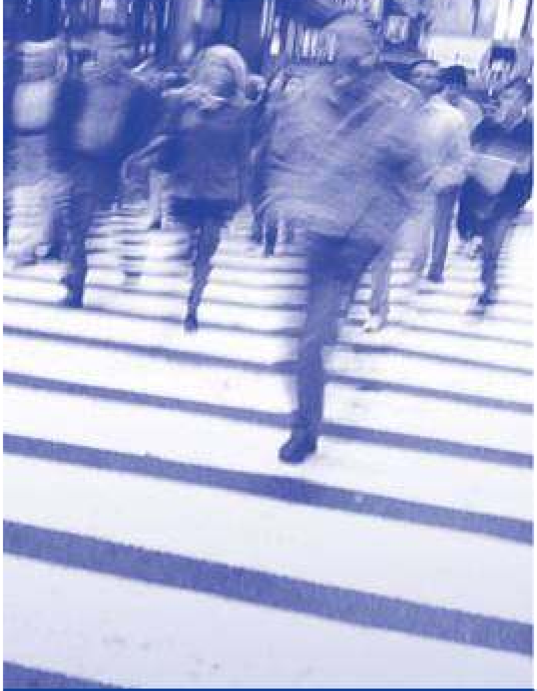

CIVITAS
Cleaner and better transport in cities

ARCHIMEDES
AALBORG • BRIGHTON & HOVE • DONOSTIA-SAN SEBASTIÁN • IAŞI • MONZA • ÚSTÍ NAD LABEM

Monza

T82.1 – Public Transport Priority System in Monza

City of Monza

June 2012

THE CIVITAS INITIATIVE
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1 Introduction

1.1 Background CIVITAS

CIVITAS - cleaner and better transport in cities - stands for CIty-VITAlity-Sustainability. With the CIVITAS Initiative, the EC aims to generate a decisive breakthrough by supporting and evaluating the implementation of ambitious integrated sustainable urban transport strategies that should make a real difference for the welfare of the European citizen.

CIVITAS I started in early 2002 (within the 5th Framework Research Programme);
CIVITAS II started in early 2005 (within the 6th Framework Research Programme) and
CIVITAS PLUS started in late 2008 (within the 7th Framework Research Programme).

The objective of CIVITAS-Plus is to test and increase the understanding of the frameworks, processes and packaging required to successfully introduce bold, integrated and innovative strategies for clean and sustainable urban transport that address concerns related to energy-efficiency, transport policy and road safety, alternative fuels and the environment.

Within CIVITAS I (2002-2006) there are 19 cities clustered in 4 demonstration projects, within CIVITAS II (2005-2009) 17 cities in 4 demonstration projects, whilst within CIVITAS PLUS (2008-2012) 25 cities in 5 demonstration projects are taking part. These demonstration cities all over Europe will be funded by the European Commission.

Objectives:

- to promote and implement sustainable, clean and (energy) efficient urban transport measures
- to implement integrated packages of technology and policy measures in the field of energy and transport in 8 categories of measures
- to build up critical mass and markets for innovation

Horizontal projects support the CIVITAS demonstration projects & cities by :

- Cross-site evaluation and Europe wide dissemination in co-operation with the demonstration projects
- The organisation of the annual meeting of CIVITAS Forum members
- Providing the Secretariat for the Political Advisory Committee (PAC)
- Development of policy recommendations for a long-term multiplier effect of CIVITAS

Key elements of CIVITAS

- CIVITAS is co-ordinated by cities: it is a programme “of cities for cities”
- Cities are in the heart of local public private partnerships
- Political commitment is a basic requirement
- Cities are living ‘Laboratories' for learning and evaluating

1.2 Background ARCHIMEDES

ARCHIMEDES is an integrating project, bringing together 6 European cities to address problems and opportunities for creating environmentally sustainable, safe and energy efficient transport systems in medium sized urban areas.

The objective of ARCHIMEDES is to introduce innovative, integrated and ambitious strategies for clean, energy-efficient, sustainable urban transport to achieve significant impacts in the policy fields of energy, transport, and environmental sustainability. An ambitious blend of policy tools and measures will increase energy-efficiency in transport, provide safer and more convenient travel for all, using a higher share of clean engine technology and fuels, resulting in an enhanced urban environment (including reduced noise and air pollution). Visible and measurable impacts will result from significantly sized measures in specific innovation areas. Demonstrations of innovative transport technologies, policy measures and partnership working, combined with targeted research, will verify the best frameworks, processes and packaging required to successfully transfer the strategies to other cities.

1.3 Participant Cities

The ARCHIMEDES project focuses on activities in specific innovation areas of each city, known as the CIVITAS corridor or zone (depending on shape and geography). These innovation areas extend to the peri-urban fringe and the administrative boundaries of regional authorities and neighbouring administrations.

The two Learning cities, to which experience and best-practice will be transferred are Monza (Italy) and Ústí nad Labem (Czech Republic). The strategy for the project is to ensure that the tools and measures developed have the widest application throughout Europe, tested via the Learning Cities' activities and interaction with the Lead City partners.

1.3.1 Leading City Innovation Areas

The four Leading cities proposed in the ARCHIMEDES project are:

- Aalborg (Denmark);
- Brighton & Hove (UK);
- Donostia-San Sebastián (Spain); and
- Iasi (Romania).

Together the Lead Cities in ARCHIMEDES cover different geographic parts of Europe. They have the full support of the relevant political representatives for the project, and are well able to implement the innovative range of demonstration activities proposed.

The Lead Cities are joined in their local projects by a small number of key partners that show a high level of commitment to the project objectives of energy-efficient urban transportation. In all cases the public transport company features as a partner in the proposed project.

2 Monza

Monza is a city on the river Lambro, a tributary of the Po, in the Lombardy region of Italy, some 15km north-northeast of Milan. It is the third-largest city of Lombardy and the most important economic, industrial and administrative centre of the Brianza area, supporting a textile industry and a publishing trade. It is best known for its Grand Prix.

The City of Monza, with approximately 121,000 inhabitants, is located 15 km north of Milan, which is the centre of the Lombardia area. This area is one of the engines of the Italian economy; the number of companies is 58,500, i.e. a company for every 13 inhabitants.

Monza is affected by a huge amount of traffic that crosses the city to reach Milan and the highways nodes located between Monza and Milan. It is also an important node in the Railways network, crossed by routes connecting Milan with Como and Switzerland, Lecco and Sondrio, Bergamo and Brianza. "Regione Lombardia", which in the new devolution framework started in 1998, has full responsibility for establishing the Local Public Transportation System (trains, coaches and buses) and has created a new approach for urban rail routes using an approach similar to the German S-Line or Paris RER.

Monza has recently become the head of the new "Monza and Brianza" province, with approximately 750,000 inhabitants, so will gain the full range of administration functions by 2009. Plan-making responsibilities and an influence over peri-urban areas will require the city to develop new competencies.

In this context, the objective of the City of Monza in participating in CIVITAS as a Learning City is to set up an Urban Mobility System where the impact of private traffic can be reduced, creating a new mobility offer, where alternative modes become increasingly significant, leading to improvements to the urban environment and a reduction in energy consumption (and concurrent pollution).

3 Background to the Deliverable

In the context of encouraging sustainable mobility, the use of Public Transport in the City of Monza needs to be increased. In order to achieve this objective, within the framework of the CIVITAS ARCHIMEDES project a clear decision has been made, which has the full support of the government of the Municipality. This is based on the implementation of technological measures to make Public Transport more attractive to citizens.

Through ARCHIMEDES measure number 81 (“UTC System in Monza”), several intersections have been controlled by the Urban Traffic Control (UTC) System which implements the coordinated and centralised control of traffic lights. The UTC system selected is called RoadManager®. It is designed and implemented by Project Automation, technological partner of the Municipality of Monza in the ARCHIMEDES project. Please see Deliverables R81.1 and T81.1 for details.

Through ARCHIMEDES measure number 78 (“Bus Management System in Monza”), the buses of the Public Transport fleet are localised and monitored closely, i.e. it is known where each bus is with respect to its scheduled timetable. Please see deliverables R78.1 and T78.1 for details.

This measure (number 82, Public Transport Priority System in Monza) is concerned with implementing a framework that allows for the traffic light plans of the intersections (managed by the UTC) to adapt when the actual situation of the buses would benefit from more green time at these intersections (as long as the overall traffic status allows this.)

The measure has covered 2 tasks.

Research Stage: Task 11.8.6 Public Transport Priority Management Study
A study has been undertaken by Project Automation, in agreement with Comune di Monza and with Nord-Est Trasporti (NET) which is the owner of the Public Transport fleet, to propose a conceptual framework to manage Public Transport Priority at the relevant intersections. Results have been deeply described in Deliverable R82.1**.** In summary, they consist of:

- a first "Decision Module (hereinafter called DM1)" which has the role to receive priority requests issued by buses approaching the intersections of the Corridor and to decide whether to consider them eligible to be served or not;
- a second "Decision Module (hereinafter called DM2)" which filters all the incoming priority requests for each intersection, deciding which of them (one or more, if compatible) will be served by the UTC system;
- an "Interface Module" which must translate the winning priority requests to specific commands that the UTC can process and activate.

Demonstration Stage: Task 8.17 Public Transport Priority System
Four intersections of the CIVITAS Corridor for Public Transport have been equipped with the devices necessary for them to be put under the control of the UTC System. These devices allow application of the Priority Management scheme that emerges from the study carried out in the Research stage, outlined above.

4 Description of the Work Done

4.1 Summary

Whereas in the research task focus was on the conceptual approach, the demonstration stage has been devoted to apply such approach in the real context. Is has to be highlighted that the buses travel in the same traffic streams as private cars.

This demonstration stage will be reported through the following sections:

1. Description of the ARCHIMEDES Corridors (please see §4.4);
2. Recall of the conceptual approach carried out in the RTD stage of the project (please see §4.3);
3. Detailed analysis of the actual behaviour of the buses in the Public Transport Corridor, defining the right sample to be queried and analysed (please see §4.4);
4. Creation of a relational database, in which all the localisation and monitoring data provided through Measure no. 78 have been saved, to allow a detailed statistical analysis (please see §4.5);
5. Accomplishment of a detailed statistical analysis of collected data, to find out the right timing to adapt the cycles of traffic lights plan to prefer buses (please see §4.6);
6. On-site experiments, to assess in the reality the results achieved (please see §4.7).

4.2 The CIVITAS-ARCHIMEDES Corridors

Before entering into details of what has been carried out, the corridors are summarised in this section. In Figure 1 the corridor for Public Transport is highlighted with an orange line and the intersections involved are shown as blue crosses. The corridor for private traffic, managed in Measure no. 81, is highlighted with a brown line and intersections are shown with a red cross.

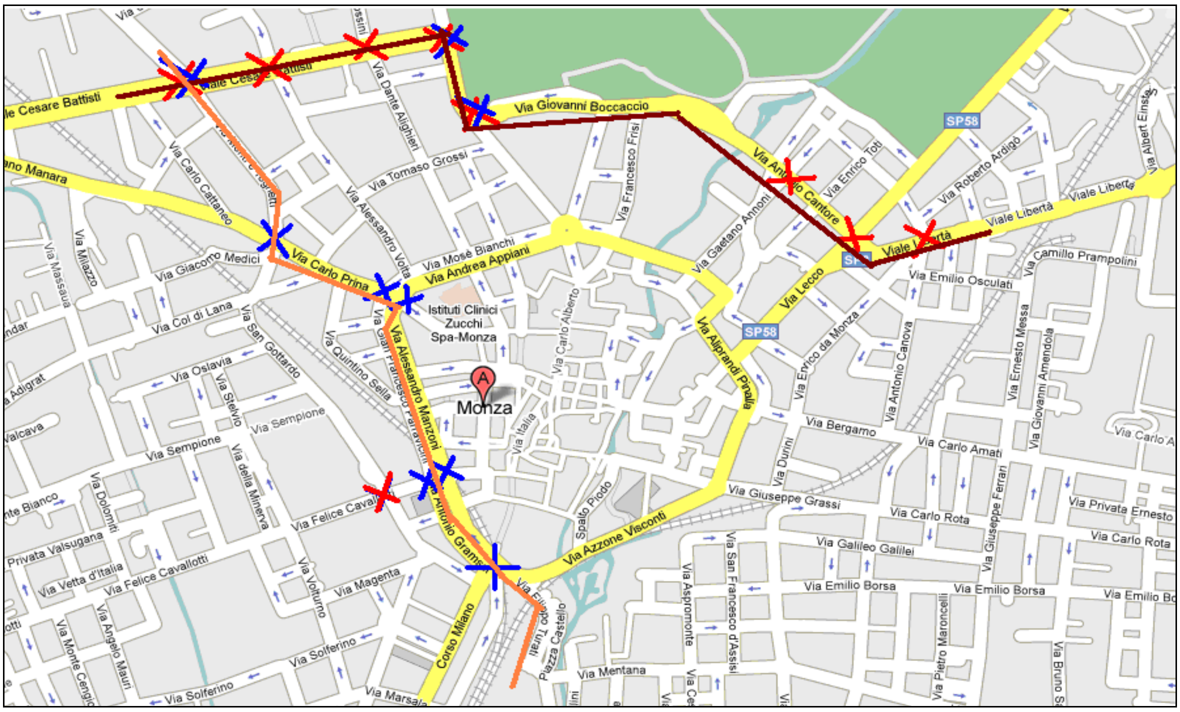

Figure 1 - Monza CIVITAS Corridors

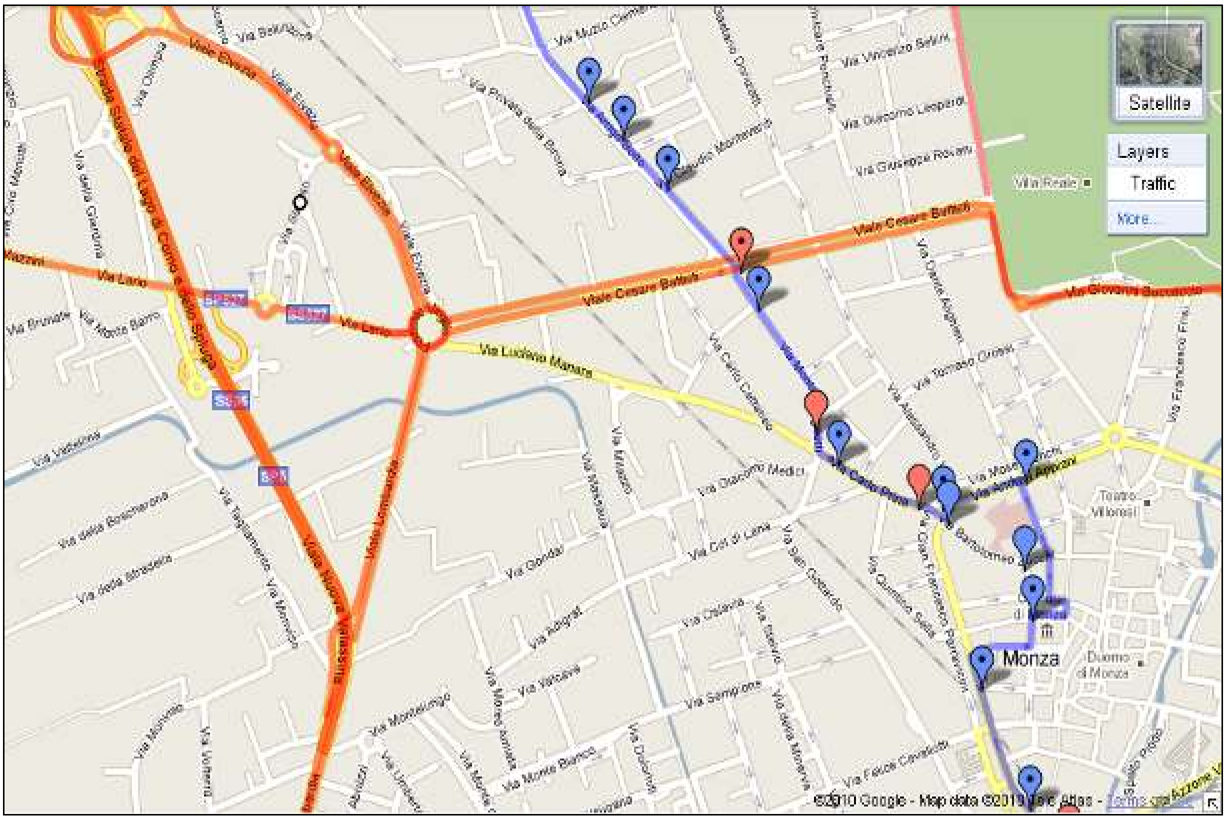

Figure 2 - Markers which identify the bus stops (blue) and virtual bus stops (red)

In Figure 2 a detail of the corridor for Public Transport is shown. The blue and red knots identify the real bus-stops (blue knots) and virtual bus-stops (red knots) which generate the localisation data of the buses, as described in §4.4.

4.3 Recap of the conceptual approach

What has so far been described concerns the production of priority requests. As far as the realisation of these requests is concerned, other organisations need to be involved. These are shown in Figure 3.

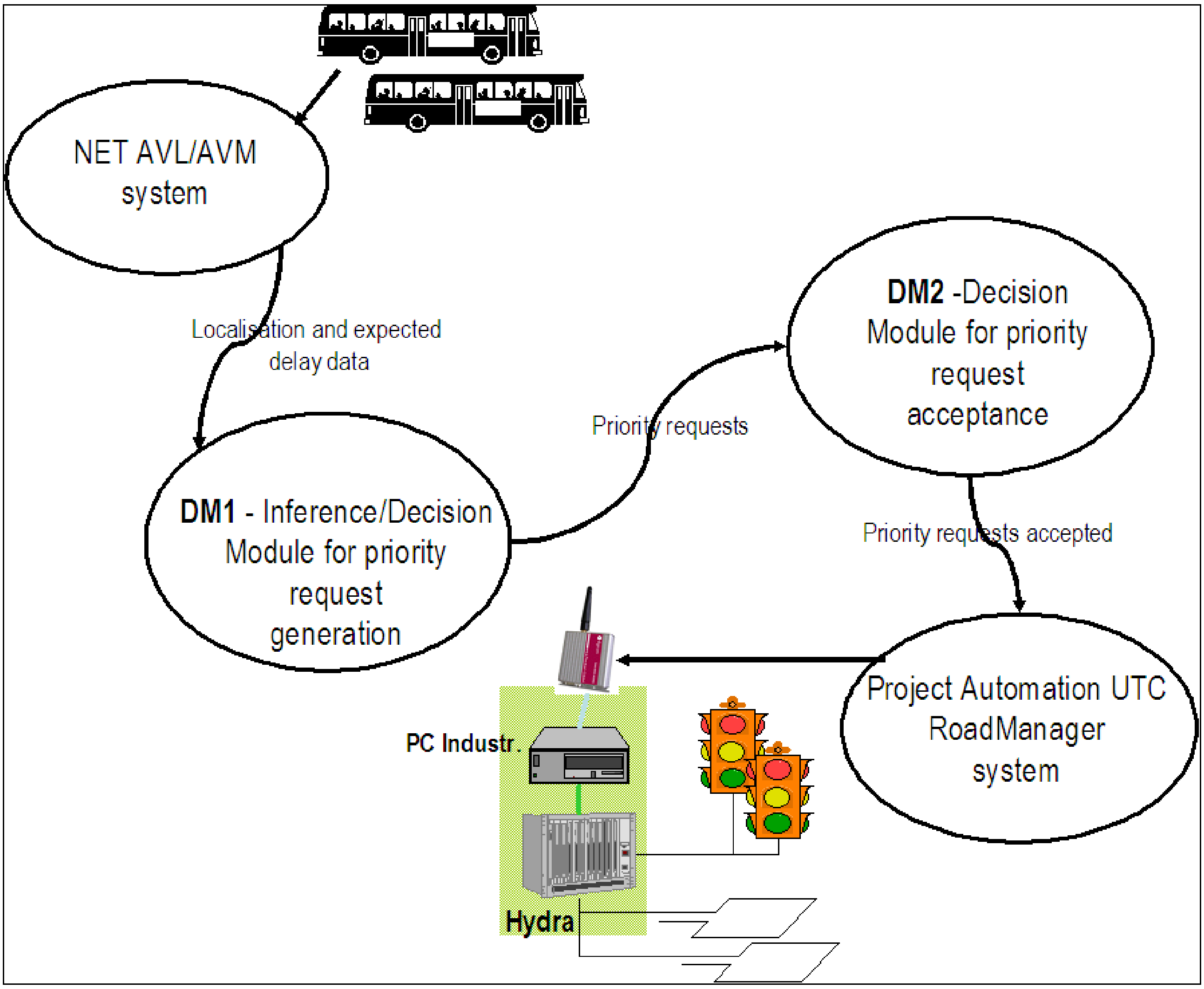

Figure 3 – Functional flow for management of bus priority requests

The functional flow involves four elements:

- - the AVL/AVM system which generates localisation and monitoring data of the Public Transport fleet; starting form these data, it is possible to compute the "expected delay" feature, described in deliverable R82.1;

- - a first decision module (DM1), which is aimed at taking decisions on which priority requests generated by the actual behaviour of the Public Transport service are to be issued (see paragraph 4.3.1);
- - a second module DM2 which processes the priority requests issued and must decide which of them can be fulfilled (see paragraph 4.3.2);
- - the UTC system, namely the RoadManager Suite running in the city of Monza to manage the centralised traffic lights (see paragraph 4.3.3).

As far as the technological framework to get data from the AVL/AVM system operational in NET is concerned, see Figure 4. This framework has been described in detail in the deliverables concerning measures 78 and 79, but is it reported here to focus on the functions made available to other applications by a Web Server through appropriate Web Services.

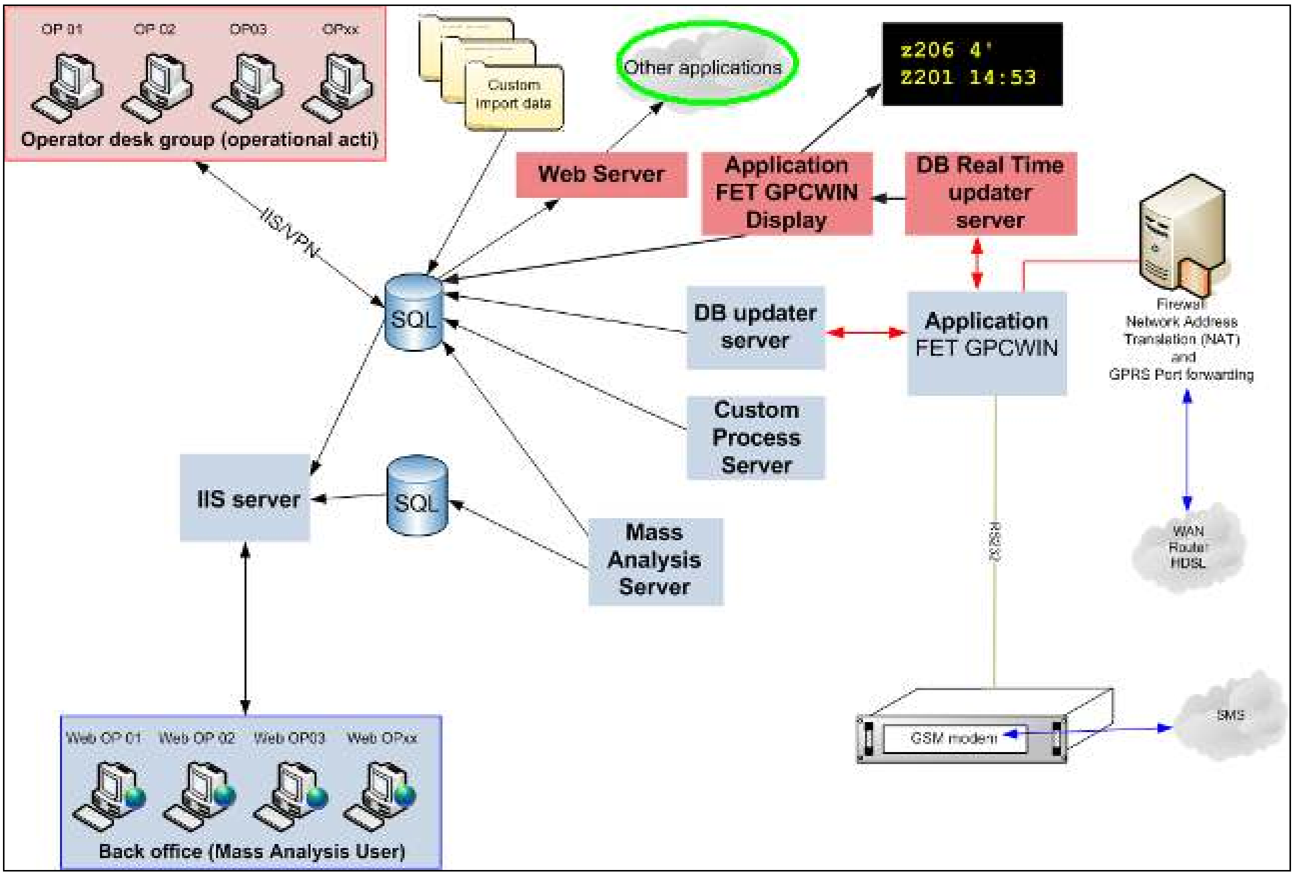

Figure 4 – Technological Framework to get data by AVL/AVM system

4.3.1 Decision Module 1

The first decision module, DM1, is aimed at taking decisions on which priority requests generated by the actual behaviour of the Public Transport service are to be issued. This module will apply one of the decision schemes described in deliverable R82.1 (e.g. priority request issued if expected delay greater than 300 seconds, greater than 180 seconds and so on) that will be chosen by the experts in Traffic Office of the Municipality, who are in charge decisions of traffic policies to be applied.

This module is continuously updated since it accesses through appropriate Web-services to a dedicated Web Server made available by AVL/AVM system, in order to keep updated the “Expected Delay” feature which represents a degree of need of priority for a given run of a Public Transport bus.

It has to be pointed out that the generation of priority requests is independent by factors external to the Public Transport Service; such factors will be taken into account by subsequent stage of this process. Requests are generated each time a bus is delayed according to the chosen criterion.

4.3.2 Decision Module 2

The second decision module, DM2, processes the priority requests issued and must decide which of them can be fulfilled.

Decisions can be undertaken following a wide set of criteria, both qualitative and quantitative, depending on the real information available; possible decision variables to undertake a decision that can vary along time, are:

- - Satisfaction of priority requests stated by authorised people (e.g. the traffic engineers of the Municipality) enabled/disabled;
- - Status of the Traffic along the Corridor, if appropriate sensors are available; this is not the case in the city of Monza at this time, nor likely in the immediate future;
- - Maximum number of priority actions satisfied at a given timeframe (e.g. the last 20 minutes) for a given intersection or for a set of coordinated intersection related to the corridor or part of it;
- - Temporal threshold within which it is not possible to satisfy other priority requests for a single intersection or a group of coordinated intersections, to avoid heavy side effects on private traffic.

Another important objective of this decision module is to solve conflicts among different priority requests. To do this, the following topics must be defined:

- - correspondence between priority requests and signal groups of the Traffic Light Controller, and, consequently, with the stages of the traffic light plan.

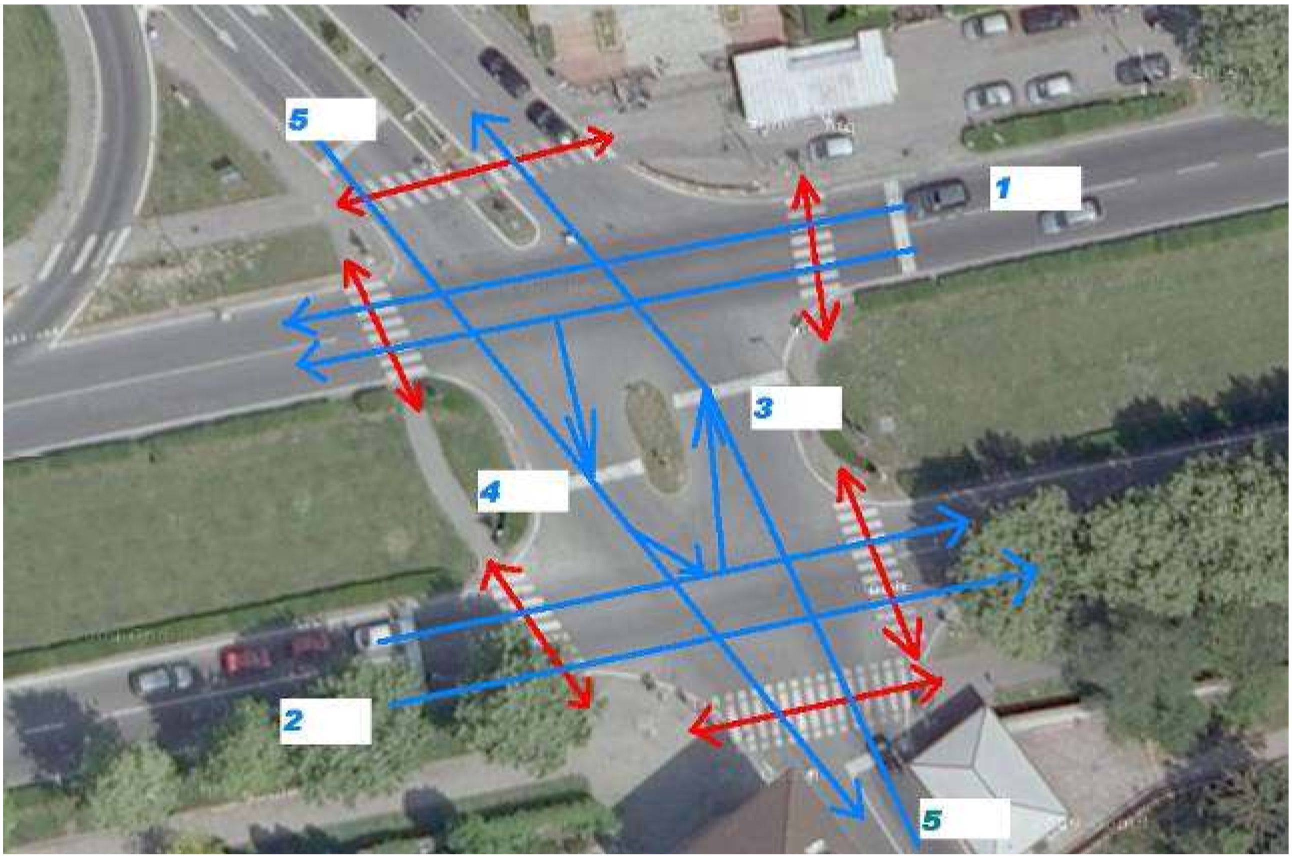

Figure 5 - Intersection no. 19 (Boito-Battisti)

In the example depicted in Figure 5, the movements for vehicles are expressed by the blue arrows and marked with an identification number (1 to 5) which represents the Signal Group number of the Traffic Light Controller. Signal Groups 1 and 2 are dedicated to the main flow, i.e. the CIVITAS Corridor for private traffic explained in deliverable T81.1.

Signal group 5 manages the CIVITAS Corridor for the Public Transport, driving the movements for vehicles coming from the Centre of the City (the road on the lower part in the picture) and coming from the City Hospital (the road on the higher part in the picture).
In the relationships among stages and Priority requests are shown:

Stages/Prior. Req.	R1	R2
F1		
F2		
F3	X	X

Table 1 - Relationships stages - priority requests at Intersection 19

Table 1 shows information that expresses the relationship between stages and requests. In particular, for this situation, the two requests are compatible, since they are managed by the same stage of the plan. This is a lucky situation, but it is quite common that different priority requests are served in different stages of the plan or that there are only partial commonalities.

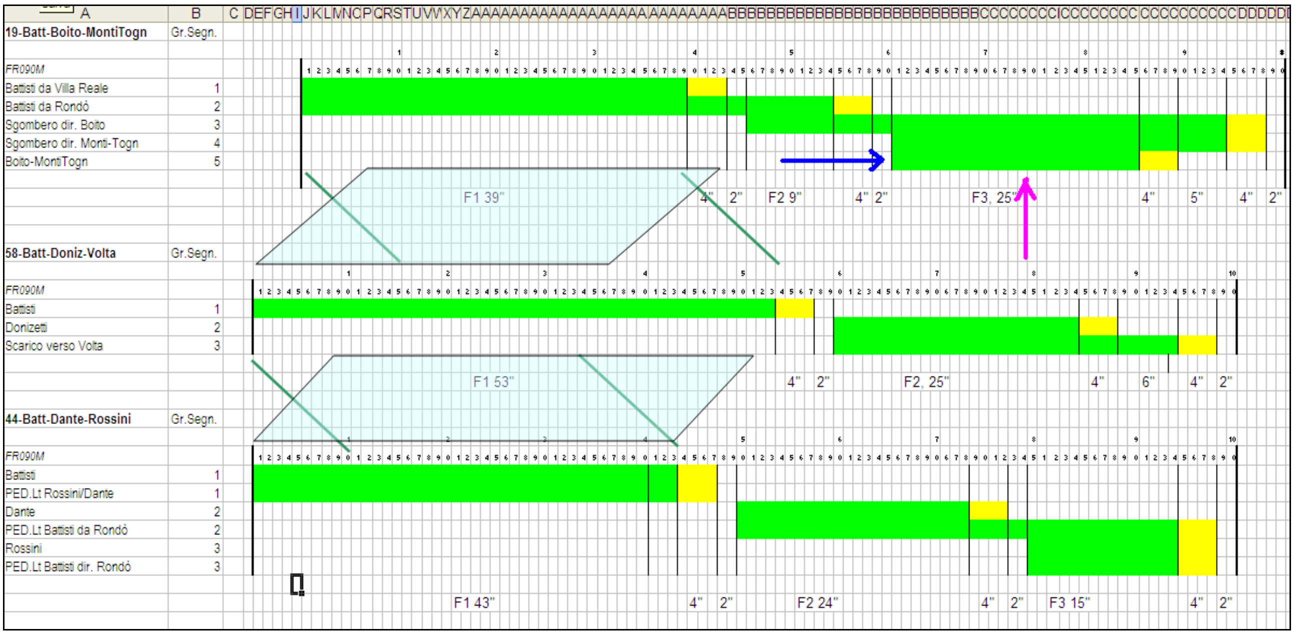

Figure 6 - Coordination group involving the intersection no. 19

Figure 6 represent the plans of three coordinated intersection, the blue arrow indicates the signal group involved with the transit of buses and the magenta arrow indicates the stage of the traffic light plan when the signal group 5 gets green.

Through the application of this formula, DM2 takes decisions about the requests to be fulfilled, which are then sent to the UTC Roadmanager to be served.

4.3.3 Fulfilment of the Priority Request within the UTC System

The traffic light plans concerning the intersections belonging to the corridor for Public Transport priority management will be designed and coded to fulfil priority requests. The central component of the UTC system will forward to its peripheral software component managing the relevant intersection the proper information to serve the priority request to be delivered.

Specifically, each traffic light plan which is involved in priority management for Public Transport will be designed and coded to manage priority requests. Continuing the example concerning the intersection no. 19, Boito-Battisti, (which belongs to both the Monza CIVITAS corridors, depicted in Figure 5 and whose reference traffic light plan is presented in Figure 6), the plan adjusted to manage priority requests is shown in Figure 7.

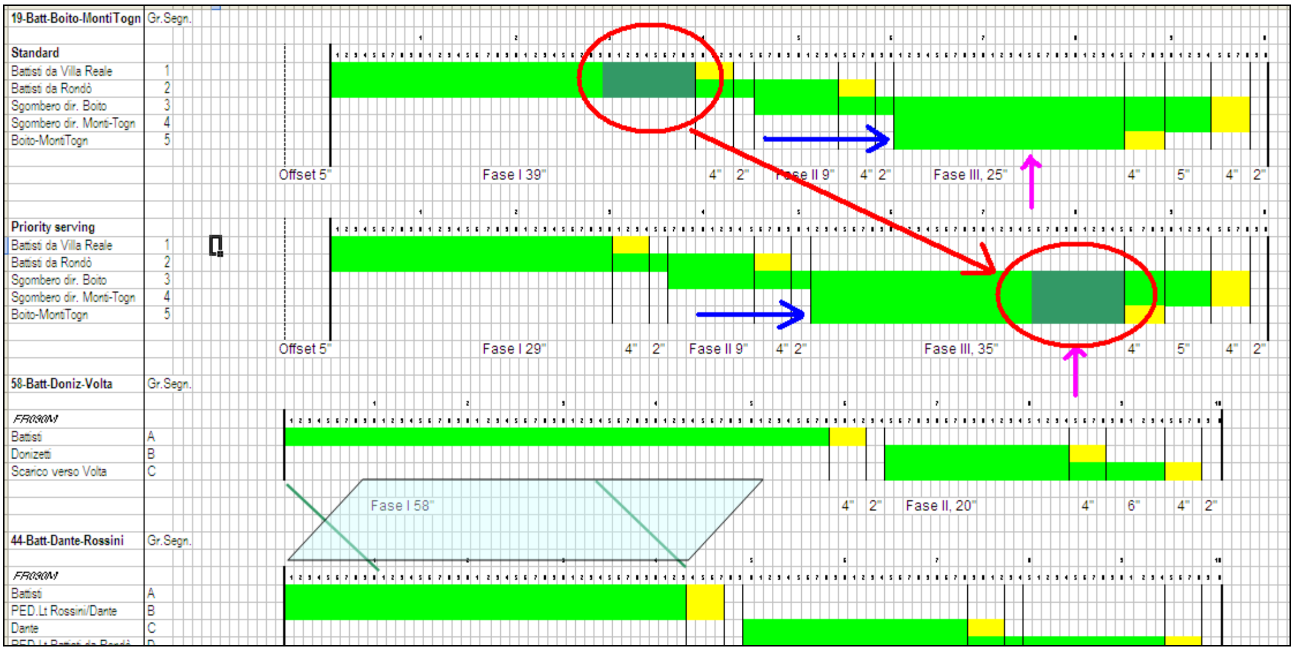

Figure 7 - Traffic light plans with priority management for Public Transport

In Figure 6 the signal groups were already marked with the coloured arrow and the stage to be preferred; in Figure 7 other information are added: the second traffic light plan from the top is the plan activated when a priority request has to be fulfilled.

Specifically, the proposed approach consists of a different split assignment: to fulfil the priority request, ten seconds of green time are moved from Stage I to Stage III, as pointed out by the dark green time slot red-circled. The number of cycles for which this different split holds may depend on the relevant bus completing its transit of the intersection or on a maximum number of cycles for which this different split can be applied, knowing that this plan penalises the private corridor leading to increased congestion on the other roads.

During the demonstration stage of the project all these parameters will be tuned to provide a good starting point for the evaluation session.

As far as some technological details of the traffic light plan coding are concerned, the plan will remain the same; the durations of the Stages I and III will be conditioned on the status of a variable name “Priority_ON” which will become TRUE when the priority scheme has to be applied and FALSE viceversa. The cycle time will remain the same but the green split percentage will change in accordance with the above-mentioned policy.

4.4 Analysis of behaviour of the buses on the Corridor

The first aspect to be analysed was the actual behaviour of the bus throughout the corridor. This task has been carried out in two ways:

7. analysing the behaviour being present at the intersections of the corridor to understand the practical problems encountered by the buses along the day;
8. accessing and analysing AVL/AVM data made available through the Webservice implemented in Measure no. 78.

For this purpose a specific relational database has been implemented, in order to collect all data published through the Webservice, described in the next paragraph.

The result of this activity consists of understanding how the “model” we setup fits the process. It is correct to use the term “model” since throughout this measure the real process consisting of buses that travel across the city fulfilling the Public Service is seen only through their travel data collected in automatic way.

This analysis led to define “virtual stops” that allow the decision modules to follow in a correct way the route if the bus, in order to decide when to generate priority requests and to assess that such requests arise in the correct moment: only in this case the adaptation of traffic light plans can help making the service as regular as possible.

A concrete use case of this aspect, collected on May 25th 2012, is described in Table 2.

line	vehicle	stopId	Stop_name	tstamp_plan	tstamp_real	delta_time
z206	7511	NET302	Mentana - Aspromonte	2012/05/25 07:51:41	2012/05/25 07:49:39	-122
z206	7511	NET387	Castello - Turati	2012/05/25 07:53:26	2012/05/25 07:53:24	-2
z206	7511	ATM90005	MONZA - ARCHIMEDES - Turati verso Ospedale S. Gerardo	2012/05/25 07:54:15	2012/05/25 07:55:54	99
z206	7511	NET283	Manzoni - Osio	2012/05/25 07:56:00	2012/05/25 07:59:42	222
z206	7511	NET315	Monti e Tognetti - Sirtori	2012/05/25 08:05:39	2012/05/25 08:10:06	267
z206	7511	ATM90001	MONZA - ARCHIMEDES - Monti e Tognetti prima di viale Battisti verso Ospedale S. Gerardo	2012/05/25 08:05:50	2012/05/25 08:10:21	271
z206	7511	NET121	Boito - Battisti	2012/05/25 08:07:01	2012/05/25 08:13:21	380

Table 2 - Progress of the bus 7511 of line z206

The meaning of the table columns is the following:

- Line: represents the line of the bus (“z206”)
- Vehicle: Bus Id (“7511”)
- StopId: represents the “Bus Stop Id”; each bus stop is uniquely identified within the system;
- Stop_Name: represents the name of the Bus Stop;
- Tstamp_Plan: Timestamp concerning the planned arrival time at the bus-stop;
- Tstamp_Real: Timestamp concerning the actual arrival time at the bus-stop;
- Delta-Time: delay of the bus detected at the bus stop with respect to the planned timestamp;

The two highlighted lines show that the time between the two stops “Manzoni-Osio” and “Monti e Tognetti-Sirtori” is too long, so a virtual stop is needed in the middle; it has been defined and its relevant data will be available by Mid June; this data will be useful for evaluation as well.

Another aspect concerning the process that is evident in the sample shown in Table 2 concerns the behaviour of the bus in terms of respect of the planned timetable. This sample is very significant for this case. The seven points along the bus route shown in Table 2 are spread along the ARCHIMEDES corridor. More in detail:

- the first stop "Mentana-Aspromonte" is before the corridor: the bus approaches this stop 122 seconds in advance.
- Just after this stop the queue originated by an important intersection start, so the second stop "Castello-Turati" is reached on time; this means that approximately in three hundreds meters the bus has lost two minutes;
- The third stop is a virtual one: its position has been chosen since the beginning of the demonstration stage to be in the middle of the queue that is present at peak hours: bus has been detected there with 99 seconds delay;
- The fourth stop is just after the critical intersection ("Largo Mazzini"); bus has been detected there with 222 second delay with respect to the planned timetable, and so on.

This example clearly show that there all good reasons to apply priority schemes for Public Transport buses.

4.5 Design and implementation of the Relational Database

A simple and effective database has been implemented to store all data collected through the webservice. This database contain the following table:

- "operations": each row contains data of every detection (one bus at one stop) for the time slot 7am – 8 pm; data is richer than those shown in Table 2: additional data present are:
    - Run: identification of the specific run of the line; in a given day, a bus leaves the depot for a mission that ends when it comes back to the depot; the mission consists of a set of runs from one end to the other of the line;
    - Tstamp_Unit: Timestamp that tell the instant when the data was produced;
    - Tstamp_Acc: Timestamp that tell the instant when the data was accessed;
    - Total-Time: time interval between the timestamp when data was accessed and bus actually was at that point; this indicator is very important to judge whether the data is "fresh" or too old to be used. This is a process issue to be managed and a concrete example will be shown in the next paragraph describing statistical analyses carried out on the data collected. In a few cases, it may happen that the connection line between the bus and the central room has been used by the driver for a phone-call for emergency reasons. In such cases the transmission of localisation data is suspended until the voice communication is completed; data collected in the mean time are then sent and this indicator is used to check if the data is too old to provide a useful update, in which case it is discarded.
- "stops": each row describe a bus stop.

More in detail, the data collected (and transposed for better understanding) is the following:

Table field	*Content*	*Description(if needed)*
id	135247	Unique record identification
timestamp_acc	2012/04/20 14:34:37.000	Timestamp when the data was accessed
response_time	406	Response time of Webservice in milliseconds
id_stop	NET283	Used as key to retrieve description data in the Table "Stops"
timestamp_unit	2012/04/20 14:34:18.000	Timestamp when the data was produced
vehicle	7511	Vehicle Id (each vehicle of the fleet has an unique number)
line	z206	Bus Line
run	20180000000020604892	Run Id
lon	9,3	Longitudine
lat	45,6	Latitude
speed	0	Speed of the bus (254 means "data not available")
direction	208	Direction of the bus (from 0 to 360 degrees)
timestamp_plan	2012/04/20 14:29:00.000	Timestamp concerning the planned arrival time at the bus-stop
timestamp_real	2012/04/20 14:30:09.000	Timestamp concerning the actual arrival time at the bus-stop
Period-of-the-day	4	(1: morning peak; 2: evening peak; 4: nopeak)
delta_time	69	Seconds between actual and planned
total_time	272	Seconds between actual and planned

4.6 Statistical analyses

Once data are stored in the database, it becomes affordable to start a detailed analysis to determine how to use them to activate priority at the intersections managed by the UTC System.

The focus of this task is to determine when to trigger the event to the UTC system; to do this, all the data made available by the AVL/AVM system has been analysed.

A first set of data is reported in Figure 8.

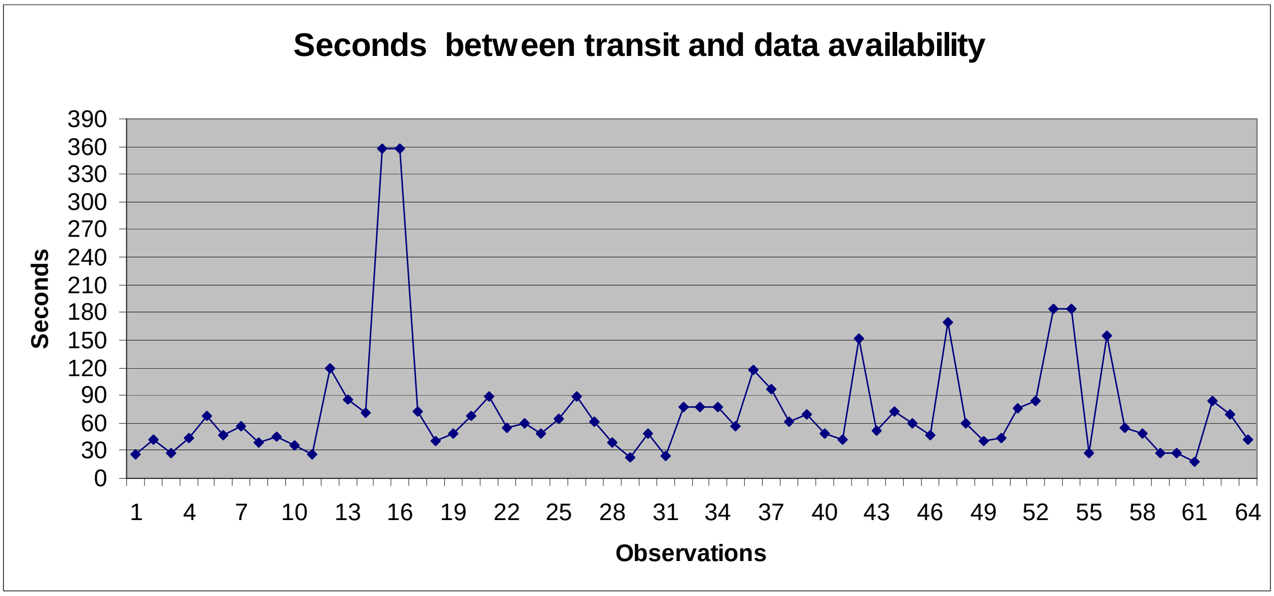

Figure 8 - First sample of data

As written in Figure 8, the "x" axis represent the number of the observation and the "y" axis the number of seconds between the transit of the bus at a bus stop and the moment in which such data is known by the first Decision Module. The expectation is that such data should be available after a fixed delay, in order to decide when to activate the trigger: if, for example, such data is available 60 seconds after the real transit, the bus stop to be considered to analyse the current will be chosen accordingly: it can't be the last bus stop before the intersection to be preferred but it should be the second last or a virtual stop created for the purpose.

The example depicted in Figure 8, extracted in April 2012, is affected by a consistent variance and can't be used to predict the arrival time; it is necessary to reduce the variance. This data has been then immediately reported to the Public Transport Company, whose AVL/AVM originated the data, asking to reduce the variance increasing under this viewpoint the performances of the AVL/AVM system.

A set of successful actions were therefore carried out, acting both on the units installed on the buses generating data and on the central software system.

The set of data shown in Figure 9 has been selected after the actions on the AVL/AVM system; it is evident that the variance has been put under control; some observations show a high value, but it may depend on the use of the carrier for voice communication between the driver and the central control room.

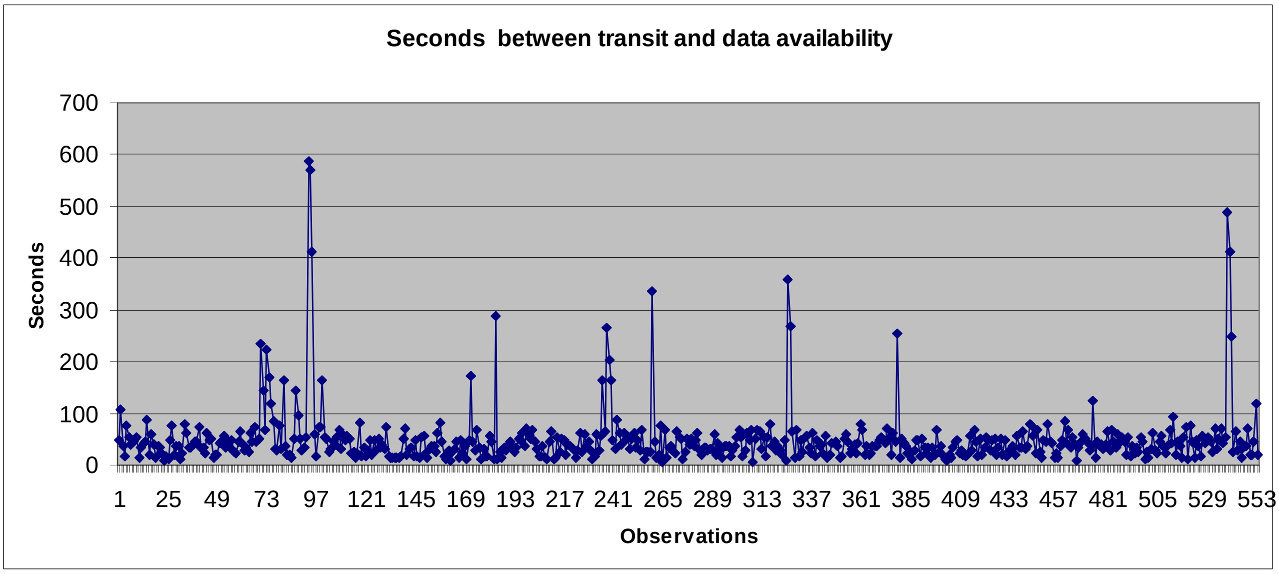

Figure 9 - Second sample of data, including outliers

Even at a fast glance, it is evident that data reported in Figure 9, excluding such outliers, are concentrated below 100 seconds.

Since the objective is to determine the number of seconds to be chosen to activate the trigger, the same sample of data except the few outliers detected is shown in Figure 10. This issue is important because if this value is too small, the traffic light plan can't be adapted in time, but if this value is too high the variance on the behaviour of buses is too large, so the action may not be effective as it will be viewed as giving unreliable data.

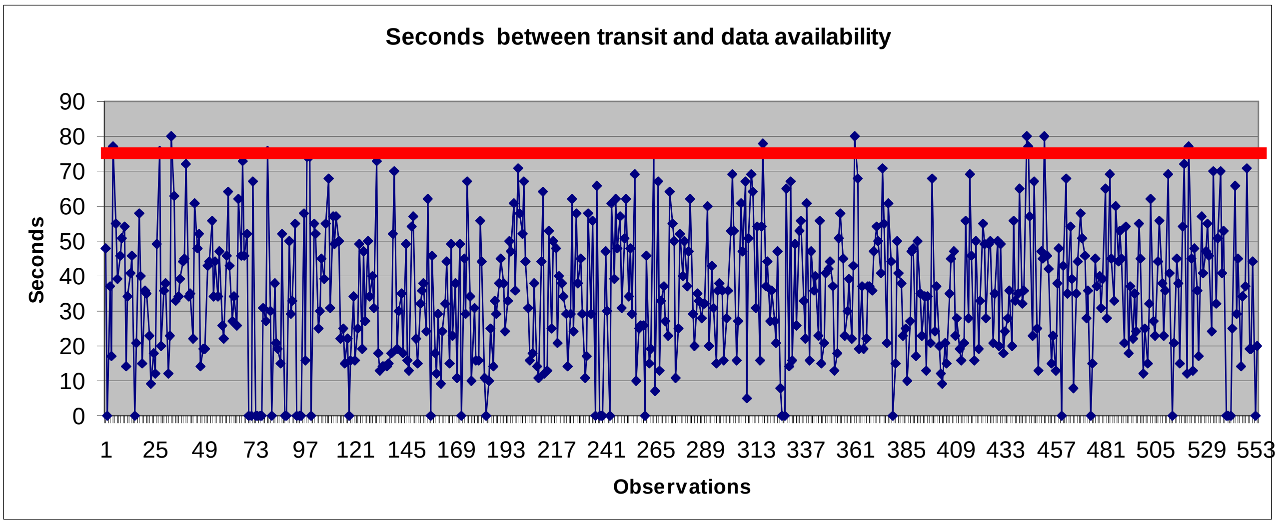

Figure 10 - Second sample of data without outliers

A relatively small variability of data concerning the seconds between the effective transit at the bus stop and the availability of such data, as depicted in Figure 10, is normal for this kind of process; an analysis on percentiles has been thus carried out on this sample as well as on other samples extracted on several days of May 2012.

The series of 90th percentile of these samples consist of values like 76, 80, 83, 74 seconds; the variability is small. The average value of the 90th percentile values is 76 seconds and this value has therefore been chosen for two purposes:

- to decide whether to accept or not the data; if a data received from the AVL/AVM is greater than 76 seconds, it will not be considered by the Decision Module 1 and it is discarded;
- to decide, for each movement at the intersections considered, which is the bus stop for which such data is to be considered.

The final, but not least, consideration concerns how to deal with the variability that is evident in Figure 10; a relevant question could be this one: what should happen when a data item from AVL/AVM is made available in few tenths of seconds? Since the action of the traffic light involved consists of increasing the green time for the movement where the bus approaches the intersection and since the bus is travelling together with other vehicles, this action will provide benefit even in these cases. The situation to be absolutely avoided is the opposite one, i.e. to extend green time to favour the movement of the bus when the trigger comes after the bus has already crossed the intersection. The choice of the threshold of 76 seconds described above ensures that this situation is avoided.

4.7 On-site experimentation

To show what has been experimented at the intersections involved, two printouts of the UTC User Interface are reported. It has to be pointed out that the threshold set in the Decision Module 1 to request a priority action has been set to 30 seconds. In normal operations and in the evaluation stage for this measure, this threshold will be set to 300 seconds (5 minutes).

The first one is reported in Figure 11.

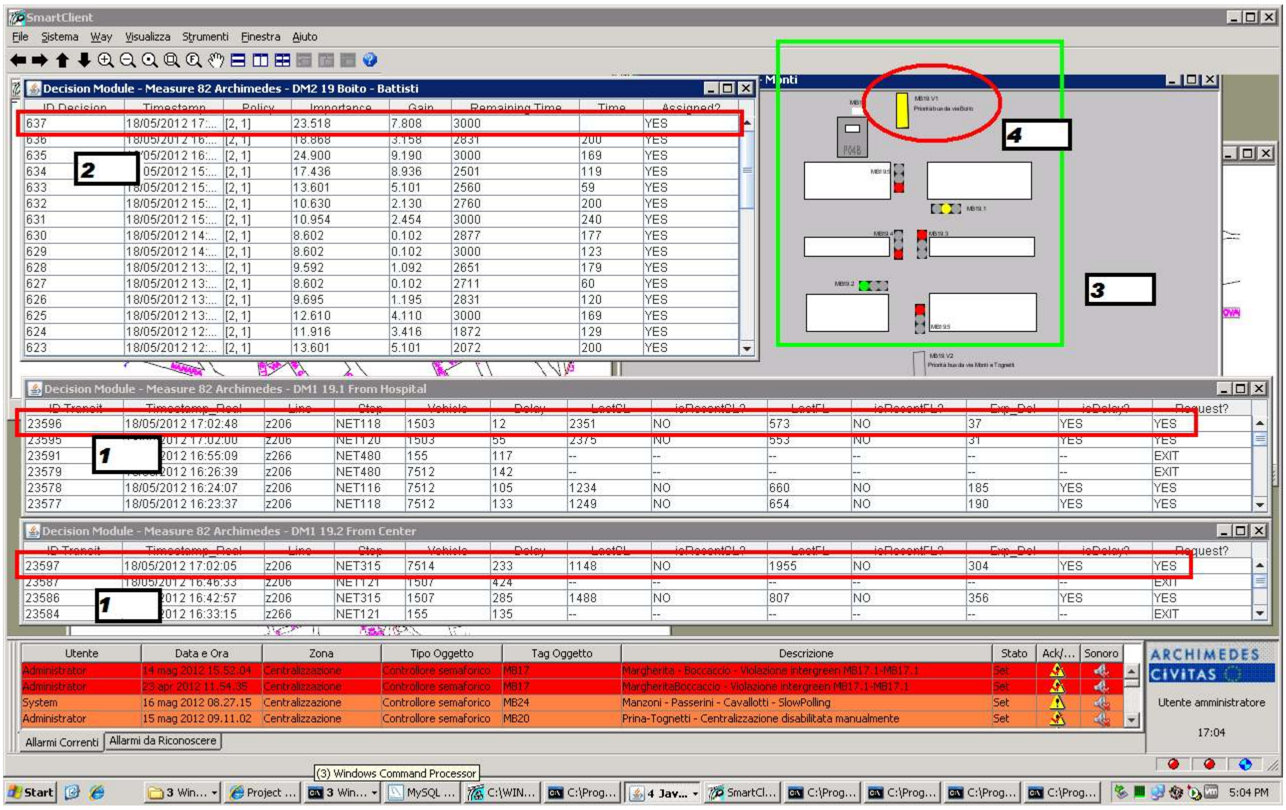

Figure 11 - UTC Roadmanager: User Interface for Priority Management: Priority Request ON

Four important elements are reported in Figure 11, and are indicated by a black number.

1. output of Decision Module 1 for two contextual requests generated approaching the intersection by two buses: the rows in the red frame show the following data (the same content like in Figure 11, reported and commented in Table 3 for the first bus):

Field	*Content*	*Description(if needed)*
ID Transit	23596	Unique record identification
Timestamp_Real	18/05/2012 17:02:48	Timestamp when the bus was catched
Line	z206	Bus Line
Stop	NET118	Bus Stop where the detection was done
Vehicle	1503	Vehicle Id
Delay	12	Actual delay
LastSL	2351	Last priority request for the same bus line (z206)
IsRecentSL?	NO	
LastFL	573	Last priority request for a “friend” bus line (e.g. z266)
IsRecentFL?	NO	
Exp. Delay	37	Expected delay of the bus at the bus-stop after the intersection
isDelay?	YES	Is the bus delayed?
Request?	YES	Has a request to be generated?

Table 3 - Output from Decision Module 1 for the request for bus no. 1503

And in Table 4 the data related to the second bus:

Field	*Content*	*Description(if needed)*
ID Transit	23597	Unique record identification
Timestamp_Real	18/05/2012 17:02:05	Timestamp when the bus was catched
Line	z206	Bus Line
Stop	NET315	Bus Stop where the detection was done
Vehicle	7514	Vehicle Id
Delay	233	Actual delay
LastSL	1148	Last priority request for the same bus line (z206)
IsRecentSL?	NO	
LastFL	1955	Last priority request for a “friend” bus line (e.g. z266)
IsRecentFL?	NO	
Exp. Delay	304	Expected delay of the bus at the bus-stop after the intersection
isDelay?	YES	Is the bus delayed?
Request?	YES	Has a request to be generated?

Table 4 - Output from Decision Module 1 for the request for bus no. 7514

2. output of Decision Module 2: the highlighted row show the following data (the same content like in Figure 11, reported and commented in Table 5):

Field	*Content*	*Description(if needed)*
ID Decision	637	Unique record identification
Timestamp	18/05/2012 17:03:17	Timestamp when the decision was taken
Policy	[2.1]	Priorità Policy related to the movement the bus comes from
Importance	23.518	Value of the importance function (*)
Gain	3	Value of the gain (**)
Remaining Time	3000	Time left for applying the preferred green; this value will be optimised during the evaluation stage
Time	-	
Assigned?	YES	The priority request has been submitted to the UTC System

Table 5 - Output from Decision Module 2

(*) The Importance function (I:R→Re+) associates to each request a real positive value which expresses how important the fulfilment of the request is; the larger the value, the more important is the request; the function used to compute the importance of a request is the square root of the expected delay of the bus at the stop after the intersection. The square root has been used to concentrate the values of delays which are used to compute the gain function: using the expected delay as it is would lead to the assignment of an excessive weight to this factor. For this case, the Importance factor takes the value 23.518, which is the sum of the square root of the values of the expected delay: $\sqrt{37} + \sqrt{304} = 6.082 + 17.436 = 23.518$.

It is straightforward to understand that two delayed buses approaching the relevant intersection whose movements are compatible can generate a higher Importance value.

(**) The Gain value is computed subtracting from the Importance factor a Cost factor, computed with the following formula:

$$C = (flow/3600 * T)^2$$

The flow value used in the formula expresses the throughput on the link affected by the priority action, i.e. the link penalised by the fulfilment of the priority action. The higher the throughput, the more penalising the priority request.

T represents the number of seconds of green time moved to the stage devoted to the bus movement(s). The greater T, the higher the cost.

Finally, the gain is computed as a weighted difference between importance and cost. This approach has been developed to allow Decision Module 2 to take a decision among possible conflicting priority requests related to the same intersection. The request or, more in general, the group of non conflicting priority requests with the highest gain will be chosen by Decision Module 2 as the ones to be fulfilled.

In the example above, the cost applies on a link with a throughput of about 1200 vehicle per hour and the duration of the green time moved from the movement of the corridor for private vehicles and the bus movement is 10 seconds (please see Figure 7, in particular the heavy green bar indicated by red arrow); thus, the cost is about $(1/3 * 10)^2$, i.e. 10. Since in the gain function the importance is weighted 1 and the cost is weighted 2, the final rounded result of gain is 3. In the evaluation stage, all these weight factors will be tuned to get the optimal results.

3. Still referring to Figure 11, Real Time synoptic view of the colours of the lamps and of detectors at the relevant intersection; the movements of the Public Transport fleet to be preferred are in the vertical direction;

4. Real Time synoptic view of the virtual detector used to inform the UTC system that a priority request to be served is active (in general terms, in the RoadManager UTC System a box represents a detector); when the box is yellow-coloured, it means that the detector is busy; should it be a real detector, e.g. an inductive loop installed beneath the pavement, it becomes yellow when a car is on it; in the case of a virtual detector like here, it is set through specific API (Application Program Interfaces) by the Decision Module 2 that acts as an external software application. Until the priority action must be active, the virtual detector is kept active.

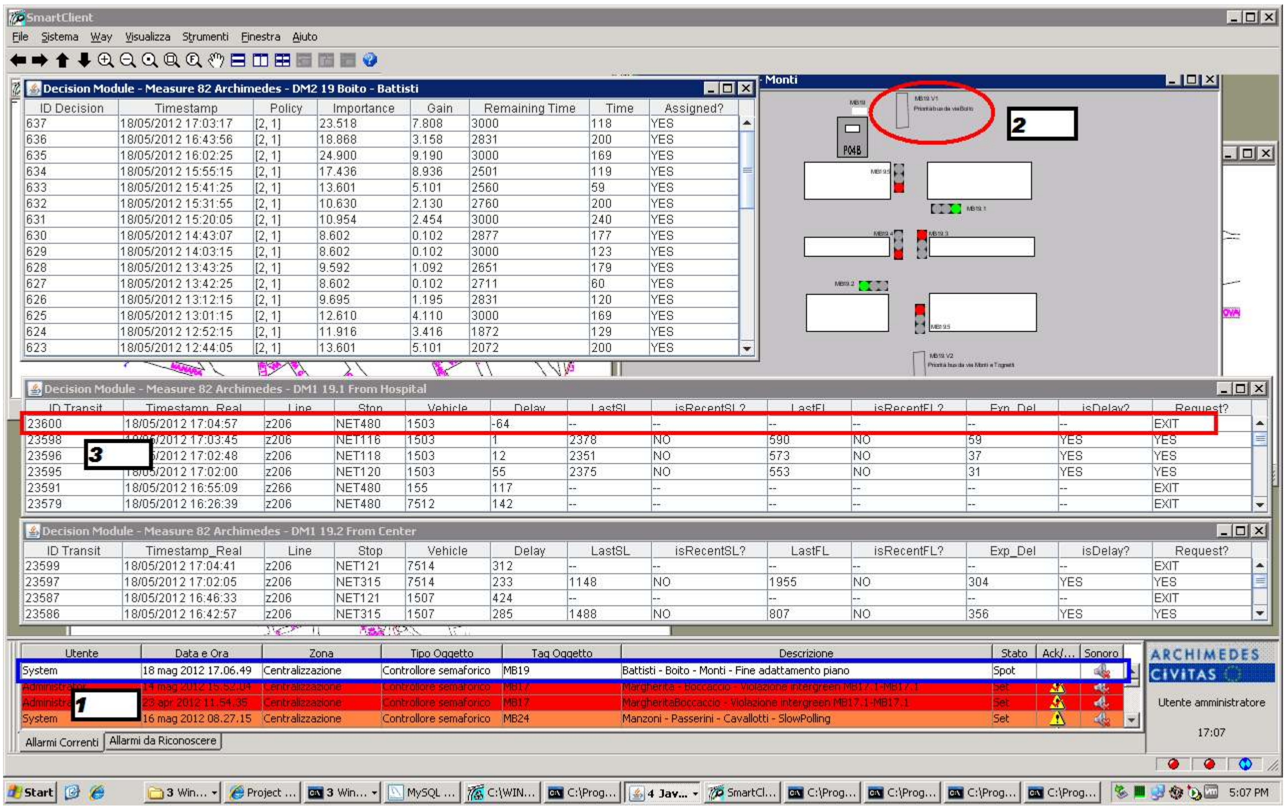

Figure 12 - UTC Roadmanager: User Interface for Priority Management: Priority Request OFF

The screenshot of the UTC Roadmanager system when a Priority action has been completed is reported in Figure 12.

The following important information are shown:

1. A system event, indicated in the white line of the table dedicated to show active alarms, tells that the priority action has been completed;
2. the Real Time synoptic view of the colours of the lamps and of detectors does no longer show the yellow colour in the box which represents the detector;

3. output of the Decision Module 1 window shows a line that tells the following information: the highlighted row shows the following data (the same content like in Figure 12, reported and commented in Table 6):

Field	*Content*	*Description(if needed)*
ID Transit	23600	Unique record identification
Timestamp_Real	18/05/2012 17:04:57	Timestamp when the bus was detected at the bus-stop after the intersection
Line	z206	Bus Line
Stop	NET480	Bus Stop where the detection was done
Vehicle	1503	Vehicle Id
Delay	-64	Actual delay (in this case the bus is now in advance with respect to its timetable)
Request?	EXIT	“EXIT” means detection at the bus stop after the intersection

Table 6 - Output from Decision Module 1 when a bus is over the intersection involved

5 Accomplishments

5.1 Main Outcomes

The application of a priority management approach for Public Transport, together with precise information on the real arrival time of buses proposed in Measure no. 79 is a good opportunity to attract more people to use Public Transport Services in Monza through improved service levels and perception of the service.

The effective collection of data relating to the movement of the buses of the fleet across the city, (which has been accomplished through measure 78,) as well as the implementation of an UTC system are necessary preconditions to carry out this measure.

5.2 Problems Identified

No functional issues have as yet been identified as problems.

5.3 Mitigating Activities

Not applicable.

5.4 Future Plans

The proposed approach, both on the conceptual and technological side, is open to the management of other Public Transport fleets operating in Monza. In particular, referring to the functional flow depicted in Figure 3, other AVL/AVM systems are used by other fleet: a software interface, based on Webservice, could be the way to feed the Decision Module 1 with priority requests originated by other fleets. Following this approach, each fleet will refer to its AVL/AVM system; only relevant information will be gathered from it if priority actions could be helpful to increase the service level.

The number of traffic lights can be extended as well: the UTC system can manage without problems the eighty traffic light controllers operating in Monza.