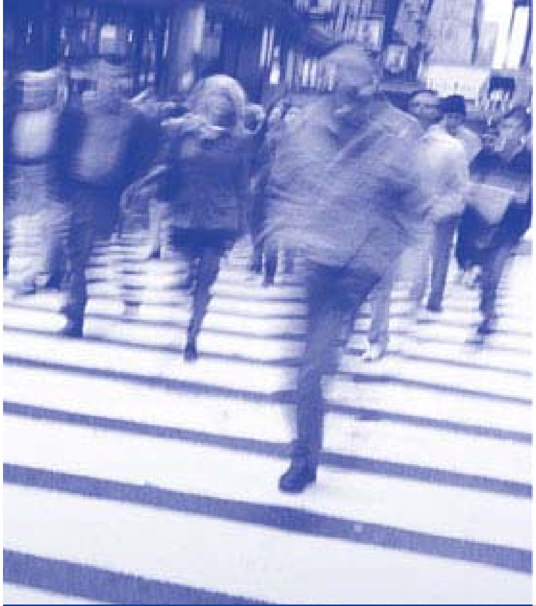

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Measure Evaluation Results

BOL 8.3 CISIUM: New Traffic Control Centre

Valentino Zanin
Giorgia De Chiara
Davide Rossi
(TeMA Territorio Mobilità Ambiente S.r.l., municipality of Bologna consultant for the measure evaluation)

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Executive Summary

The new traffic control centre of Bologna (CISIUM) was part of a general strategy implemented by the Municipality in recent years to optimise traffic management. The centre was already in service at the launch of MIMOSA project. CISIUM is connected and integrated to the Intelligent Transport System (ITS) of the Municipality. The main work achieved at the centre are the centralization of real-time traffic information collected by several and diverse tools, the treatment and analysis of the information and the implementation of strategic actions to achieve optimal real time traffic management on the city scale. For instance, most of the traffic lights in the city are controlled from the centre. One of the objectives of CISIUM is to solve traffic congestion problems, with a specific focus on improving quality of Public Transport (PT) services in terms of regularity.

The MIMOSA measure 'CISIUM: New Traffic Control Centre' aimed at improving the traffic control in the urban area, to transmit real-time information to users and to elaborate more efficient traffic planning tools. To reach these objectives, focused activities were conducted in order to improve CISIUM's efficiency, to fine-tune traffic models and scenarios, to provide real-time information to road users and finally to assess an evaluation of the achieved activities. The measure was implemented in the following stages:

Stage 1: Software refining (Oct 08 – Oct 09) The first activities carried out to optimize the CISIUM system concerned the improvement of the existing software and the elaboration of an interaction database software which collects, treats and transmits real-time traffic information on site (traffic light system, public transport time, etc)

Stage 2: Traffic Monitoring and parameter tuning (Oct 08- 2012) A new mathematical algorithm for congestion detection was implemented in CISIUM, based on treatment of data provided by the bus control centre and by traffic lights connected to the system. In 2011 Bologna signed an agreement with Google to provide traffic data for publication on the Google traffic service. Bologna was the first city in Italy to provide this service. Finally, the Municipality of Bologna signed an agreement with Bologna Airport in order to provide information panels at the airport arrivals terminal.

Stage 3: Testing and calibration (Feb 2010 – 2012) This stage started during stage two, where several tests and adaptations of the software developed during the previous stages were conducted based on site test, simulations, statistical analysis and real-time information transfer test.

Stage 4: Dissemination activities (2012) A new webpage was launched to provide citizens with real time information on traffic conditions and traffic events; a press conference was held to explain the features of CISIUM.

Because of the expected positive results, this measure was selected as focused measure and in addition to the impact and process evaluation, a cost-benefit analysis (CBA) was conducted. Thereby, the evaluation strategy of this measure sought to focus only on transport indicators such as the BPR curve analysis (Bureau of Public Roads), a method for predicting vehicle delay as a function of volume/capacity ratio in travel demand models. This indicator provided inputs for congestion measurement, measuring the effectiveness of the CISIUM junction management. Moreover, the degree of PT regularity was used as indicator to verify the benefits of the measure on the PT service quality.

The key results of the impact evaluation of the Measure were:

- a general improvement in traffic conditions thanks to each of the CISIUM actions (crossings managed by CISIUM);

- enhanced bus prioritisation at traffic lights. This led to shorter travel times on the bus routes measured in the data, with a reduction in delays and an increase in slightly early bus departures.

The CBA showed how overall the system was producing benefits for the part of the network analysed in terms of saved time. Benefits were estimated with two different approaches for economic evaluations; in both cases the Net Present Value calculations gave positive results.

Several barriers were encountered during the Measure implementation stages. Firstly, different systems' sources of data often gave discordant results: input data was not always homogeneous. This required technical testing and tuning for the system which required more time and resources than initially planned. Secondly, some software modules did not respond to the specific requirements due to the insufficient competences of the providers in transport issues. Finally, the last local electoral campaign which took place in May 2011 made the implementation of the measure difficult, since the measure did not receive political support during this period. These tree barriers slowed down the deployment process for the communication module on real time traffic information.

On the other hand, the Municipality benefitted from the fact that other IT systems utilized CISIUM information. This overlapping condition increased local technicians' knowledge and allowed new features for the system. Another positive event which stimulated the achievement of the measure objectives was the new Italian project called SIMONE. Thanks to it a public bid was published for the management of floating car data. This **driver** improved the overall system.

For the cities interested in these types of measures it is highly recommended to consider in advance that a large portion of the urban network must be involved in the project (as in Bologna) in order to obtain significant benefits. Otherwise, the lack of control over areas where the centre is not operative will outweigh the benefits of the project.

CISIUM helped to reduce traffic congestion problems, with a specific focus on improving the quality of Public Transport services in terms of its regularity. As the results of the system are positive, activities to further improve the system will be carried out after the end of the MIMOSA measure.

A Introduction

A1 Objectives

The Measure objectives were:

(A) High level / longer term:

- To improve the efficiency of the transport system

(B) Strategic level:

- To develop innovative Transport Telematic Systems

(C) Measure level:

(1) To improve traffic control in the urban area

(2) To provide the public with real-time traffic information through different channels

(3) To provide the Municipality's technicians with better traffic planning tools

A2 Description

Measure 8.3 was part of the Municipality of Bologna's general strategy to improve traffic conditions, particularly for the PT service (buses), by optimising traffic management. Bologna's public transport service is provided by ATC/TPER. In 2010 the service included 46 urban routes and 3 shuttle buses and covered around 18,500,000 Km. The total passengers per year were round 94,500,000, with 55,000 yearly season tickets.

The Traffic Centre connected and integrated the city's Intelligent Transport Systems to facilitate optimal real time traffic management. The main features were:

- traffic lights management, with a global supervisor system connected to an Automatic Vehicle Monitoring (AVM) centre for public transport, in order to guarantee priority for buses;
- an advanced real time traffic monitoring and modelling system which helped traffic managers to better understand traffic conditions and to quickly respond to improve congestion. The number of sensors and traffic lights connected to the centre was increased to cover 75% of the instruments available on site. Controls began for 33 new intersections, and more than 400 inductive loops, 5 tracking route devices for vehicles and 24 more Variable Message Signs were added, as were interconnections with ITS systems and 8 traffic flow sensor stations;
- online dynamic traveller support information via Variable Message Signs, Internet, text messages, in-car satellite navigation, etc. The aim was to reach the majority of users and identify the best route/means of transport for the public.

CISIUM was already funded outside the CIVITAS Initiative and its development was underway. Within CIVITAS MIMOSA improvements to the new traffic control centre were completed. Several activities were designed to connect and integrate various intelligent transport systems and facilitate optimal real-time traffic management.

All activities were carried out with the aim of providing real time information both for technicians *and the general public*.

Activities included: (i) fine-tuning of traffic models and scenarios, (ii) an evaluation analysis and (iii) a publicity campaign for road users.

A detailed scientific study analysed traffic models and scenarios. This was followed by analyses of traffic models and algorithms to define several technical aspects within the framework of CISIUM. A study was made of the Traffic Message Channel (TMC) protocol. TMC technology is used to display traffic news on enabled devices. Information is transitted on FM radio frequencies through the RDS channel, and uses the TMC protocol, which defines the codification rules. The Intelligent Transport System was developed using these insights. The control centre entered an extensive testing period, during which bugs and other issues were addressed and the algorithm was fine-tuned. Parameter tuning remained an ongoing task.

A number of innovative communication tools were deployed (messages on real time traffic situations for car radio and on-board satellite navigators, and for other traffic operators such as the Highways control centre). Variable message signs in the city were divided in 3 groups/zones: each sign displayed two fixed messages (common to all signs) and two variable messages, specific to each zone. In addition, Municipality technicians designed a project to integrate traffic flow data from the traffic control centre into Google maps. The necessary software was developed and the city signed an agreement with Google. As a result, Bologna was the first city in Italy to provide a traffic service on Google maps.

Another important activity was the construction of a detailed database of traffic scenarios in different areas (according to time bands, special events or meteorological conditions). The new traffic model made for better planning of road modifications in order to promptly react to unexpected congestion.

A new dedicated webpage was launched http://cisium.webhop.net/home.do to provide the public with real time information on traffic conditions and traffic events. A press conference was held to present the features of CISIUM.

B Measure Implementation

B1 Innovative Aspects

The innovative aspects of the Measure were:

- **New conceptual approach**. In order to identify traffic congestion as soon as it happens, CISIUM was given a 'traffic scenario characterization' tool. This helped recognise congestion immediately and optimise traffic lights.
- **Use of new technology/ITS**. Real time tools improved the traffic control strategy. The recent upgrade of the traffic control centre added several innovative features, such as real time communications. Vehicle tracking via a satellite positioning system was also introduced and tested in some prototypes to improve traffic modelling.
- **New organisational arrangements or relationships.** Municipality technicians designed a project to integrate traffic flow data from the traffic control centre into Google maps. The necessary software was developed and the city signed an agreement with Google.

B2 Research and Technology Development

RTD activity included a study carried out entirely by the Municipality of Bologna, aimed at: i) collecting and analyzing all traffic data, ii) analyzing the algorithm for traffic congestion calculations using information provided by traffic lights and Public Transport data, iii) defining performance indexes in order to redesign the CISIUM system and to define functional models.

During the RTD activity a new set of indexes was elaborated in order to evaluate the system:

delay index = average individual delay/traffic lights cycle duration. The indicator distinguishes whether a delay is due to a single traffic light cycle or whether it is accumulated from more than one cycle. Therefore the driver is obliged to "stop and go" several times;

filler index = average queue/max acceptable queue, where the max acceptable queue is a configuration movement parameter defined using the topological UTOPIA software database (Urban Traffic Optimisation by Integrated Automation);

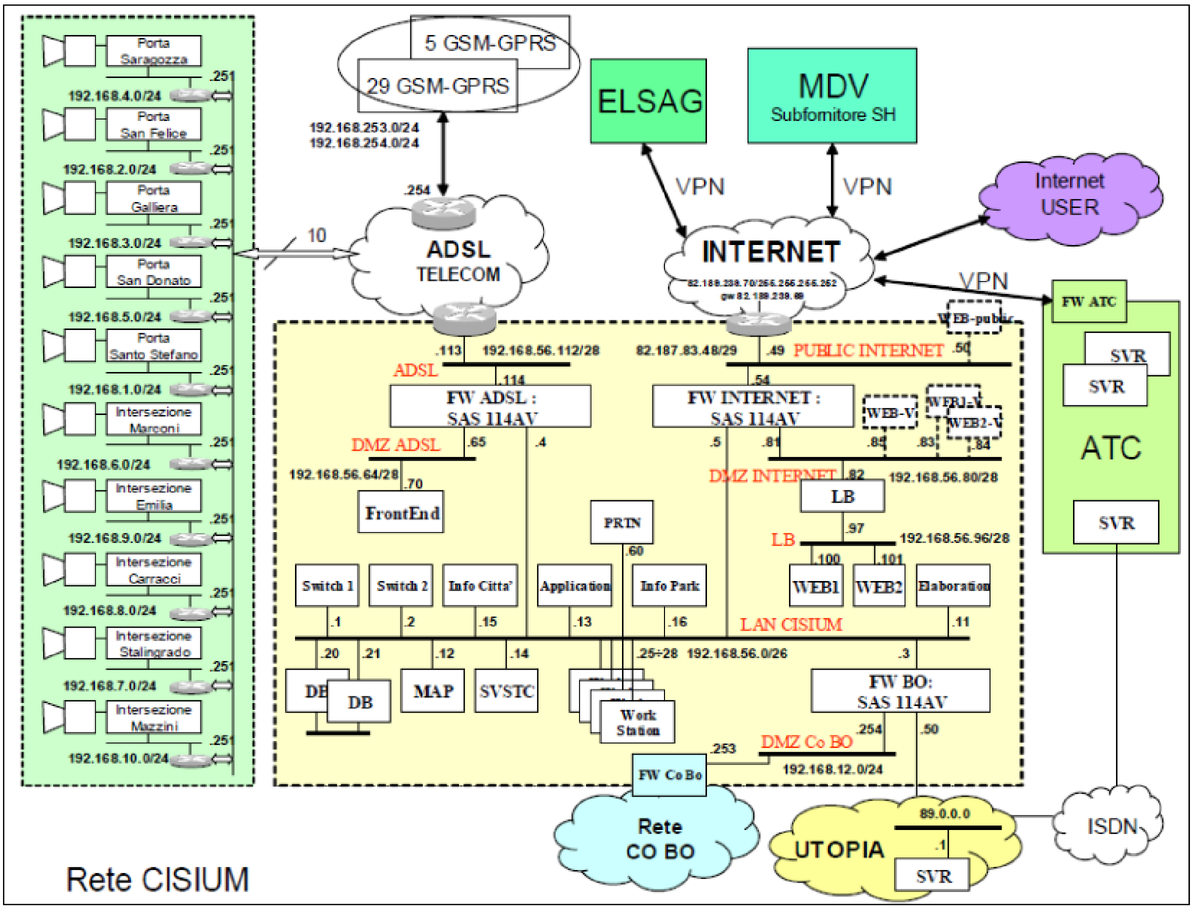
congestion index = total time in saturation/traffic light cycle duration, where total time in saturation conditions is when the instantaneous queue is greater than the max acceptable queue;

control effectiveness = average individual delay/average individual BPR delay (Bureau of Public Roads), a method for predicting vehicle delay as a function of volume/capacity ratio in travel demand models.

The tender specifications for the CISIUM upgrade summarized the main features studied, representing the technical specifications of the supply as follows:

- new loop detector and coil specifications. Loop detectors and coils to be connected to traffic lights;
- interface unit to extract data in order to populate the Municipality's cartographic database;
- new servers to optimize the telecommunications network;
- variable message signs to replace existing ones.

FIGURE B2.1: CISIUM network



Source: Municipality of Bologna

The technological aspects learnt and developed during the analysis were summarized into the working plan, the technical document showing all interventions developed during the design phases.

B3 Situation before CIVITAS

The core features of the CISIUM system were implemented outside the MIMOSA project.

The MIMOSA measure included fine-tuning for the system, consisting of an in-depth study of all real time processes and a consequent regulation of parameters. The system needed to become more *user oriented*, providing real-time traffic information for each road user through different channels.

B4 Actual Implementation of the Measure

The Measure was implemented in the following stages.

Stage 1: Software refining *(Oct 08 – Oct 09)*

Software refining, bug solving, data configuration relating to:

- cartography,
- traffic light topology and indicators (traffic flows, queues, etc.)
- subsystem integration,

- variable message signs,
- PT travel times.

Stage 2: Traffic Monitoring and parameter tuning *(Oct 08- 2012)*

Identifying traffic scenarios, designing algorithms for congestion detection:

- After a long test period, all minor bugs were solved and the accuracy of the algorithm was proved before implementation. Fine- tuning of CISIUM continued, focusing in particular on:
  - writing software for the exchange of data with Google Traffic;
  - configuring Geographic Information System data in the urban traffic vector cartography;
  - integrating the software into the variable message panel control;
  - checking/tuning the correlation algorithm between private vehicle information and public transport information;
  - checking/tuning the congestion detection algorithm, representing the real status of the network;
  - testing the website and travel planner;
  - checking subsystem connections;
  - developing new software for detecting accidents and road works in the traffic management algorithm;
  - implementing new web services to interconnect the traffic control centre and other external systems.
- A new algorithm was implemented in CISIUM. The two new main features consisted of:
  - modification of data provided by the bus control centre. The new module was based on delays to buses in relation to the timetable; the variation in delays per bus on each road gives information about congestion. This data was classified into several thresholds which were set and tuned using information provided by the bus operator.
  - modification of data provided by traffic lights. The new module was based on the new traffic index provided by traffic lights. Instead of the queue index used previously, the Municipality of Bologna adopted the delay index, that is, the average of vehicle waiting times at each traffic light. Once it has been set and tested, this data is more accurate than the previous one.
- In 2011 Bologna signed an agreement with Google to provide traffic data for publication on the Google traffic service; Bologna was the first city in Italy to provide this service.
- In 2011 the Municipality signed an agreement with Bologna Airport to provide information panels at the airport arrivals terminal, with information on traffic and road works.
- A public bid was published for the management of floating car data (outside MIMOSA, as part of the Italian project SIMONE); it was awarded in September 2011. The object was to increase the size and location of detection systems, reducing the number of infrastructures needed and improving the timeliness and significance of the information provided.

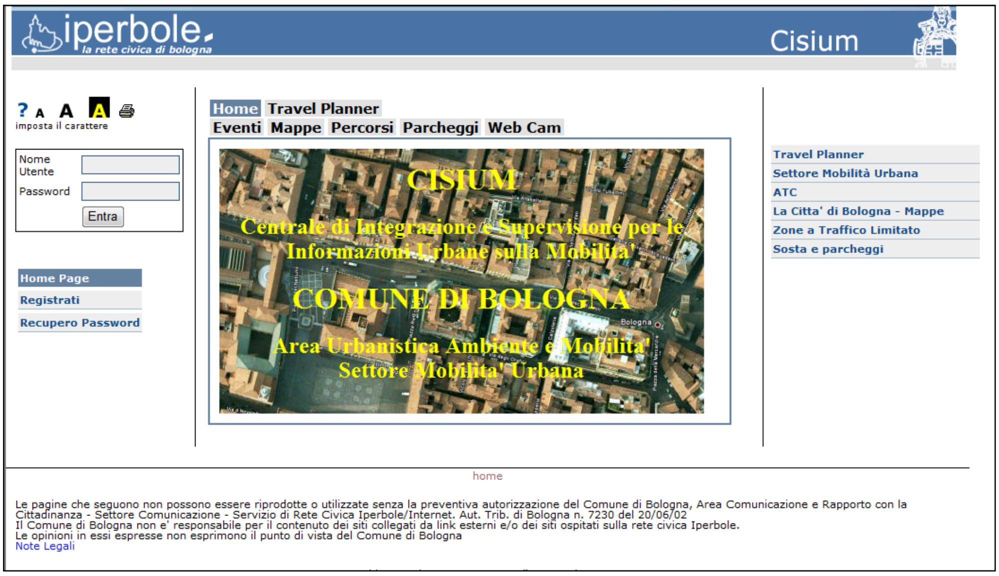
Stage 3: Testing and calibration *(Feb 2010 – 2012)*:

- The system was compared on road and desktop tests, statistical analysis were carried out.

Stage 4: Dissemination activities *(2012)*:

- as part of the Italian project SIMONE, a conference was organized in April 2012 to present the new features of CISIUM;
- a new dedicated webpage was launched http://cisium.webhop.net/home.do (Figure B.4.1) to provide the public with real time information on traffic conditions and traffic events.

FIGURE B4.1: The new CISIUM webpage



B5 Inter-Relationships with Other Measures

The focus of Measure 8.3 was part of the Municipality's general strategy to improve urban traffic conditions. The Measure may therefore be considered in a more general context which also includes the effects of Measure 8.2 (regarding the effect of illegal parking on PT timekeeping). However, the two measures acted on different aspects: 8.2 acted on driver behaviour, with results seen in the long term; 8.3 acted in real time, considering congestion and its effect on Public Transport. In addition the two measure domains were different: Measure 8.2 only applied to some PT routes, whereas CISIUM checked the whole of the network in Bologna to optimize total traffic fluidity. Therefore there are no bundled indicators to be considered.

Other projects outside MIMOSA had inter-relationships with this Measure:

- The European SMART IP Project, which aimed to make CISIUM services and tools more functional and practical from the public's point of view, using a participatory approach.
- The Italian SIMONE Project, as part of which a public bid was awarded for the development of a third congestion indicator, helping to estimate congestion levels more accurately.

C Impact Evaluation Findings

C1 Measurement Methodology

C1.1 Impacts and Indicators

This Measure was designed to improve the general efficiency of Bologna's transport system, using an innovative IT transport System. Therefore, the improvement of traffic control was measured using the BPR curve, indicator 4 (see description below), since BPR improvements showed optimizations on the road network capacity both for private vehicles and public transport.

In addition, the Measure was expected to enhance public transport by prioritising buses, as measured by analysing the accuracy of PT timekeeping (indicator 1). A reliable service minimizes waiting times at bus stops. It is very important in urban networks, where the interchange is an essential element for providing the best service extension in the city. At the beginning of the project, the Municipality had planned to use other indicators as the basis for this impact evaluation: average peak PT speed and average off-peak PT speed (indicators 2 and 3). Nevertheless , these effects were not evaluated due to CISIUM operation and approximations (see part D1).

The Measure was designed to offer traffic managers a tool and planning instrument for traffic scenarios and recurring congestion (objective 3). This tool was represented by CISIUM itself, considering its activation and functioning.

Finally, real time traffic information for the general public (objective 2) was guaranteed by the new tools provided by CISIUM (Google, information panels, etc). The effectiveness of these tools should have been verified by involving the public. Considering the complexity of the system and the difficulty of finding 'skilled' road users, public surveys were not planned. This was a limit of the evaluation which characterizes similar measures with a high level of complexity.

TABLE C1.1.1: 8.3 Measure Indicators

Indicator	Evaluation area	Evaluation category	Impact	Indicator	Source of data
1	Transport	Quality of Service	Service reliability	Accuracy of PT timekeeping	Bus fleet control centre/ survey before/after
~~2~~ (*)	~~Transport~~	~~Quality of Service~~	~~Quality of Service~~	~~Average speed – peak~~	~~Bus fleet control centre/ survey before/after~~
~~3~~ (*)	~~Transport~~	~~Quality of Service~~	~~Quality of Service~~	~~Average speed – off peak~~	~~Bus fleet control centre/ survey before/after~~
4	Transport	Transport system	Delay times	BPR	On road sensors

(*) For deleted indicators see: Deviations from the original plan

Detailed description of the indicator methodologies:

- **Indicator 1 'Accuracy of PT timekeeping'**. In order to compete effectively with private transport, PT must enhance the quality of the transport service, first of all its reliability. PT passengers must be able to rely on the scheduled arrival and departure times in order to plan their journeys with confidence and make connections without unpredictable waiting times. This means that the public transport service should neither depart earlier than is stated on the timetable nor arrive later than a couple of minutes from the time stated on the timetable. Accuracy of timekeeping was defined as the number and percentage of public transport services arriving within an acceptable interval of the times stated on the timetables. The term of reference was the Service Contract signed between the Municipality and the transport company.

The analysis looked at the most important routes by passengers and distances covered. Their services covered the main roads leading into the centre of Bologna.

This indicator accounted for the real (not perceived) reliability of arrival times of public transport services at PT stops and stations.

Unit: number and % of the total arrival times per year that were within a given interval of the time shown in the timetable. Data was collected each year the Measure was in force.

- **Indicator 4 'BPR'** – This indicator provided input for congestion measurement, measuring the effectiveness of CISIUM junction management. It was a measurement of the theoretical delay due to private vehicles waiting their turn to clear the intersections (1).

  BPR (Bureau of Public Roads) is a method for predicting vehicle delay as a function of volume/capacity ratio in travel demand models. The BPR function represents the average delay experienced by a vehicle crossing a traffic light in the Municipality of Bologna: the time spent by a vehicle at a crossing grows with the increase in traffic flows. The curve was extracted by an interpolation of values of delay which occurred to a certain flow (registered by coils for every traffic light in the CISIUM project). The curve represents values averaged from all crossings, at different times and on days of each quarter of the year.

  Unit: average travel times. Data was collected for every quarter of each year the Measure was in force. Data is shown considering the 4th quarter of each year, when the highest volumes are observed.

C1.2 Establishing a Baseline

As all indicators defined above were continuously monitored and stored in the IT system, a set of historical data was available to compare results after the Measure implementation. Thus the starting point for these parameters was assumed to be the situation before the Mimosa project began (October 2008), even though it does not correspond to the start of the CISIUM project. In 2008 MIMOSA resources where added to the system implementation in order to make it more effective and customer oriented.

'Accuracy of PT timekeeping' The baseline is October 2008. Accuracy of timekeeping was defined as the number and percentage of public transport services arriving within an acceptable interval (-0:29/4:29) of the times shown on the timetables. Data was sourced from the bus fleet control centre. Data on public transport arrival times was divided into 5 time bands, following the Service Contract between the bus operator and the Municipality. 53 bus routes were observed and 45.8% of the 192,698 scheduled journeys were monitored. Data was organized into different timekeeping tables concerning road crossings and time bands.

'BPR curve' The baseline is the 4th quarter of 2008, the last quarter before MIMOSA implementation. It evaluated the theoretical delay due to private vehicles waiting their turn to clear an intersection, providing a good input for congestion measurement.

C1.3 Building the Business-As-Usual Scenario

In order to evaluate the traffic enhancement expected under the Measure, the Business as usual scenario was analysed considering historical data and evaluating what would happen without CISIUM or what was happening where its information was not yet available.

Bus prioritisation at traffic lights was not applied to the whole of the Public Transport network. Therefore the original idea for building the BAU for indicator n.1 was to consider PT routes where CISIUM was not applied (control lines approach). However, this approach was dropped because every bus route had its own characteristics: traffic conditions, road geometries, number of passengers served. It was very difficult to find comparable lines and there was a risk of influencing the results.

With reference to indicator n. 2 (BPR), it should be considered that the curve represented an average value obtained from experimental data. Its values were experimental, obtained by real data related to flows and delays recorded during the period. Since it was impossible to build a new curve as an interpolation of new hypothesized points or by considering new parameters for curve behaviours (the individual curves hardly varied), it was decided to refer to BPR from the 4th quarter of 2008 (not influenced by the Measure).

C2 Measure Results

The results are presented under the sub heading 'transport' since indicators from other areas were not chosen.

C2.1 Economy

Not applicable

C2.2 Energy

Not applicable

C2.3 Environment

Not applicable

C2.4 Transport

Indicator 1 "Accuracy of PT timekeeping" The following tables show the Measure results for 2008, 2009, 2010 and 2011. Comparisons and comments are given below.

Differences between years show a slight improvement in PT regularity, with particular reference to comparisons between 2008 and 2009, and relatively constant values in the last two years. In general data shows that punctuality slightly decreased but in a *not perceptible way*. Delays were reduced and the slight advances increased. This meant the traffic control system improved traffic conditions and reduced journey times. A new Public Transport schedule is required.

TABLE C2.4.1: PT Timekeeping: results 2008-2009-2010-2011

PT Timekeeping	2008	2009	2010	2011
Wide advance (> -2:30)	4,50%	4,20%	5,30%	7,32%
Slight advance (-2:29 / -0:30)	13,70%	13,70%	14,50%	17,22%
Punctual (-0:29 / +4:29)	58,10%	62,40%	57,80%	57,04%
Delay (+4:30 / +10:29)	18,10%	16,30%	17,30%	15,00%
Wide delay (> +10:30)	5,60%	3,30%	5,10%	3,42%

Source: Bus fleet control centre

TABLE C2.4.2: PT Timekeeping: results

PT Timekeeping	**Pre Mimosa** baseline = BaU (2008)	**Mimosa** (2011)	Δ
Wide advance (>-2:30)	4,50%	7,32%	+2,82%
Slight advance (-2:29/-0:30)	13,70%	17,22%	+ 3,52%
Punctual (-0:29/4:29)	58,10%	57,04%	-1,06%
Delay (4:30/10:29)	18,10%	15,00%	-3,1%
Wide delay (>10:30)	5,60%	3,42%	-2,18%

Source: Bus fleet control centre

Significance test: considering the chi-squared test, the reported differences between before and after Mimosa data can be considered statistically significant with a significance level of 1%. This means that there is probability of 99% of rejecting the true null hypothesis (difference = 0%) as true.

The results of the test are $\chi 2$= 29.962,148>13,277; Degree of freedom = 4. The high results obtained in the test were due to the high number of values considered (each year there were more than 1 million arrival times for public transport services at PT stops and stations) In general these tests are applied to smaller samples; in this case the significance could have been directly assumed.

TABLE C2.4.3: PT Timekeeping (punctual) in time bands: results 2008-2011

PT Timekeeping in time bands	**2008**	**2009**	**2010**	**2011**
	Punctual			
First shift (< 6:59)	65,2%	69,0%	64,5%	63,3%
Morning peak hour (7:00/8:59)	59,6%	61,3%	56,6%	56,2%
Morning off-peak hour (9:00/12:29)	54,3%	59,5%	53,6%	55,1%
Noon peak hour (12:30/14:29)	59,7%	64,3%	60,7%	57,9%
Noon off-peak hour (14:30/16:29)	62,5%	67,5%	62,9%	60,8%
Afternoon peak hour (16:30/19:29)	54,5%	60,0%	55,2%	55,5%
Last shift (> 19:30)	59,4%	63,7%	59,8%	56,8%

Source: Bus fleet control centre

TABLE C2.4.4: PT Timekeeping (punctual) in time bands: results

PT Timekeeping in time bands (punctual)	**Pre Mimosa** baseline = BaU (2008)	**Mimosa** (2011)	**Difference**
First shift (< 6:59)	65,2%	63,30%	-1,90%
Morning peak hour (7:00/8:59)	59,6%	56,20%	-3,40%
Morning off-peak hour (9:00/12:29)	54,3%	55,10%	+0,80%
Noon peak hour (12:30/14:29)	59,7%	57,90%	-1,80%
Noon off-peak hour (14:30/16:29)	62,5%	60,80%	-1,70%
Afternoon peak hour (16:30/19:29)	54,5%	55,50%	+1,00%
Last shift (> 19:30)	59,4%	56,80%	-2,60%

Source: Bus fleet control centre

Significance test: for high sample values like those measured in PT timekeeping, the significance can be directly assumed.

TABLE C2.4.5: PT Timekeeping (punctual) for main roads. Results 2008 - 2011

Road	**2008**	**2009**	**2010**	**2011**
	Punctual			
Barca-Andrea Costa	61,50%	63,60%	58,40%	57,20%
Corticella	60,10%	62,70%	55,40%	59,80%
Emilia levanter	53,70%	56,50%	53,10%	44,90%
Emilia ponente	57,30%	64,50%	61,40%	58,80%
Massarenti	58,50%	62,70%	57,90%	58,60%
San Donato	59,10%	64,60%	60,10%	60,60%
Saragozza	56,70%	58,40%	54,70%	53,30%
Murri-Toscana	58,60%	65,10%	62,60%	60,10%
centro storico	58,90%	63,60%	57,50%	57,20%
viali nord	57,10%	63,00%	59,20%	58,80%
viali sud	56,30%	60,00%	52,40%	55,60%

Source: Bus fleet control centre

TABLE C2.4.6: PT Timekeeping (punctual) for main roads

Road	**Pre Mimosa** baseline & BaU (2008)	**Mimosa** (2011)	**Difference**
Barca-Andrea Costa	61,50%	57,20%	-4,30%
Corticella	60,10%	59,80%	-0,30%
Emilia Levante	53,70%	44,90%	-8,80%
Emilia Ponente	57,30%	58,80%	+1,50%
Massarenti	58,50%	58,60%	+0,10%
San Donato	59,10%	60,60%	+1,50%
Saragozza	56,70%	53,30%	-3,40%
Murri-Toscana	58,60%	60,10%	+1,50%
centro storico	58,90%	57,20%	-1,70%
viali nord	57,10%	58,80%	+1,70%
viali sud	56,30%	55,60%	-0,70%

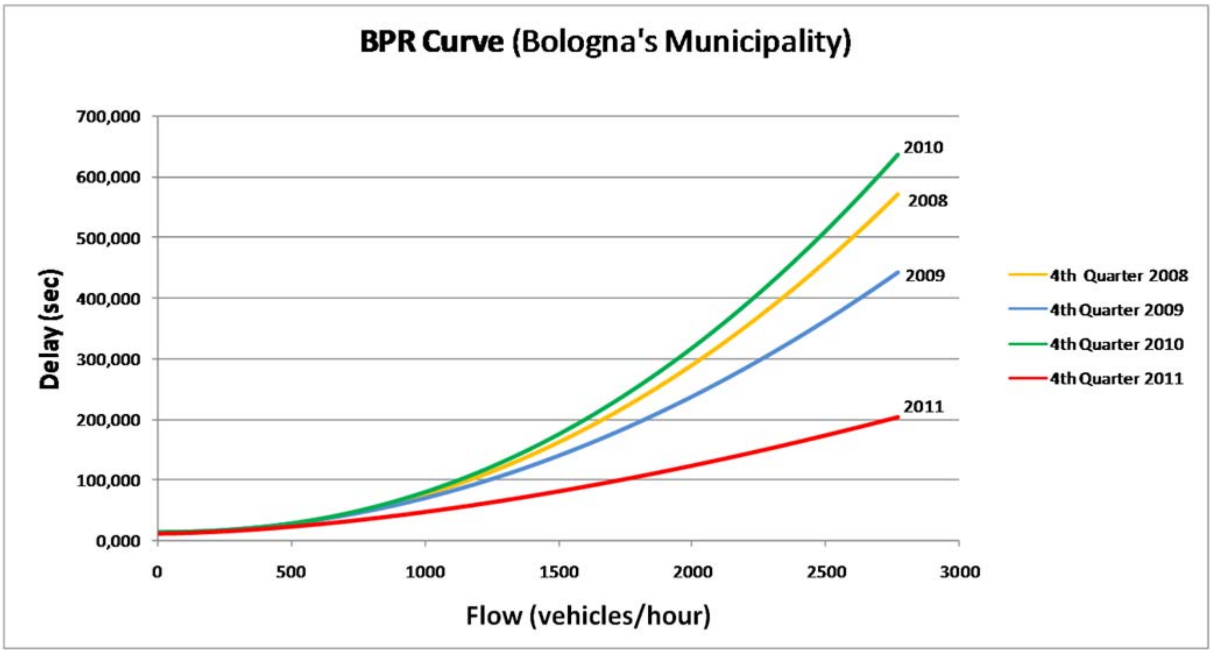
Source: Bus fleet control centre

Significance test: for high sample values like those measured in PT timekeeping, the significance can be directly assumed.

Traffic light management helped improve public transport traffic conditions. This can be seen from the reduction in delays and the increase in buses arriving early (see TABLE C.2.4.1). On the other hand, the number of on-time buses did not change substantially, with increases or reductions in punctuality at different times and on different monitored road sections. Therefore, a new Public Transport schedule is required to reformulate PT times based on new journey times. PT timekeeping values could be modified with a new PT schedule. Tables from C.2.4.3 to C.2.4.6 describe in detail the behaviour of public transport considering time bands and the main street of the Municipality.

Indicator 4 'BPR'. Annual BPR results (4th quarter of each year) are shown in the graph below. These curves associate the average delay at traffic lights with the incoming flow at the same traffic light.

FIGURE C2.4.1: BPR indicators detail 2008-2010-2011



	Before – BaU (2008)	2009	2010	After (2011)
t0	13,81523	13,37104	13,57076	12,51637
a*	37,9596	35,96568	40,33530	24,36748
b*	2,16114	1,99556	2,20346	1,6544

Source: Municipality of Bologna

TABLE C2.4.7: BPR indicators differences 2008-2011

	Before – BaU (2008)	After (2011)	Differences	Δ %
t0	13,81523	12,51637	-1,29886	-9,4%
a*	37,9596	24,36748	-13,59212	-35,8%
b*	2,16114	1,6544	-0,50674	-23,4%

Source: Municipality of Bologna

* Parameter "a" determines the ratio of free-flow travel time to the travel time at capacity; "*b*" determines how abruptly the curve rises from free-flow travel time.

BPR data recorded after the implementation of the Mimosa Project did not show the benefits of CISIUM for the first 3 years 2008-2010 (BPR curve trends did not change substantially). As shown in Graph C.2.4.1, the curves only changed for flow values over 500 vehicles. The first benefits were seen from 2011 onwards, where delays were reduced for high volumes of traffic flow. For any detail about BPR curve see References point (1).

There were several different reasons for these results, possibly related to driver behaviours, road characteristics and boundary conditions during the periods analysed, in particular:

- The downward traffic trend in the Municipality, as shown by data from fixed cameras at the entrances to the city centre (2).
- Road works near some of the intersections (e.g. during 4th quarter/2010 more than 2,000 intersections were in working order; during the 3rd quarter there were only 826).
- An increase in monitored intersections and as a consequence differences in BPR analysis results.

These considerations did not confute the quality of the system; instead they revealed the limitations of the evaluation. BPR was nonetheless a good indicator, considering that this curve connects flows to delays; it is representative for vehicle times spent.

C2.5 Society

Not applicable

C2.6 Cost-Benefit Analysis

Since CISIUM is a focused measure, data was considered from the Cost Benefit analysis. As originally planned it was a true ‘ex-post CBA’, therefore only costs and benefits from the project period were considered.

The CBA (see also detailed report as Annex) showed how at a general level the system was producing benefits in terms of time saved in the entire network. Considering that BPR curves did not always show these positive effects, it was deduced that benefits were generated by a better flow equilibrium and that as a result incoming flows at traffic lights were being managed better. Total flows were always the same but they were better distributed around the network.

The CBA considered the following stakeholders: Authorities (Municipality of Bologna), the transport operator (ATC/TPER), households, measure users (public beneficiaries) with their own costs and benefits.

The following costs and benefits were selected using the “net present value” formula (3) to calculate the overall gain for society:

- Costs: costs of centralising traffic lights, setting up the Traffic Control Centre, dedicated personnel to operate and develop the system, road maintenance costs (sensors, centralisation modules on traffic lights), ADSL for traffic lights, connection to the Traffic Control Centre, electric power and software maintenance.
- The Benefits related to the reduction in traffic congestion measured through the average delay experienced by incoming private/public flows at traffic lights.

The following assumptions were made for the CBA calculation:

- Only the radial Via Saffi has been evaluated with:
  - PT prioritization inbound,
  - Private vehicles outbound,
- no freight traffic (since no reliable data was available);
- split (4) of travel purpose for all days (weekdays and weekends) as follows:
  - for Public Transport: 46% work, 7% school, 54% other
  - for Private cars: work 37.9%, leisure 62.1%

- time values were taken from the CBA guidelines (Guidelines for focused measure – cost for benefit analysis in Civitas Mimosa);
- average occupation of vehicles: 1.2 units/car (weekdays) 1.4 (weekends);
- number of representative weeks per calendar year: 40;
- no investment occurred in BaU scenario;
- average demand (pax/day) for working days and weekends follows this assumption: the number of passengers proportional to the number of trips, since no better estimation was available.
- interest rate: 3.5%;
- start year (year of initial investment: 2009).

TABLE C2.6.1: CBA Cost evaluations

Costs		2009	2010	2011	2012
Capital Costs	Centralization of traffic lights*	175.000	0	0	0
	Traffic control centre**	600.000	0	0	0
Operating cost	Personnel	90.000	90.000	90.000	90.000
	On road maintenance	5.185	5.185	5.185	5.185
	ADSL	4.200	4.200	4.200	4.200
	Connection to traffic control centre	1.659	1.659	1.659	1.659
	Software maintenance	42.000	42.000	42.000	42.000
	TOTAL	918.044	143.044	143.044	143.044

* Centralization of 7 traffic lights on via Saffi (25,000 € costs per traffic light per year, VAT included).

** Cost incurred for the installation of the control centre, with a direct link to the centralization of traffic lights. These costs are included in full since they are necessary no matter how many traffic lights are centralized (VAT included).

Private transport benefits were estimated with two different approaches: this explains why there are two different economic evaluations. The first evaluation compared real waiting times for vehicles recorded at each crossing with the data obtained from the 2008 BPR (as BAU). The second compared data obtained from the BPR curves calculated during MIMOSA years with data obtained from the 2008 BPR (as BAU).

TABLE C2.6.2: CBA Benefits evaluations-hypothesis 1(MIMOSA CASE REAL DATA)

Benefits	MIMOSA case REAL DATA BaU case BPR	2009	2010	2011
Changes in travel time	private vehicles	10.341.533	10.053.772	5.458.630
	public transport	374.260	374.260 (*)	374.260 (*)
	TOTAL	**10.715.793**	**10.428.032**	**5.805.890**

(*) not available; the same value as the previous period has been assumed

TABLE C2.6.3: CBA Benefits evaluations--hypothesis 2(MIMOSA CASE BPR)

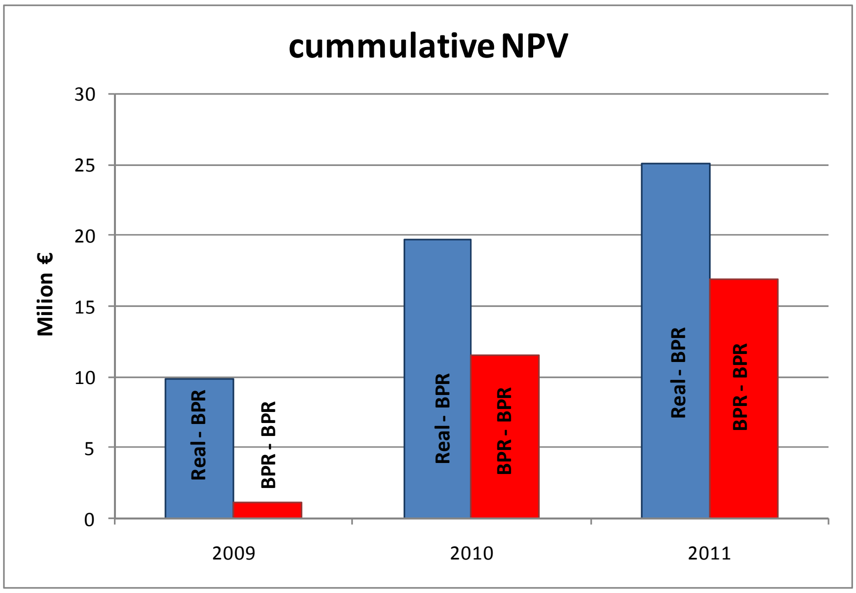
Benefits	MIMOSA case BPR BaU case BPR	**2009**	**2010**	**2011**
Changes in travel time	private vehicles	1.692.287	10.512.528	5.494.895
	public transport	374.260	374.260 (*)	374.260 (*)
	TOTAL	**2.066.547**	**10.886.788**	**5.869.155**

TABLE C2.6.4: CBA Cumulative results-hypothesis 1 and 2

Real-BPR	**2009**	**2010**	**2011**
Costs (€)	918.044	143.044	143.044
Benefits (€)	10.715.793	10.428.032	5.832.890
Net Cash Flow (€)	9.797.749	10.284.988	5.689.846
Cumulative NPV	**9.797.749**	**19.734.935**	**25.046.467**

BPR-BPR	**2009**	**2010**	**2011**
Costs (€)	918.044	143.044	143.044
Benefits (€)	2.066.547	10.886.788	5.869.155
Net Cash Flow (€)	1.148.502	10.743.743	5.726.111
Cumulative NPV	**1.148.502**	**11.528.931**	**16.874.316**

FIGURE C2.6.1: CBA results



The two methodologies used for NPV calculation produce significantly different results; however, as shown below, both cases show positive values.

C3 Achievement of Quantifiable Targets and Objectives

No.	Target	Rating
1	Improvement of traffic control in the urban area	★★
2	Provide real-time traffic information for citizens through different channels	★
3	Provide the municipality's technicians with better traffic planning tools	★
NA = Not Assessed; **O** = Not Achieved; ★ = Substantially achieved (at least 50%) ★★ = Achieved in full; ★★★ = Exceeded		

(*) Only the CBA can give substantial information on the Measure's effectiveness as regards traffic flows.

Considering the results of the impact evaluation, the first objective was achieved in full. Integration between traffic light induction loops (75% coverage of the available instruments on site) and the public transport ITS system provided a significant source of data for CISIUM. CISIUM currently represents an excellent traffic control tool. Traffic flows take a long time to be modified. Data from the last quarter of 2011 has shown how the system has begun to produce good results.

From the impact evaluation it was difficult to demonstrate the second objective, considering that the Measure could not be evaluated from the users' direct point of view. Nevertheless, the objective was substantially achieved considering the introduction of a set of innovative communication tools for the general public.

The third objective was also substantially achieved: CISIUM itself is an important instrument for traffic management and planning.

C4 Up-Scaling of Results

Part of the CISIUM system covers the whole city or metropolitan area.

The functionality for PT prioritisation was applied to some routes (the most important in terms of passengers moved and territory covered). Up-scaling the functionality to the whole network would have required more monitoring resources with subsequent risks of side effects on private traffic. It was therefore difficult to include general up-scaling for this aspect, even though an increase was possible and the positive effects could of course have been investigated.

C5 Appraisal of Evaluation Approach

The evaluation was very complicated considering that the different variables influencing traffic conditions could not always be considered in mathematical algorithms.

Other indicators to be evaluated, such as the level of user acceptance, were not appropriate for this Measure because of the complexity of the system itself. Users were unaware of the benefits obtained at every crossroad; these changes are often undetectable individually.

In addition, the original design for the study to include two more indicators (Average speed - peak, Average speed - off peak) should have measured the congestion level. This would have provided a rough but objective input for congestion measurement, considering that congestion levels are very difficult to measure in a homogeneous way. The two indicators should have been calculated as the average network/route speed by vehicle type and thus deduced from route lengths/travel times. Nevertheless, data suffered from some approximations. CISIUM primarily processes data related to timings. Changes to traffic light timings to disperse or prevent queues are defined on the basis of the intersection's crossing times. Speed as a derivative of space and time is not a monitored indicator. Therefore, the average speed – peak and the average speed - off peak were deleted from the evaluation.

Finally, the evaluation could be further improved by selecting lower time bands to verify PT timekeeping. CISIUM's contribution to PT punctuality would therefore be better evidenced.

C6 Summary of Evaluation Results

C6 Summary of evaluation results

The key results were as follows:

- **Improvement in traffic conditions –** general improvement in traffic conditions caused by interventions (crossings managed by CISIUM). At individual intersections, improvements in crossing times allowing the dispersal or prevention of queues might be of the order of a few seconds or even less: the time required to allow even a few vehicles to pass. These gains improve the flow fluidity at intersections, but they are not perceived by drivers. For this reason results are not immediately visible.
- **Decreased journey times** - Differences between years show a slight improvement in PT regularity, with particular reference to comparisons between 2008 and 2009, and relatively constant values in the last two years. Delays were reduced and the slight advances increased. This meant the traffic control system improved traffic conditions and reduced journey times. Even though, in an urban context, people can put up with buses leaving slightly early because of the high frequency of scheduled buses, a new Public Transport schedule is required.

C7 Future Activities Relating to the Measure

Activities to further improve the system will be carried out after the end of the Measure. These will cover the following:

- Including other traffic lights in the system.
- Using data on private vehicle flows.
- Installing Automatic Vehicle Monitoring on a larger number of buses.
- Introducing new control systems (e.g. new traffic monitoring cameras).

D Process Evaluation Findings

D0 Focused Measure

CISIUM was evaluated as a focused measure. The three most important reasons, from highest to lowest, are shown in the box below:

2	Most important reason
4	Second most important reason
1	Third most important reason

These choices refer to the checklist below.

1	**The measure fits into the EU policy towards clean urban transport (five pillars of the EU Green Paper)**
2	**The measure fits into the city policy towards sustainable urban transport and / or towards sustainability in general**
3	The expected impact on the transport system, environment, economy and/ or society / people is very high
4	**The high level of innovativeness of the measure with respect to technique, consortium, process, learning etc**
5	The measure is typical for a group of measures or a specific context
6	The possibility of carrying out a good Cost Benefit Analysis
7	Participation of a range of different actors
8	The high degree of complexity of managing the measure
9	The measure is regarded as an example measure
10	Others

D1 Deviations from the Original Plan

Deviations from the original plan included:

- **An unexpected increase in bug solving** – A number of software bugs slowed down deployment of the Measure.
- **Removing two indicators from the evaluation -** Data such as route lengths and travel times suffered from some approximations. Therefore the evaluation of the average speed was not significant considering the available data. These indicators were removed as a result.
- **Late launch of website and communication tools for the public.** During the implementation phase, political changes slowed down the deployment of the communication module for real time traffic information.

D2 Barriers and Drivers

D2.1 Barriers

Overall barriers

- **No comparable data**: The Measure was very complex in terms of software and technology. The system picks up different types of data which are not always comparable. This required technical testing and tuning for the system, often involving greater efforts than scheduled both in terms of money and time.

With particular reference to the **Implementation phase only**, the following barrier occurred:

- **Software bugs –** During the implementation of the system, the Municipality faced several technical problems. Some software modules did not respond to the requirements and the technical tests and system tuning took more effort than expected. This was because the software provider did not have wide experience of transport software. The impact was that the deployment of the system was slowed down.
- **Political changes-** There was a lack of political will in Bologna for a year and a half. The problem was solved in May 2011 with the election of a new mayor. During the implementation phase, political changes slowed down the deployment process for the real time traffic communication module. The public launch of the system took place later than planned, leading to missed user feedback.

D2.2 Drivers

Overall Drivers

- **Other IT systems utilize CISIUM information broadcasted via the DATEX protocol**. An initial application, for example, was the connection with the local freight distribution platform under Measure 7.1. This was a driver because it increased local technicians' knowledge and brought new features to the system.
- **SMART IP-**A European Project named SMART IP was put into operation during the Measure development. It was designed to make CISIUM services and tools more functional and practical from the users' point of view by involving them directly in the development of CISIUM with a participatory approach. The impact of the driver was to widen CISIUM users.

With particular reference to the **Operation phase** only, the Municipality encountered the following driver:

- **Italian Project – SIMONE**. A public bid for the development of a third congestion indicator was awarded in 2011 outside MIMOSA, as part of the Italian project Simone. This was considered a driver because it made it possible to obtain new data. This new indicator was based on floating car data (FCD), i.e. measurements of average travelling times for vehicles with on-board boxes for telemetric measurements. Tests related to the spread of the data through communications based on the vehicles' TMC protocol. New data was collected in order to estimate congestion levels more accurately.

D2.3 Activities

Overall activities

- **The number of technical staff was increased –** This action was taken to solve the problems detected (software bugs and discordant results) and improve the system. A new algorithm was introduced and the software was improved.
- **The number of congestion indicators was increased -** This action was taken to improve the accuracy and significance of data obtained (see barrier n. 1 and driver n. 3).

D3 Participation

D3.1 Measure Partners

- **Municipality of Bologna (COBO)** – the Municipality played a leading role and was directly responsible for coordinating and implementing the Measure.
- **ATC/TPER- Bologna PT operator** - as the main participant in the Measure, ATC/TPER contributed to bus prioritisation and interconnection with its Advanced Vehicle Monitoring centre.

D3.2 Stakeholders

- **Car drivers,** who can benefit from real-time traffic information and shorter waiting times at traffic lights.
- **Public transport users,** who can benefit from the prioritisation of public transport buses.

D4 Recommendations

D4.1 Recommendations: Measure Replication

- **Consider in advance the difficulty of the evaluation** – The evaluation was very complicated, considering that different variables influence traffic conditions and they cannot always be considered in mathematical algorithms. The Measure cannot be evaluated from the users' direct point of view because they are unaware of the *particular benefits obtained at every crossing*: these changes are often undetectable individually.
- In order to obtain significant benefits, **these kinds of projects must involve a large portion of the urban network** (as was the case in Bologna). Otherwise, the lack of control over the network where the traffic control centre is not operative would outweigh the benefits of the project.

D4.2 Recommendations: Process (Related to Barrier-, Driver- and Action Fields)

- **Invest in internal personnel skills -** Implementing the traffic control centre took a long time and required a lot of work in terms of analysis, testing and developing algorithms. This extensive work made it possible to study all aspects in depth and to focus on particularly important details of the system. The implementation process showed that the daily work of internal personnel is fundamental and cannot be replaced by external contributions. Very often the internal technicians were able to provide the software company with a logical solution. This driving role is the winning aspect in projects which require in-depth knowledge of the local traffic context.

F Annex

(1) BPR CURVE

The functions used to express the travel time (or cost) on a road link as a function of the traffic volume f are usually expressed as the product of the free flow time multiplied by a normalized congestion function f(x):

$$t = t_0 (1 + a (f/C))$$

where the argument of the delay function is the f/C ratio, C being a measure of the capacity of the road.

The BPR equation was originally applied to 1965 Highway Capacity Manual freeway speed flow data. Since then additional research has been carried out, giving the equation this form:

$$t = t_0 (1 + a (f/C)^b), \text{ where}$$

t: predicted waiting time spent

t_0: free-flow travel time

f: traffic flow [vehicles/h]

C: capacity [vehicles/h]

a: coefficient (often around 0.15)

b: exponent (often around 4.0)

The function uses two constants to fit the equation to various types of roadways and circumstances. Parameter “a” determines the ratio of free-flow travel time to the travel time at capacity; “*b*” determines how abruptly the curve rises from free-flow travel time. The BPR function is a major simplification of traffic engineering, which points out that traffic delay is an exponential function of roadway loading (f/C).

(2) Access to the LTZ (Bologna’s limited traffic zone) as recorded by fixed SIRIO cameras

Decreasing traffic trend in the Municipality of Bologna, as shown by the following table

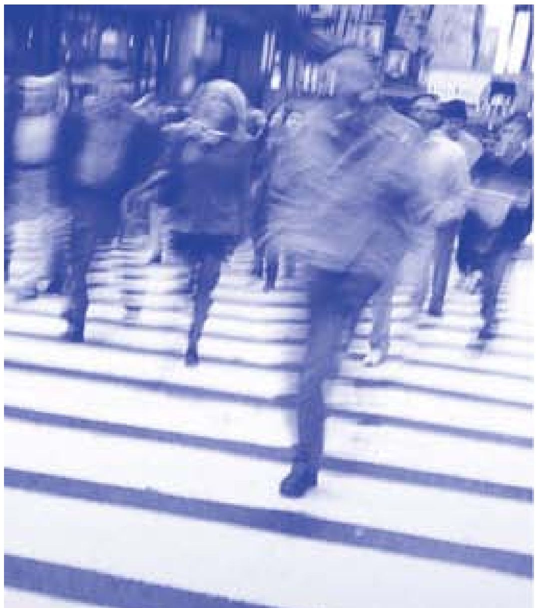
Period	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
7 am to 8 pm	48.806	49.794	49.955	49.668	50.794	45.138	39.887	38.860	37.899	40.875	40.241	38.155
All day	66.958	67.875	67.075	65.213	67.482	59.808	52.894	51.171	49.244	52.545	51.454	48.752

Access to the LTZ (average weekday in February) Source: Municipality of Bologna – SIRIO

(3)

$$NPV = \sum_{a} \sum_{t=0}^{n} \frac{(R_{ta} + UB_{ta} + NUB_{ta} + E_{ta} - OC_{ta} - C_{ta})}{(1+r)^t}$$

(4) Source: Federico Rupi (2010): MONITORAGGIO DEL LIVELLO DI UTILIZZO E DELLA TIPOLOGIA DI UTENZA DEL “NODO RIZZOLI” (publication on the monitoring of modal split in a portion of the Bologna traffic network).



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Bologna 8.3 Cisium: New Traffic Control Centre

Authors: Valentino Zanin - Davide Rossi- Giorgia De Chiara – (TeMA Territorio Mobilità Ambiente S.r.l.)

Riedel Veronique (T.U.B)

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6 Annex 1

1 Introduction

Bologna's new traffic control centre (CISIUM) was part of a general strategy implemented by the Municipality of Bologna to improve congestion, especially for the Public transport service (buses), by optimising traffic management.

CISIUM connects and integrates the Municipality's ITS systems. It controls the majority of the traffic lights in the city and influences traffic regulation in the whole metropolitan area in order to achieve optimal real time traffic management. In this measure, the deployment of communication tools based on TMC-DATEX protocol has been carried out. This allowed messages to be sent about the real time traffic situation to car radio, satellite navigators on board, PT customers and to other traffic operators like the Highways control centre. Another important objective of the CISIUM was the construction of a detailed database of traffic scenarios recurring in different areas (according to time bands, special events or meteorological conditions). This allowed a detailed and scientific calibration of the traffic model used for private and public traffic, which will help technicians to better plan road modifications and to allow the control centre to promptly react to unexpected congestion using an innovative heuristic[1] approach.

As stated in the local evaluation plan of the MIMOSA project, this measure aims to optimize traffic management within the city in both regular and congested situations. Thereby, the objectives were formulated as follows:

High level / longer term:

- Efficiency of the transportation system

Strategic level:

- Innovative Transport Telematics Systems development

Measure level:

- To improve traffic control in the urban area
- To provide the public with real-time traffic information through different channels
- To provide the Municipality's technicians with better traffic planning tools

This measure tries to improve transport efficiency through the reduction of travel time resulting from an improvement in traffic flow within the city.

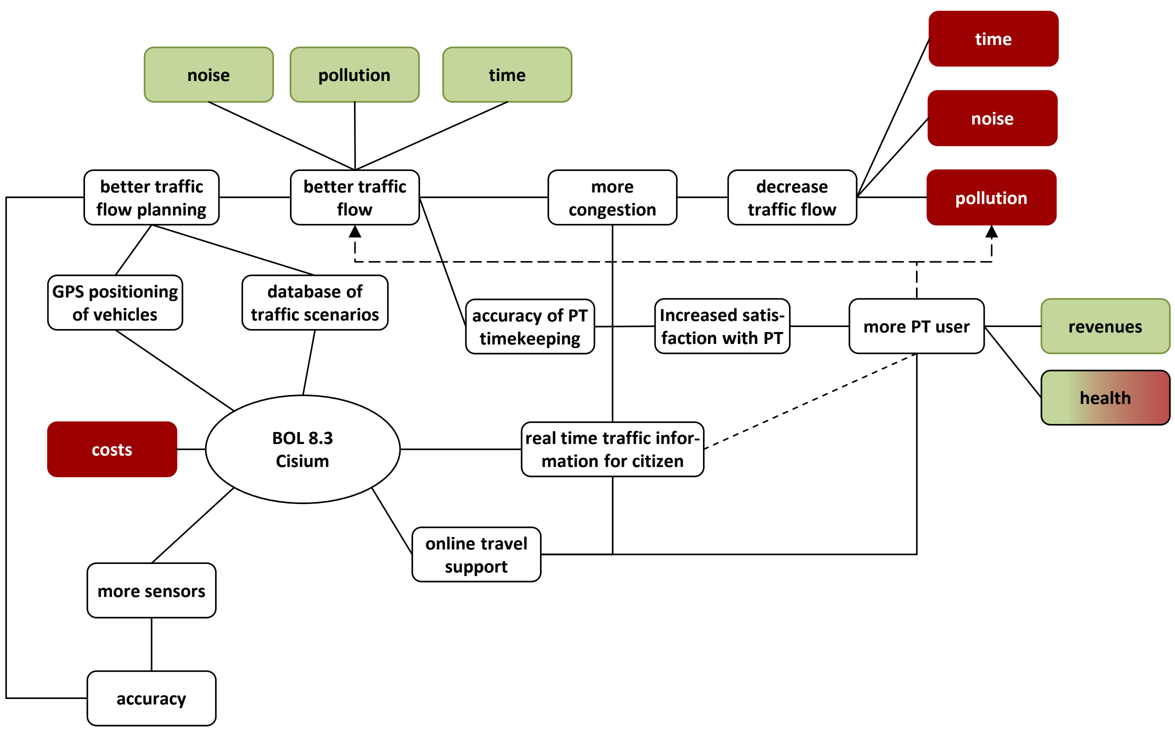
[1] Heuristic refers to experience-based techniques for problem solving, learning, and discovery. Where the exhaustive search is impractical, heuristic methods are used to speed up the process of finding a satisfactory solution.

2 Costs and benefits

2.1 Scope of the evaluation

The implementation of a new algorithm supports GPS positioning of vehicles and real time traffic information. Together with the implementation of new sensors and the compilation of traffic scenarios it will be possible to conduct more accurate traffic flow planning, resulting in better traffic flow through the city. This again will result in a reduction in emissions and noise, since moving traffic emits less than traffic characterized as stop-and-go. Thus citizens will spend less time getting to their destination. Also, through the new algorithm, citizens will be able to make more rational choices as to what and where to drive since they will be able to access information about current traffic situations. This however can again result in a congestion increase since all citizens will follow those routes without congestion, thereby negating some of the positive effects.

Figure 2.1: *Cause- and effect chain for BOL 8.3 Cisium, New Traffic Control Centre*

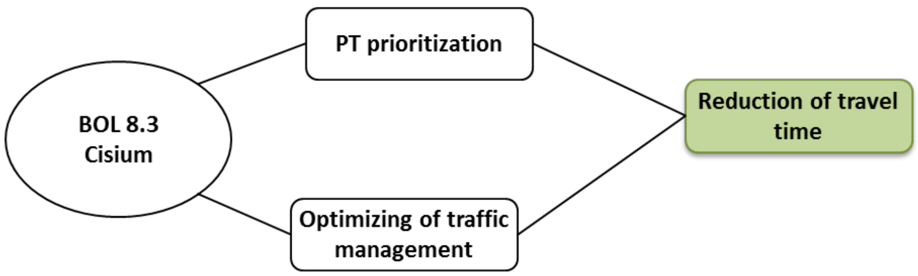


Nonetheless, with the increased traffic flow and a better green light prioritization, on-time public transport can be offered as an alternative travel mode. This increase in attractiveness might result in more PT users and henceforth in more revenues. This could also have an impact on citizens' health and the environment. If citizens use public transport instead of their own vehicle, they free up the road, resulting in less congestion and better traffic flow, hence they contribute further to the reduction of noise, pollution and travel times. Furthermore, since the bus station is usually not a door-to-door journey, citizens will have to walk for some parts of their trip, thereby actively increasing their health. However, if they use public transport instead of other modes of transport (bicycle, walking, car sharing), the effects are partially reversed. All in all, the effects of a fully functional traffic control centre are numerous and very difficult to predict as they sometimes negate themselves.

For this analysis, it was first decided that the effects resulting from people changing due to an increase of attractiveness of the public transport service will not be considered because the data is not available. Also, the effects on citizens, considering the launch of on-line traffic information services, will not be taken into account since it is difficult to estimate the impact of society indicators that seems to be mainly influenced by the overall mobility policy.

The appraisal of this measure is very limited due to the data availability. After careful consideration, it was decided to exclude the effects on the environment since no emission modelling and or measurement would be available to determine the effect of better traffic flows. Consequently, this would reduce the analysis to the travel time aspect of measure. Also, this would ultimately mean that the high level objective is not included in the economic appraisal. However, this step is justified as firstly, no data is available and secondly it could not be obtained without ridiculing the entire appraisal because of cheated assumptions.

Figure 2.2: *Main benefit from the measure*[2]



As a consequence, this analysis will focus only on the benefit from travel time reduction for public transport and private vehicles.

The Cisium Measure involved many stakeholders: authorities who invested money in the organization of Traffic Control Centre, equipment of traffic lights, maintenance of system, etc…) and roads users (both private and transport operators). Citizens were also involved given the obvious benefits of less air

[2] Own compilation.

pollution and less noise caused by the reduction in congestion. The table below shows all stakeholders' benefits/costs.

Table 2.1: *Costs and benefits for different stakeholder groups of measure BOL 8.3*

Stakeholder Group	Cost	Benefit
Authorities	Investment cost for implementing new algorithm Investment cost for new sensors Investment cost for communication platforms with citizens and other institutions Operating costs for the new system	
Transport operator		Increased revenues
Households		Fewer pollution due to moving traffic Less noise due to moving traffic
Users of the measure		Less travel time due to moving traffic

2.2 Data restrictions

Despite not having data on emission and noise, the choice of data in estimating travel time reduction – especially for private vehicles – is very limited. Usually, travel time data is collected in the field. In Bologna, it would be possible to record the precise location of a probe vehicle via GPS tracking at specific time intervals and thus record its travel time on a specific journey.[3] If this is done repeatedly throughout the years during different times of the day it would be possible to gain a complete picture of travel times throughout the city. Although this is technically possible, this has not been done on a large scale to produce viable data. From the many cars equipped with appropriate technology, it is still very sensible and on average, only 2 to 3 are available. In combination with the shortage on personnel, this data collection has not been done.

As a consequence, the travel time reduction for private vehicles is estimated by the reduction of average waiting times on the intersections and is further restricted to traffic on radials. This is where bus prioritization takes place and the effects of optimized traffic light timing should have the highest impact. The first radial investigated is via Aurelio Saffi. It has seven traffic lights and a total length of approximately 2.4 km. Private vehicle traffic is only allowed outbound, consequently public transport prioritization takes place inbound.

[3] Other methods to measure travel times include license plate matching, and emerging ITS technologies such as cell phone tracking, Advance Vehicle Identification and inductive loop signature matching.

Nonetheless, it should be noted that the overall travel time is the sum of the waiting time and the time needed to accelerate and decelerate. Hence, the value obtained should be increased by a coefficient that takes into account the deceleration and acceleration time. Since this analysis only compares the waiting times due to a lack of appropriate data, this step is not necessary and it is assumed that the travel times between intersections is constant. As a consequence, this approach neglects queuing delays. During times with high traffic flow, the deceleration and acceleration time can be much longer as traffic usually begins moving slowly. Since there is no other data available, this problem is neglected.

2.3 Hypothesis and Assumptions

Hypothesis

In order to evaluate all costs-benefits these hypothesis have been done:

- Only one radial has investigated, Via Saffi, with:
    - PT prioritization inbounds,
    - Private vehicles outbound,
- no freight traffic (since no reliable data is available),
- split[4] of travel purpose for all day (weekday and weekend) as follows:

  about Public Transport: 46% work, 7% school, 54% other

  about Private car: work 37,9%, leisure 62,1%,
- Interest rate: 3,5%,
- starting year (first year of initial investment: 2009),
- number of traffic lights centralized on considered radial: 7 (135 total lights equipped in Bologna),
- Average occupation of vehicles: 1,2 units/car (weekday) 1,4 (weekend),
- number of representative weeks per calendar year: 40,
- time values constant equal to:

4 source: Federico Rupi (2010): Monitoraggio del livello di utilizzo e della tipologia di utenza del “nodo Rizzoli” (publication about monitoring of modal split in a portion of Bologna’s network).

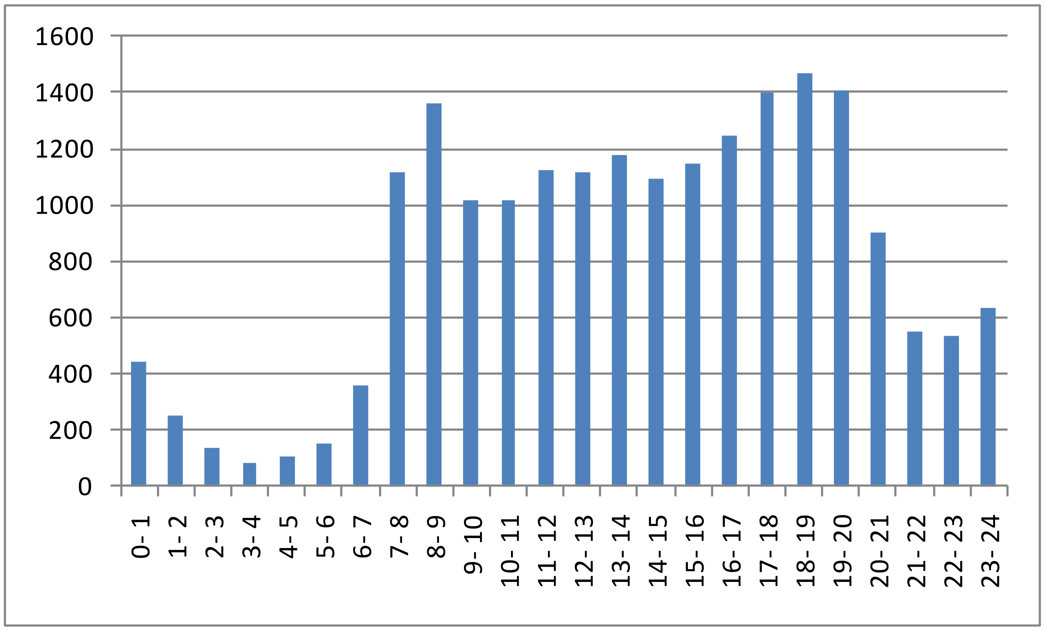
Table 2.3.1: *Different values of travel times*

Value of travel time (€ per passenger per hour, 2008 factor prices)				
work		Leisure		freight
Bus	Car, Train	Bus	Car, Train	Road
23,86	29,73	7,10	9,88	3,64

Assumptions

The greatest benefit of the system occurs during time bands with high traffic volume. Thus, the period in which changes in travel time are accounted for only extends from 7 am to 8 pm. As an example, Figure 1.5.1 shows the average traffic flow (in terms of vehicles per hour) at one crossroads on Wednesday, March 3rd 2009[5]. This graph demonstrates that only between these hours, traffic flows are high enough to justify a positive effect from the Cisium system (with a very lower flow than the capacity of the traffic lights, time spent does not change in terms of vehicles incoming).

Graph 2.3.1: *Average traffic flow at induction loop 2.34 2.33 4 1 on March 3rd 2009*



Reduction in travel times for private vehicles has been estimated through the reduction of the average

[5] This day is representing a typical day in the scholar year where weather conditions are moderate and have minimum effect on traffic conditions.

waiting time at seven traffic lights. Data is from the first week of March starting in 2009 to determine traffic demand and the average waiting time. Only 40 weeks are evaluated each year, when both schools and universities are teaching.

2.4 Costs

In this paragraph the main costs of the measure have been considered: every cost has been identified with methodology used for its assessment. Two kinds of costs have been considered for the installation of Cisium system:

- Public investments for installation of system (Public Authorities),
- Operating costs (Public Authorities).

Investments for installation of system

Initial investments include the Cisium offices, the software housing, and the related personnel assigned to (expenditure is 600.000 euro) and the centralization of traffic lights, which unit cost is 25.000 euro. Considering only benefits of Via Saffi have been investigated, in this CBA only seven lights have been taken into account as centralization's costs.

Personnel used for using Cisium is equal to 2,5 people employees for every year of Cisium activity, with a cost of 36.000 euro/employee.

Operating costs

Operating costs take into account ordinary maintenance on road (sensors, loops and centralization modules on traffic lights), ADSL yearly cost, connection to the Central centre and software maintenance.

The table below shows all costs considered in the Cost-Benefit Analysis.

Table 2.4.1: *Costs table.*

Cost categories	Description	Overall cost	Costs per traffic light per year	Remarks
INVESTMENTS	Centralisation of 1 traffic light		25.000	vat included
	Traffic control centre	600.000		vat included, considered only costs related to traffic light improvements
PERSONNEL	2,5 man/year	90.000		
OPERATING COSTS	On road maintenance (sensors, centralization modules on traffic lights)	100.000	740	VAT included
	ADSL per 1 traffic light/year	81.000	600	VAT included
	connection traffic control centre	32.000	237	VAT included
	electric power	0	0,00	the difference between traffic light centralised and non-centralised is not significant
	Software maintenance	42.000		VAT included

2.5 **Benefits**

Benefits considered are linked only to the reduction of travel times, that is the main aspect connected to Cisium system. The reduction in travel times was estimated by the reduction of the average waiting time at seven traffic lights.

Bus prioritization on radials

The Advanced Vehicle Monitoring (AVM) - a system part of the Cisium in charge of PT monitoring - is able to adapt the traffic lights timings in order to make the PT circulation faster.

The system is able to provide data regarding the travel times of each bus and, in case the bus is delayed according to the scheduled time, it may also ask for prioritization of a bus journey.

The measure focuses on the radials which are the main roads of the city connecting the centre to the adjacent neighbourhoods.
In order to simplify the regulation of traffic, private vehicles are only allowed to travel one way, while a bus lane is solely reserved for the opposite direction. Hence prioritization deals with the bus lanes, as only the PT vehicles are allowed to drive on them.

Private vehicles traffic on radials

The core of the Cisium is UTOPIA which is in charge of traffic lights timings' optimization. Each traffic light's timing is adapted by UTOPIA to traffic demand every 3 seconds. Through the induction loops in the pavement, the system is able to continuously monitor traffic flows and according to their variations, it modifies the timings and hence the green phases.

The traffic lights regulation depends on the traffic demand, the method deployed by the CISIUM in order to have an overall strategy for the whole network. Each traffic light counts the vehicles, and every 3 seconds it sends the information to CISIUM. Once the CISIUM has received the data from *all* the traffic lights, it deploys the better strategy, taking into account actual traffic flow and historical events (data). If a problem occurs in connectivity with the central, the traffic lights deploys a local strategy.

Available data are:

- traffic flows from the induction loops (5 min. aggregation), see Annex (1);
- average travel times: estimate as a changing in waiting time at the links, see Annex (2).

For the evaluation of the benefits provided by CISIUM to private vehicles, two approaches have been applied:

1. ***BPR curve***: from the raw data provided by the CISUM about traffic demand and average delay, it is possible to obtain a BPR curve for the radials. From this curve, it is possible to estimate the benefits for the pre Cisium, the post Cisium and the BaU.

Table 2.5.1: *BPR curve parameters*

Data for the BPR curve (for each year of Cisium activity)			
	2009	**2010**	**2011**
t0	12,75	11,87	12,52
gamma	40,02	25,73	24,37
beta	1,98	1,615	1,66

2. ***Rough delay and flows data***: the data obtained from the road's system can be used directly in the cost analysis (delay and demand). The main problem connected to this approach lies in the identification of the travel time values for the BaU scenario. Considering any road has its own peculiarity and no comparison to other similar road can be done, it is not possible to estimate what delay would occur in the same scenario if Cisium was not applied on the road (see next chapter about BaU scenario).

3 Computing the Business-as-usual Scenario

In order to evaluate the improvement by this measure, a business-as-usual (BaU) scenario has been designed to evaluate what would have happened without the tools provided by Cisium. For its evaluation two theoretical approaches are available:

1. *Control site design*: average travel times on a radial that is not subject to centralized traffic lights can be compared to those that are part of Cisium. This would be valid if street characteristics are very similar in terms of geometric values, flow's direction (into or out of the city), number of lanes available, traffic flow and number of traffic lights.
2. *Simulation*: many mathematical approaches and simulations can be used to determine the average travel times for a given traffic volume without implementation. These are often derived using historical data (data derived before measure implementation) and statistical approaches.

As of today, traffic lights on all radials in Bologna have been centralized, thus no control site will be available for a business-as-usual scenario. As a consequence, appropriate statistical approaches have to be defined to derive the necessary data. For the data available in Bologna, the approach ***Bureau of Public Roads (BPR) curve*** seems valid (point 2 above): from the raw data provided by the CISUM about traffic demand and average delay, it is possible to obtain a BPR curve for the radials. It is a measurement of the theoretical delay due to vehicles waiting their turn to clear intersections and is a function of traffic flow and delay time.

This curve was based on the 1965 Highway Capacity Manual from the Bureau of Public Roads in the United States and was parabolic in shape, and speed is fairly sensitive to increasing flows. Its general shape is:

$$waiting\ time = t_0 + \gamma \left(\frac{Demand}{800}\right)^{\beta}$$, where

t_0 is the so called free-flow time on a link and

γ , β define the shape of the curve.

Thereby, the parameters are defined by fitting the actual data to its general shape. In Bologna, this curve has long been used as measurement for the success of the system and is derived for each quarter of the year by the software supplier.

This curve is available for radials starting as early as 2008. It is important to note that this curve could only be computed for centralized traffic lights. *Nonetheless, the first BPR curve determined in 2008 could* *be used for the BaU since later curves should show the improvement of the system, the first one representing the traffic conditions before Cisium implementation.*

Given that BaU traffic conditions are considered to be the same as pre-Cisium implementation, no money investments have been assumed in BaU scenario (no investment in control tools).

BaU builds with Bureau of Public Roads (BPR) curve

The table below shows how data is used to estimate time delay occurring in business as usual and allows for the construction of the BaU BPR curve. This data is from 2008 and represents an average output of all traffic lights centralized.

Parameter for BPR	
t0	13,82
gamma	37,96
beta	2,16

Average time spent at crossroads has been calculated starting from registered incoming flows[6] i to traffic lights during 2009 -2011. The table reported below is an explicative example for one of seven traffic lights considered.

Table 3.1: *Example of demand to one crossroad of via Saffi*

2.33 2.32 4 1						
	Average demand (working day)			Average demand (weekend)		
	2009	2010	2011	2009	2010	2011
7 to 9	1.894,9	1.841,3	1.483,0	861,8	792,0	601,8
9 to 17	1.950,5	1.900,1	1.474,2	1.599,3	1.581,3	1.167,8
17 to 20	2.213,1	2.127,4	1.722,1	1.990,2	1.837,7	1.494,0

Table 3.2: *Example of average waiting time to one crossroad of via Saffi*

2.33 2.32 4 1						
	Average waiting time (working day)			Average waiting time (weekend)		
	2009	2010	2011	2009	2010	2011
7 to 9	7,3	5,8	6,6	6,0	6,3	4,5
9 to 17	6,2	6,4	7,3	7,2	4,8	6,4
17 to 20	7,3	7,1	8,7	8,4	5,9	6,4

[6] Flows are values really registered by loops during period of analysis (see Table 3.3.2)

4 Economic Evaluation

In this study, the net present value (NPV) is used to quantify the overall economic impact. It is defined as the total present value of all future benefits less the discounted sum of all future costs over the appraisal period. It measures the excess or shortfall of monetised resources, in present value terms.

This is based on a standard social cost benefit analysis of the following form[7]:

$$NPV = \sum_{a}\sum_{i}\frac{(R_{ia} + UB_{ia} + NUB_{ia} + E_{ia} - OC_{ia} - C_{ia})}{(1+r)^{i}}$$

where,

i = years of project appraisal

a = stakeholder involved and/or affected

NPV = Net present value summed over all stakeholder

R_{ia} = Revenue in year i to stakeholder a,

UB_{ia} = User transport benefits in year i accruing to stakeholder a,

NUB_{ia} = Non user transport benefits in year i accruing to stakeholder a,

E_{ia} = External benefits in year i accruing to stakeholder a,

OC_{ia} = Operating (and maintenance) costs in year i to stakeholder a

C_{ia} = Capital costs accruing to stakeholder a in year i (with the assumption that capital costs begin to be incurred in year 0).

r = Discount rate

If the net present value is positive, the benefits are higher than the costs and the project impact on social welfare is positive.

Below all costs-benefits are resumed in their economic evaluation comparing Mimosa's scenario and BaU's one.

[7] CIVITAS POINTER (2009).

4.1 Public Transport benefit

Using a table of hourly travelling costs and daily volumes moved by PT on the radial analyzed, total saving time has been estimated and its related economic benefit.

$$Money_{SAVED} = Time_{\ saved} \times \overline{Demand} \times n.tips \ \times Time_{VALUE}$$

Travel purposes for Public Transport are from phone surveys made in Bologna on 1997; no differentiations in time bands and type of day (weekday/weekend) are available.

Table 4.1: *Travel purpose in Bologna's Municipality*

Travel purposes				
	Working day		Weekend	
	Work	Leisure	Work	Leisure
7 to 9	37,9%	62,1%	37,9%	62,1%
9 to 17	37,9%	62,1%	37,9%	62,1%
17 to 20	37,9%	62,1%	37,9%	62,1%

Public transport data about 2010 and 2011 is not available and the CbA the values have been considered equal to 2009. This assumption is a strong hypothesis, which could influence significantly results of CbA. Nevertheless, considering PT benefits have a smaller order of magnitude compared to private vehicles benefit, this assumption doesn't modify the NPV in the CbA (see Chapter 4.3 about NPV calculation).

Table 4.2: *Public Transport values table.*

Public Transport	2009		2010		2011	
	weekdays	Weekend	weekdays	weekend	weekdays	weekend
changes in travel time [sec]	73	82	73	82	73	82
number of inbound trips per day	1000	250	1000	250	1000	250
average demand [pax/day]	5602	1400[8]	5602	1400	5602	1400
change in user benefit [€/day]	1682,3	472,4	1682,3	472,4	1682,3	472,4
change in user benefit [€/week]	9356,5		9356,5		0	

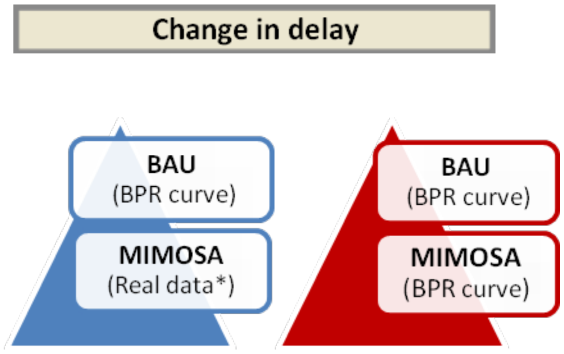
[8] Assumption is that the number of weekend passengers is proportional to the number of trips since no better estimation is available.

4.2 Private Transport benefits

Benefits for private users has been estimated as the difference in change in delay occurred between Mimosa's scenario and BaU's one. As mentioned above, since no data is available for any[9] roads not equipped with Cisium, BaU's time spent at traffic lights have been calculated considering an average Municiplaity's BPR curve calculated in 2008 (the first calculated before traffic lights centralized).

Comparison (differences in time spend at traffic lights) between two scenarios have been calculated as follows:

Figure 4.2.1:*Two approaches used to delay evaluation*



* Real data are directly from system as indicate in chapter 2.3 with the name of "***Rough delay and flows data"***

Warning: tables starting at this point does not resume take into accounts all intersections mentioned in the analysis but only one of them (crossing n° 2.33 2.32 4 1). Tables below are exclusively an example of how data was collected and elaborated: it seems easier to comprehend the text. In the Annex all crossing's data is available.

Below are results for the two different approaches used in the CbA. Each one has taken note of the differences in time spent at traffic lights and the related economic value.

[9] with the same characteristics of lights considered: capacity, volumes, green time, etc...

Delays occurred BPR.Real Data

Table 4.2.1: *Differences in delay between Mimosa (real data) and BaU (BPR) scenario*

2.33 2.32 4 1						
	Change in delay (working day)			**Change in delay (weekend)**		
	2009	**2010**	**2011**	**2009**	**2010**	**2011**
7 to 9	251,2	238,1	151,3	52,4	44,7	29,8
9 to 17	268,1	253,6	148,8	176,2	174,5	93,4
17 to 20	348,8	321,0	204,2	277,5	236,9	153,8

Related economic evaluation as:

$$Money_{SAVED} = \sum_{i=1}^{7\ TRAFFIC\ LIGHTS} Time_{SAVED} \times Average\ demand_{INCOMING} \times Time_{VALUE}$$

Table 4.2.2: *Example of related benefits calculated at one intersection.*

2.33 2.32 4 1						
	Benefit (work)			Benefit (leisure)		
	2009	**2010**	**2011**	**2009**	**2010**	**2011**
7 to 9	18.692,7	17.102,2	8.752,2	10.164,3	9.299,5	4.759,1
9 to 17	98.428,9	91.837,2	40.644,9	53.521,5	49.937,2	22.101,0
17 to 20	58.072,3	49.969,2	25.880,1	31.577,3	27.171,1	14.072,5

Delays occurred BPR.BPR

Table 4:2.3: *Differences in delay between Real Data (BPR) and BaU (BPR) scenario*

2.33 2.32 4 1						
	change in delay (working day)			change in delay (weekend)		
	2009	**2010**	**2011**	**2009**	**2010**	**2011**
7 to 9	25,9	133,0	77,7	-0,7	13,8	6,6
9 to 17	28,7	144,0	76,6	13,4	90,1	41,7
17 to 20	44,5	191,3	113,7	30,9	132,3	79,2

Related economic evaluation as:

$$Money_{SAVED} = \sum_{i=1}^{7\ TRAFFIC\ LIGHTS} Time_{SAVED} \times Average\ demand_{INCOMING} \times Time_{VALUE}$$

Table 4.2.4: *Example of related benefits calculated in one crossroad*

2.33 2.32 4 1						
	Benefit (work)			Benefit (leisure)		
	2009	**2010**	**2011**	**2009**	**2010**	**2011**
7 to 9	1.832,5	9.400,2	4.404,0	996,5	5.111,4	2.394,7
9 to 17	9.928,8	51.160,1	20.392,3	5.398,9	27.818,7	11.088,4
17 to 20	7.167,7	29.351,5	14.158,4	3.897,5	15.960,1	7.698,8

4.3 NPV calculation

These calculations show all the costs and benefits, calculated NPV for each year of Cisium activity. The table below shows the cost and benefit in terms of a 2 differentiation approach (BPR vs. Real Data and BPR vs. BPR).

Given that in BaU there is no control centre/no centralization of traffic lights, no investment costs were assumed. In Mimosa the only costs assumed are the ones sustained in Saffi Road as it is included in the benefit calculation in terms of traffic flow. .

Table 4.3.1: *Resume of Measure costs*

			2009	**2010**	**2011**
Capital Costs	**Centralisation**		175.000	0	0
	Traffic control centre		600.000	0	0
Operating cost	**personel**		90.000	90.000	90.000
	On road maintenance		5.185	5.185	5.185
	ADSL		4.200	4.200	4.200
	connection traffic control centre		1.659	1.659	1.659
	electric power		0	0	0
	Software maintenance		42.000	42.000	42.000
		Sum	918.044	143.044	143.044

* Centralization of 7 traffic light on Saffi road (25.000 € costs per traffic light per year VAT included).

** Cost which occurred due to the installation of the control centre and have a direct link to the centralization of the traffic light, these costs are included fully since they are necessary no matter how many traffic lights are centralized (Vat included).

Table 4.3.2: *Resume of Benefit (REAL data – BPR BaU comparison)*

Benefits	MIMOSA case **REAL** BaU case **BPR**		**2009**	**2010**	**2011**
Changes in travel time	private vehicles	work	10.341.468	10.053.709	5.458.596
		leisure	65	63	34
	public transport		374.260	374.260	374.260
	Sum		10.715.793	10.428.032	5.832.890

Table 4.3.3: *Resume of Benefit (BPR data – BPR BaU comparison)*

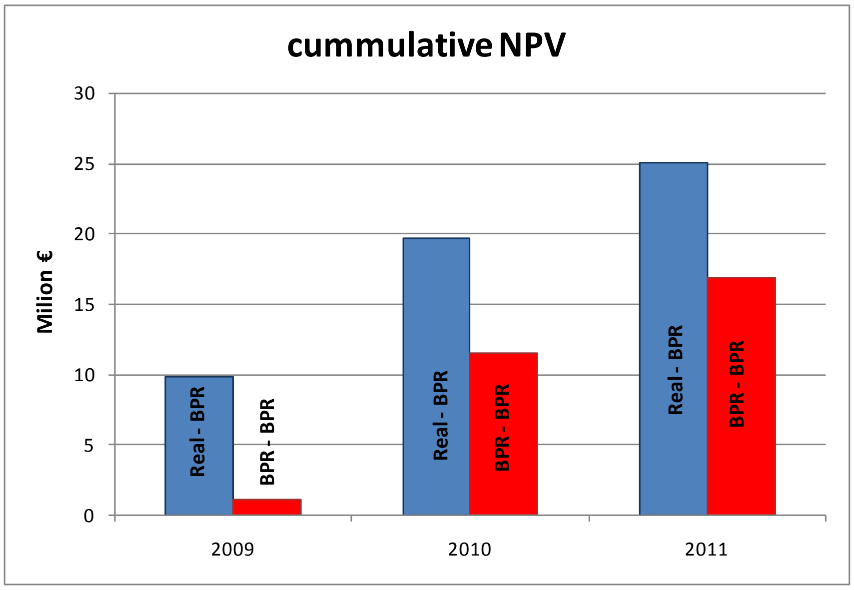
Benefits	MIMOSA case **BPR** BaU case **BPR**		**2009**	**2010**	**2011**
Changes in travel time	private vehicles	work	1.096.213	6.809.700	3.559.428
		leisure	596.074	3.702.827	1.935.467
	public transport			374.260	374.260
	Sum		2.066.547	10.886.788	5.869.155

Table 4.3.4: *Cumulative NPV in the two scenarios hypothesized*

BPR.real	**2009**	**2010**	**2011**
Costs (€)	918.044	143.044	143.044
Benefits (€)	10.715.793	10.428.032	5.832.890
Net Cash Flow (€)	9.797.749	10.284.988	5.689.846
Cumulative NPV	**9.797.749**	**19.734.935**	**25.046.467**

BPR.BPR	**2009**	**2010**	**2011**
Costs (€)	918.044	143.044	143.044
Benefits (€)	2.066.547	10.886.788	5.869.155
Net Cash Flow (€)	1.148.502	10.743.743	5.726.111
Cumulative NPV	**1.148.502**	**11.528.931**	**16.874.316**

Graph 4.3.1: *NPV calculation*



In both cases, the centralization of traffic lights generates an economic benefit. This is despite the fact that the centralization in itself is not financially viable since it does not generate revenues.

This analysis is based on many assumptions that have a direct impact on the value of the cumulated net present value. Thereby, the greatest impact will come from changes in the user benefit for private vehicle since they account for the greater part of user benefits.

5 Conclusion

The main characteristic of this measure is its high values of initial investment and relatively low cost of maintenance. Cisium software needs updating constantly as well as an efficient ordinary maintenance on operating roads. As mentioned in the related MRT, the Cisium system can achieve good results only if it is applied to a big part of an urban network. The main software equipment and the centralization of most traffic lights in the Municipality represents a significant initial investment for Public Administration given that generated benefits are only available after a long period of model calibration over many months.

Nevertheless, CBA results shows that investment in transport management can have positive effects on traffic itself and produces benefits for all users (drivers and citizens) even in the first year of activity. In the best case scenario, benefit exceeds the cost of 9.000.000 €, and in the worst case, it equalled it).Considering the two mathematical approach to the NPV calculation, it’s important to underline that the private benefits occur after 2008, demonstrating the soundness of each methods used and their mutual validity. Nonetheless, this analysis demonstrated that cost-benefit analysis is generally possible with little data obtainable. However, one should be refrained from interpreting too much from the results.

For more detailed conclusions on the measure see the MRT document.

6 Annex

(1) Average demand on 7 traffic lights of Via Saffi

2.34 2.33 4 1								
	Average demand (working day)				Average demand (weekend)			
	2009	2010	2011	2012	2009	2010	2011	2012
7 to 9	1.385,1	1.241,6	937,4	n.a	573,0	484,6	359,8	n.a
9 to 17	1.311,5	1.233,6	893,8	n.a	1.045,1	979,7	685,1	n.a
17 to 20	1.635,1	1.421,0	1.155,9	n.a	1.239,0	1.158,1	861,3	n.a
2.34 2.33 4 1								
	Average demand (working day)				Average demand (weekend)			
	2009	2010	2011	2012	2009	2010	2011	2012
7 to 9	1.256,0	1.125,9	1.178,5	n.a	526,5	445,3	448,0	n.a
9 to 17	1.209,3	1.137,5	1.138,9	n.a	956,1	896,2	877,1	n.a
17 to 20	1.439,8	1.251,3	1.367,2	n.a	1.111,0	1.038,5	1.095,7	n.a
2.33 2.32 4 1								
	Average demand (working day)				Average demand (weekend)			
	2009	2010	2011	2012	2009	2010	2011	2012
7 to 9	1.894,9	1.841,3	1.483,0	n.a	861,8	792,0	601,8	n.a
9 to 17	1.950,5	1.900,1	1.474,2	n.a	1.599,3	1.581,3	1.167,8	n.a
17 to 20	2.213,1	2.127,4	1.722,1	n.a	1.990,2	1.837,7	1.494,0	n.a
2.32 2.31 4 1								
	Average demand (working day)				Average demand (weekend)			
	2009	2010	2011	2012	2009	2010	2011	2012
7 to 9	991,2	1.039,1	0,0	n.a	472,5	451,0	0,0	n.a
9 to 17	1.025,1	1.058,5	0,0	n.a	899,6	903,8	0,0	n.a
17 to 20	1.107,7	1.131,6	0,0	n.a	1.083,3	1.073,5	0,0	n.a

2.31 2.30 4 1								
	Average demand (working day)				Average demand (weekend)			
	2009	2010	2011	2012	2009	2010	2011	2012
7 to 9	1.452,9	1.424,8	1.333,7	n.a	561,3	562,3	570,3	n.a
9 to 17	1.453,6	1.475,5	1.341,4	n.a	1.173,3	1.156,5	1.097,4	n.a
17 to 20	1.624,6	1.601,5	1.467,5	n.a	1.408,7	1.439,2	1.416,0	n.a
2.30 2.29 4 1								
	Average demand (working day)				Average demand (weekend)			
	2009	2010	2011	2012	2009	2010	2011	2012
7 to 9	386,4	322,2	375,3	n.a	168,0	193,8	194,8	n.a
9 to 17	420,6	389,2	436,1	n.a	361,3	321,1	346,4	n.a
17 to 20	415,3	381,1	477,8	n.a	465,5	358,7	433,0	n.a
2.29 2.28 4 1								
	Average demand (working day)				Average demand (weekend)			
	2009	2010	2011	2012	2009	2010	2011	2012
7 to 9	780,6	738,9	433,7	n.a	299,0	299,5	170,3	n.a
9 to 17	690,6	667,1	395,5	n.a	556,9	533,0	327,0	n.a
17 to 20	751,6	717,7	440,0	n.a	701,0	639,8	351,0	n.a

(2) Average waiting time on 7 traffic lights of Via Saffi

2.35 2.34 4 1								
	Average waiting time (working day)				**Average waiting time (weekend)**			
	2009	**2010**	**2011**	**2012**	**2009**	**2010**	**2011**	**2012**
7 to 9	131,1	64,2	64,2	n.a	33,4	23,3	23,3	n.a
9 to 17	119,0	63,7	63,6	n.a	80,6	47,6	47,5	n.a
17 to 20	177,1	77,0	76,9	n.a	107,7	58,7	58,6	n.a
2.34 2.33 4 1								
	Average waiting time (working day)				**Average waiting time (weekend)**			
	2009	**2010**	**2011**	**2012**	**2009**	**2010**	**2011**	**2012**
7 to 9	45,0	17,5	15,1	n.a	31,5	21,1	16,9	n.a
9 to 17	23,9	13,9	21,2	n.a	23,1	11,0	15,5	n.a
17 to 20	41,6	17,5	55,6	n.a	35,8	12,9	19,5	n.a
2.33 2.32 4 1								
	Average waiting time (working day)				**Average waiting time (weekend)**			
	2009	**2010**	**2011**	**2012**	**2009**	**2010**	**2011**	**2012**
7 to 9	7,3	5,8	6,6	n.a	6,0	6,3	4,5	n.a
9 to 17	6,2	6,4	7,3	n.a	7,2	4,8	6,4	n.a
17 to 20	7,3	7,1	8,7	n.a	8,4	5,9	6,4	n.a
2.32 2.31 4 1								
	Average waiting time (working day)				**Average waiting time (weekend)**			
	2009	**2010**	**2011**	**2012**	**2009**	**2010**	**2011**	**2012**
7 to 9	25,1	16,2	15,8	n.a	20,0	15,3	14,7	n.a
9 to 17	21,0	16,1	15,7	n.a	25,5	14,3	14,6	n.a
17 to 20	22,3	18,2	17,9	n.a	30,6	17,5	17,0	n.a

2.31 2.30 4 1								
	Average waiting time (working day)				Average waiting time (weekend)			
	2009	2010	2011	2012	2009	2010	2011	2012
7 to 9	52,1	83,4	34,9	n.a	48,4	73,4	27,4	n.a
9 to 17	46,7	96,1	44,4	n.a	47,2	73,6	30,8	n.a
17 to 20	67,4	123,1	47,1	n.a	58,4	103,8	29,1	n.a
2.30 2.29 4 1								
	Average waiting time (working day)				Average waiting time (weekend)			
	2009	2010	2011	2012	2009	2010	2011	2012
7 to 9	72,4	97,7	97,7	n.a	60,0	94,2	94,2	n.a
9 to 17	65,0	76,5	76,5	n.a	66,0	53,3	53,3	n.a
17 to 20	80,3	100,2	100,2	n.a	66,4	57,5	57,5	n.a
2.29 2.28 4 1								
	Average waiting time (working day)				Average waiting time (weekend)			
	2009	2010	2011	2012	2009	2010	2011	2012
7 to 9	117,5	29,9	11,4	n.a	88,5	46,1	46,1	n.a
9 to 17	62,1	25,9	12,6	n.a	55,5	19,7	12,5	n.a
17 to 20	133,8	32,3	14,4	n.a	131,2	26,2	10,2	n.a