- Traffic lights controllers last generation, adapted to prioritize by phases and groups.

2.2. General description of bus geo-referential priority system.

Priority system is only a part of a set of systems installed on bus. It analyzes information from de GPS and combines it with other parameters from the bus.

It identifies virtual control points.

Wíreless communication between priority system and traffic lights controller.

Control Center application receives bus information passing through virtual points control.

Traffic lights controller identifies the virtual mark and does the priority action related to this virtual point.

To complete bus priority process, traffic management application takes into account buses information and applies evolutionary algorithms to public transport control.

2.2.1 *Functional description and on board device importance*

The GPBI on board system identifies the route based on a geo-referential system , it discriminates virtual positions and sets the confirmation protocol between traffic lights controllers and control center.

Virtual point management device

- Analyze on line bus position information.
- Any point of the terrestrial sphere can be located by two coordinates “latitude and longitude”.
- At any time GPS module provides coordinates, UTC time, direction and vehicle speed.
- Based upon the obtained coordinates, virtual positions of the vehicle route are validated.
- It analyzes the direction and the approach speed.
- It performs travel time calculations and real need to prioritize, in combination with SAE system..
- It communicates by radio to traffic lihts controller and by GPRS/3G to control traffic center.
- Traffic lights controller receives data of virtual position, bus identity, and other parameters, needed to determinate the most appropiate priority action depending on the situation of the vehicle.
- Based in virtual detected positions and the order of location, it recognizes automatically the bus line.

The device on board can be installed in any vehicule that need pass priority as ambulances, fire trucos, police, agencies vehicles….

Priority vehicular devices allows to define evacuation routes in the cities in case of emergency, imperative passes at conflicting crosses, emergency access to hospitals, save routes for governments members, etc.

2.2.2 *Basic requirements for traffic lights controllers*

Traffic lights controller must have last generation technology, it must provide communication radio and have tcp/ip interface to meet the requirements best suited for vehicular priority..

Priority fuctionality identifies virtual signals sent by bus or priority vehicle, and relates them with configured tables to trigger priority actions configured.

In addition to communication between traffic lights controller and on board device, there is communication between traffic lights controller and mobility manager in control center; they exchange all information necessary relative to vehicular priority.

Traffic lights controller will have microregulation algorithms that allow “control by groups” and provide flexibility and “control by phases”.

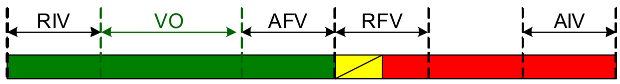

Figure 2 – Colours diagram for microregulation

- **AIV**: Early init of green phase
- **AFV**: Early end of green phase
- **RIV**: Delay init of green phase
- **RFV**: Delay end of green phase
- **FRFV**: End delay ending green phase

FRFV action that cancel the delay ending green phase is used to optimize time getting normal cross operation.

2.2.3 *Optimizing priority system using travel time data*

Geo-referential priority vehicular system uses historical and on line travel times data, as well as levels of bus delay from the SAE, to apply the priority only when it is really necessary, when the bus delay exceeds a threshold defined. The delay threshold is set by time slot and for each bus line of the city.

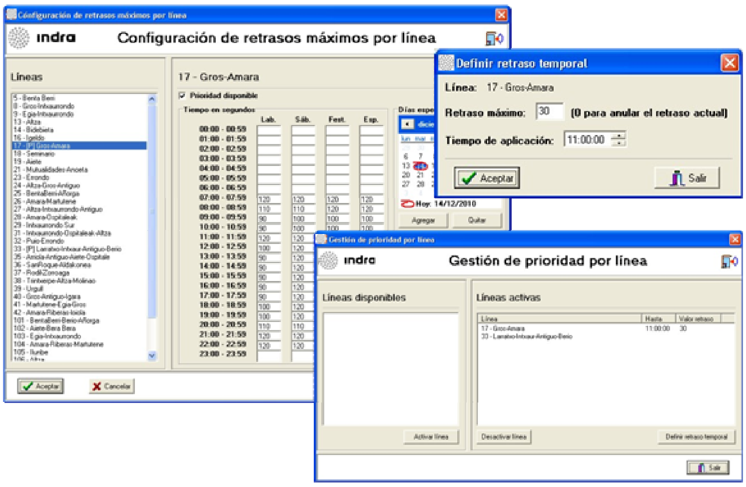

Figure 3– Setting levels of bus delay by bus lines

Joint action between real need to prioritize traffic lights and traffic management system allow us to control and optimize number of priority requests and so improve vehicular priority to be intelligent.

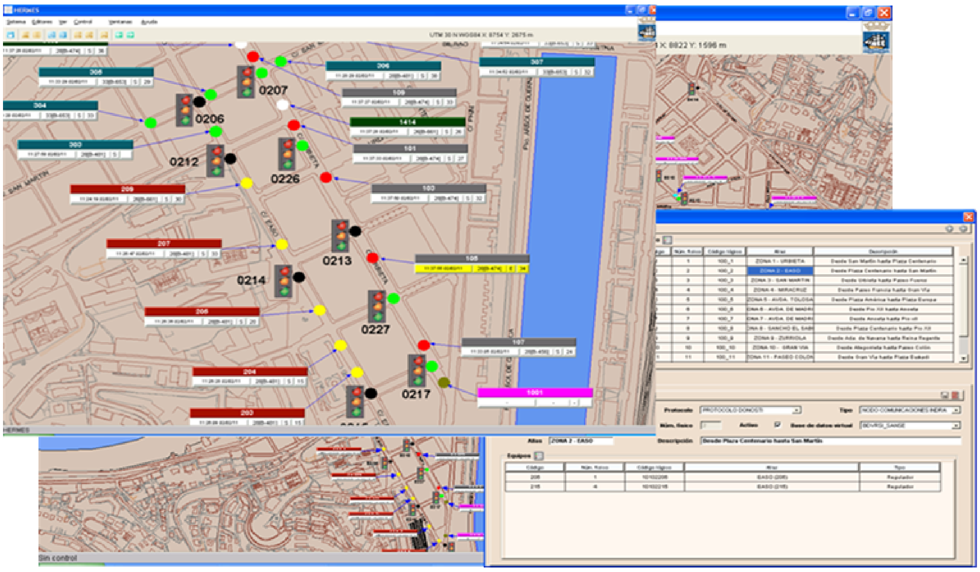

Figure 4– Bus Priority Application Manager

In the above figure we show bus passing through control points defined in the city, We generate a file of historical data that allows further statistical studies, as well as punctuality studies, and travel time of buses or any other vehicle priority.

3. INGENIERÍA DE TRÁFICO DE LA CIUDAD Y DATOS REALES DE TIEMPOS DE RECORRIDO OBTENIDOS

This chapter shows the method of analysis with data obtained from bus priority geo-referential system in the Spanish cities of Albacete and San Sebastian-Donostia. In both cases these are private bus companies.

The policy pursued since his design for the city of Donostia-San Sebastian, sought to promote public transport, giving it greater magnitude compared to private car in the modal split that exists today. To develop this aspect the objectives of the Mobility Plan [4] are:

1) Expand the coverage of public transport to reach 97% of the population and 97% of employment in 2013 (radius 150 m) and 99% in 2024.

2) Increase the weight of public transport, raising a percentage of mobility by public transport about 26% in 2016 and 30% in 2024.

3) Improve trade urban and county bus speed and avoid friction with automobile traffic. Achieve increases in average commercial speed about 10% in 2013 for urban services and 20% in 2024.

4) Increase the average speed of urban and county services that use future platforms reserved in 15 and 25% respectively.

5) Reduce travel time by public transport compared private car: decrease ratio Time TP / Time VP about 10% in 2013 and 20% in 2024.

Improve the system modal interchanges internal and external public transport. Reduce transfer times between 10 and 25%.

7) Improving pedestrian accessibility. Remodel 100% of bus stops in 2013.

8) To renew the fleet with more efficient vehicles. Having 15% of buses "clean" in 2013 and 100% in 2024.

The initial design objective was to seek a redesign of the bus network and operational measures to improve efficiency and sustainability of the network of San Sebastian:

- Strategic planning: find an optimal network based on demand. A new network design could yield benefits to a more efficient service.
- Planning tactic: find an optimal frequency for the bus lines.

The secondary objective was an operational planning, trying to manage resources based on time scheduling. Ultimately, the goal was optimal planning, so as to minimize operating costs, maximizing benefits, thereby improving overall system. The urban bus network was completely redesign in San Sebastian and also we proposed some actions to enhance the services offered

In search of the optimal network, we used the model Baaj and Mahmassani [5], but whose goal is simply to minimize user costs and transport operador costs.

3.1. Real cases of traffic engineering applied to bus priority.

The micro-regulation applies to local traffic light controller but to apply it in a bus line we must analyze its entire route considering the different intersections in its way.

The priority is determined by the moment that bus is approaching to the cross, and that instant is always in the same stretch of time because of the green wave that coordinates the route and as a result of the distance between bus stops and intersections. This coincidence of timing belt is what we call "recurrent passage route."

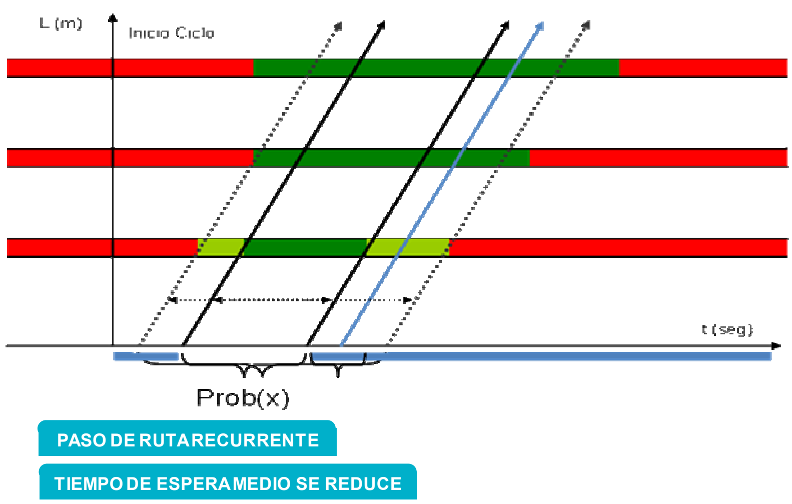

Figure 5 - Analysis of the bus approaching to the cross

Specifically for the city of San Sebastian (Spain), we have contrasted the previous study and considering 14 areas that affect the main bus routes in the city, we have thought that we can improve travel times and approximate to the 100% the punctuality of buses.

The engineering study of each area has been done considering factors such as the existence of bus lane, location of stops, matching lines, the intersections of different lines and time plots intersections. Figure 6 shows an example of graphic design studio that we made for each intersection.

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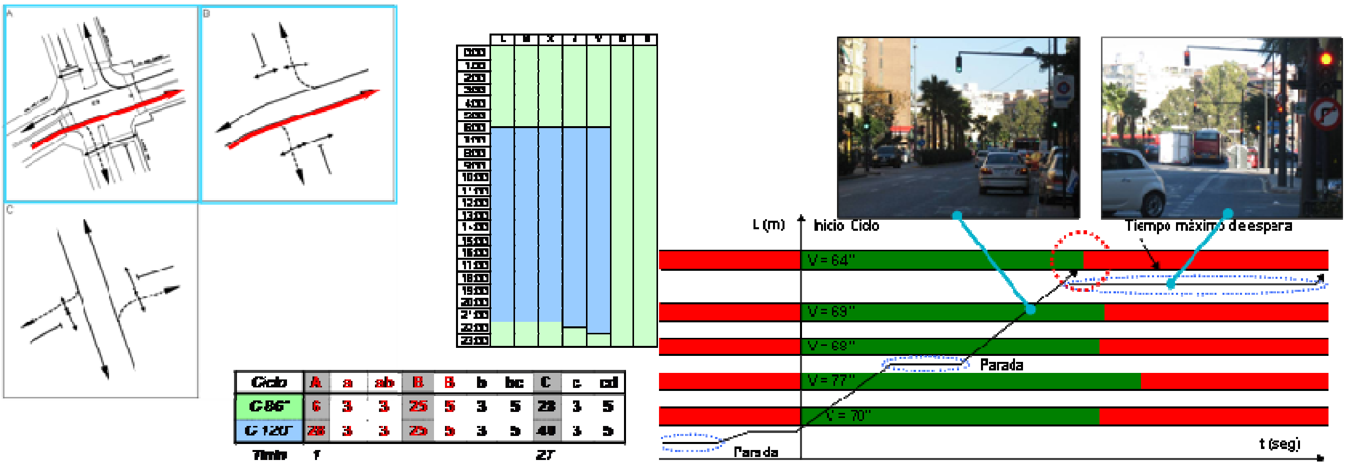

Figure 6 - Analysis of a section of bus route

3.2. Speed improvement and analysis of results obtained in the city of Donostia-San Sebastián.

The results obtained with the geo-referential bus priority in the city of San Sebastian, are very good and meet the expectations set by the client in this system. The cost of investment in development is being amortized by the increase in passengers in recent months because of the punctuality rate approaches 100%. The punctuality rate is considered optimal if the bus ends its journey with plus / minus two seconds on-time schedule.

In San Sebastián, communication between bus and center management of priority is performed with wireless GPRS/3G technology and since bus identified a checkpoint until this information is treated, we spend 2 seconds in most cases, allowing the system to work according to points and criteria defined.

The bus priority is applied together with the proper functioning of the transport management by the bus company, because any incident of vehicles in the bus lane or parked is reported to control center through the operating service. Such situations lead that buses that have lost so much time that it will can not be recovered by the system of priority, does not take passengers on a section considered, and later buses are those who do it. Maneuver plans predefined combined with bus priority maintain the good operation of public transport in the city.

Congested environments do not change too much the management of priority because these areas identified as high vehicle density have available in most cases, bus lanes to approach the cross. With regard to areas of congestion, bus priority is applicated first to vehicles in congested lanes. It is possible to observe that thanks to the bus priority requests, vehicles leaving before the congested area.

To study the benefits of geo-referential bus priority system, it is necessary to analyze the bus travel time between two specific points in different areas where bus priority is implemented.

Figure 7 – Partial map of the city with virtual points for bus priority

In the previous figure we consider an in point in the area and an out point of it. At the in point we analyze if the bus is on-time or if it has a considerable delay level to apply bus priority, if so, we apply micro-regulation actions on the different crosses of the area to help the bus to recover lost time.

Each intersection has a minimum time that must be respected to maintain road safety criteria. And we must analyze the green wave route in order to not alter the engineering criteria defined for each time interval of the day, when the priority actions are used.

We are going to analize the area which straddles the lines 17 and 33 urban buses. Here we have summary of average time between entry point into the area and output point of it:

	13/11/2010 to 14/11/2010	11/12/2010 to 12/12/2010
Total travel	135	128
Priority requests	0	59
Average time per way (seconds)	444	408

Table shows that on 11 and 12 December with 128 travels of buses, 59 requests for priority was made and average travel time was 6 minutes and 48 seconds, while on 13 y 14 November in which there was not bus priority, average travel time was 7 minutes and 24 seconds, so the bus priority system gives a real average improvement of **36 seconds**.

The results of these 36 seconds and the improvements achieved in the 12 remaining areas of the city, obtained in studies since the beginning of the year, indicate that all lines that were affected by bus priority have an on-time from the 98% to 100% at all the route

In the city of San Sebastian (Spain) we have analyzed until May 2011 priority on lines 5, 13, 17, 19, 26, 28 and 33 along the route of the 14 priority areas defined for priority bus in the city. In annex I we show the maps indicating virtual positions to apply different actions.

The study of results reflect the time between entry point and exit point of each zone for both cases, one where bus priority has NOT been applied and the other, where bus priority HAS been applied. The difference between both results, gives (apparently) the profit of appliying bus priority, time we save applying it, when buses request pass priority.

The following statements reflect some points to consider when analyzing the results:

- Bus priority is being applied precisely at times of maximum traffic density so that, improvement achieved in these intervals is reduced by the circulation itself.

- Buses that request priority and therefore carry considerable lag time, precisely because of this condition, collect more passengers than the bus that goes below it. This reduces the improve action of bus priority.

- The buses that follow one with a considerable degree of delay, find bus stop with less number of users, so indirectly the implementation of priority on the bus before it, causes the running time in this section for this bus without priority is very fast.

- The value of travel time of this case befote, where buses take advantage of fewer users per stop, means that these values of travel times reduce the value of "apparent" gain per area.

- It would be ideal to apply bus priority that bus carrying a considerable level of delay does not collect passengers at any bus stop but spreads its load with the next bus.

- The gain data in one section may be different depending on the bus line due to the different stops.

To obtain data we have used the application of specific reports and the option to consult by:

- Priority Bus (PB) area
- Start PC.
- End PC
- Bus line.
- Start date
- End date

Studies has been performed during different months of 2010 and 2011 for each of the sections and then we have separate values in two tables, one PB was applied and another that have not required the application of priority.

Below an example table that shows where we get data reflected:

Applying bus priority

Línea	Bus	Zona	PC_0	Entrada PC_0	PC_n	Salida PC_n	Dif(s)	Prioridad	Resultado	
17	532	8	821	13/04/2011 19:06	833	13/04/2011 19:10	236	Habilitada	POK	
17	669	8	821	11/04/2011 10:07	833	11/04/2011 10:11	235	Habilitada	POK	
17	739	8	821	13/04/2011 9:48	833	13/04/2011 9:52	200	Habilitada	POK	
17	739	8	821	14/04/2011 8:18	833	14/04/2011 8:21	150	Habilitada	POK	
17	739	8	821	14/04/2011 18:33	833	14/04/2011 18:36	139	Habilitada	POK	192

No need bus priority:

17	739	8	821	14/04/2011 16:20	833	14/04/2011 16:23	184	Deshabilitada		
17	739	8	821	14/04/2011 17:48	833	14/04/2011 17:53	263	Deshabilitada		
17	739	8	821	14/04/2011 19:15	833	14/04/2011 19:20	289	Deshabilitada		
17	739	8	821	14/04/2011 19:59	833	14/04/2011 20:03	268	Deshabilitada		
17	739	8	821	14/04/2011 20:41	833	14/04/2011 20:44	183	Deshabilitada		247,33

In this example, the gain between these two points in the area 8 for bus 17 would be

Gain Area 8, Bus line 17 → 247,33sec – 192sec = **55,33 seconds**

The sum of the profits from each of the areas for each bus line gives us the time savings that bus get along its entire route through the city, in particular bus line 17 of the private company San DBUS of Sebastian in April 2011 obtained 173.77 seconds.

BUS LINE 17	
TOTAL GAIN AREA 6	29,78
TOTAL GAIN AREA 8	12,3+55,33
TOTAL GAIN AREA 9	29,29+21,31
TOTAL GAIN AREA 10-11	25,76
TOTAL GAIN ON TOUR	**173,77** seconds

For each bus line on which bus priority has been applied, we made similar analysis with the following results in May 2011 in the city of San Sebastian.

BUS LINE 5	
TOTAL GAIN ON TOUR	67,4 seconds
BUS LINE 13	
TOTAL GAIN ON TOUR	73,99 seconds
BUS LINE 17	
TOTAL GAIN ON TOUR	168,6 seconds
BUS LINE 21	
TOTAL GAIN ON TOUR	115,11 seconds
BUS LINE 26	
TOTAL GAIN ON TOUR	99,41 seconds
BUS LINE 28	
TOTAL GAIN ON TOUR	173,31 seconds
BUS LINE 31	
TOTAL GAIN ON TOUR	52,26 seconds
BUS LINE 33	

TOTAL GAIN ON TOUR	91,05 seconds

1.2.1 *Succes cases and added value of Bus Priority system*

Thanks to the actions of geo-referential bus priority system, we generate the user confidence to promote the use of surface public transport, and also in cases like the one shown below, the improvement in the trade speed allows extend the tour areas of the city keeping the same frequency of buses.

By getting a trade speed improvement in some bus lines of order 5% to 8%, and as a result of the improvement we redefined bus line increasing the route.

Figure 8 - Bus line "A" maps extended by the Geo-reference bus priority

The possibility that bus indicates the position of approaching to the cross by radio allows to use this signal as a demand to change the phase at the cross.

Specifically, in Albacete (Spain) the demands generated by buses that incorporate geo-referencing bus priority system, allow demand to change the phase for exclusive bus turn.

Before | Now | Bus turning

Figura 9 – Exclusive turn bus

The traffic improvement in this specific case jeans

- Increase of 900 meters in bus line (+ 3 / 6 minutes).
- Leverage existing system (signals and devices).

- Phase that allows bus turn is activated only upon bus request (minimum impact for other users)
- The increase of 900 m. in the itinerary does not increase total travel time of the bus line.

4. CONCLUSIONS

"The Bus priority based in the geo-referencial analysis is **true**"

"Using these systems for urban traffic management in cities, we are in the good way to get **intelligent mobility"**

"We must use Priority Bus intelligently, only if it is really necessary, **at certain times and certain crosses**"

"GPBI system combined with **SAE**, (user system) complete all requirements to improve speed bus"

"The GPBI geo-referential priority systen is used as **vehicle priority sistem** for firefighters, ambulances, police, and all emergency vehicles that need priority at crosses"

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