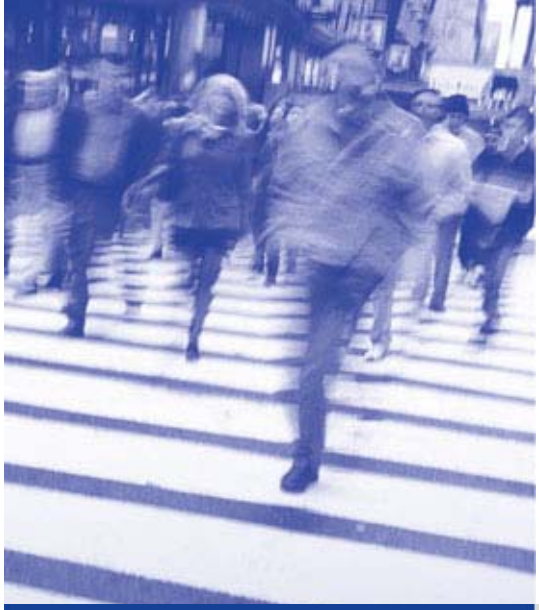

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Measure Evaluation Results

BOL 8.5 STARS: Automatic Enforcement of Traffic Lights

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Date: February 2013

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Executive Summary

Since 2004 the so-called STARS system was implemented in Bologna with the aim at enforcing traffic signals at intersection. STARS is a monitoring and automatic enforcement system which registers information on driver behaviours through the use of a photographic camera. The collected data is transferred once a week to the Municipal Police headquarters. With the MIMOSA measure 'STARS: Automatic Enforcement of Traffic Lights' the Municipality of Bologna sought to activate new structures and thus strengthen the enforcement system. The system was thoroughly tested and adapted once the public fibre optics network was available on site. The overall objective of the STARS system was a reduction of accidents at main road intersections.

The measure is related to two other MIMOSA measures which shared the common high level objective to improve road safety: BOL 5.1 'Urban Traffic Safety Plan' and BOL 5.2 'Safer Road to School'. This measure was implemented through the following stages:

Stage 1: Equipping crossings (2008 - 2012) Several strategic intersections were selected and equipped with boxes to hold surveillance cameras which raised the number of controlled intersections up to 15. Additionally, one camera has been replaced and added to the 4 already used before 2008.

Stage 2: Enforcement at intersections equipped with STARS (2009 - 2012) Based on the information collected by the STARS system, the Municipal Police Department could identify and fine drivers which transgressed the road code at the controlled intersection.

Stage 3 – Maintenance activities (2009 - 2012) A external office was set up to maintain the entire ITS system in the city. The maintenance allowed a better monitoring of operations and increase the overall efficiency in the management.

Because of the importance of the safety issue this measure was selected as a focused measure and in addition to the impact and process evaluation a cost-benefits-analysis (CBA) was conducted. The evaluation strategy of this measure sought to focus on a number of indicators in the fields of transport and society. Since the measure is related to two other MIMOSA measures aiming at reducing accidents rate in Bologna, a bundled indicator was selected to measure the accident rates on the city level and especially at the focused intersections. The second selected indicator is the amount of fines distributed on selected (dangerous) intersections. While a reduction of accidents expressed an improvement regarding road safety, a reduction of fines distributed can be interpreted due to changes in drivers' behaviors.

Key-results of the evaluation highlighted the positive effects of the measure and of the STARS concept on the road safety in Bologna. The results showed that there was a 21% reduction in accidents and a 28% reduction in injuries at traffic lights where STARS was installed, comparing data from August 2011 with the baseline. It should be mentioned that a small but constant decrease in traffic flows was also recorded in the surrounding of the focused intersections during the same periods which also impacted on the reduction of accidents.. The STARS system is distributed on the city-scale, covers a large area which influences drivers to change their behaviours at all intersections. Hence a reduction of accidents was also observed in the entire road network of Bologna as shown in the bundled indicator (accidents, people injured and killed throughout the Municipality of Bologna): a significant reduction of 21.1% on accidents from 2010 to 2007 and 21.65 fewer people injured over the same period.

The CBA was conducted taking into account all the years of the STARS 'lifetime' beyond the MIMOSA period. The net present value was computed by summing all costs and benefits for each year. The values obtained were brought back to the present using the *social discount rate*, underlying the **cost effectiveness** of the project during the 18 years of evaluation. The results of the CBA showed the great cost effectiveness of the STARS concept. With a relatively small investment, the concept produced large returns in terms of public safety and benefits for the Municipality too. The CBA showed that in one year of operation, the majority of investment costs for STARS were covered.

Surprisingly and despite the initial impressions and perplexities, positive feedback on the system from the public due to the social and safety benefits (fewer deaths and injuries) had a positive impact on the operation process and was thus an important **driver**. This was important due to the **barrier** which became apparent in the implementation phase: a negative campaign in the Italian press criticised the implementation of this kind of measure and technology. This was due to the fact that there were some bad examples in other Italian cities which led to criminal sentences against the operator of the enforcement system. The impact of this barrier, which only occurred in the initial months of the Measure (local newspapers did not help, calling STARS 'The traffic light killer'), was that it gave people the idea that the Municipality only installed the equipment to earn money 'illegally' through fines. This initially resulted in a higher number of disputes over fines.

It is recommended to cities interested in such an intervention to give special attention on **communication issues**. Indeed the implementation of controlled intersection can be negatively perceived as a repressive measure applied by the local authorities with the single aim to increase public revenues. It is therefore advised to communicate on the initial objective of the measure – improve road safety – and to present fines as an ultimate tool to enforce road rules. Thereby, the STARS system is particularly suitable in urban agglomeration where motorists generally do not obey the road code. Such behaviours are often observed in countries with the most recent and rapid phenomenon of mass motorization.

The measure *could and should* be replicated in other cities because of its good cost/benefit ratio. Compared to the investment, operation and maintenance costs, it was possible to achieve significant results in road safety in terms of: fewer accidents. STARS also allowed the Municipality to continuously monitor dangerous junctions to detect potentially dangerous behaviours which would otherwise require the continuous and expensive presence of police officers. Fines were issued automatically when vehicles crossed the junctions when the traffic lights were red. The STARS system was widely accepted by citizens of Bologna because they saw it as a mean of protecting law-abiding motorists and vulnerable users (pedestrians and cyclists). This positive trend will hopefully be continued in the future.

A Introduction

A1 Objectives

The Measure objectives were:

(A) High level / longer term:

- Improvement of quality of life

(B) Strategic level:

- To improve Innovative Online Transport Systems to reduce illegal behaviour at crossings
- Compliance with driving rules

(C) Measure level:

- To reduce accidents at crossings; to reduce the number of people killed or injured.

A2 Description

STARS is a monitoring and automatic enforcement stystem for red traffic lights, consisting of a photographic camera positioned in a protective device. When traffic lights are *red*, the camera takes pictures of vehicles illegally crossing the junction. The pictures are then sent to the Municipal Police Department. Police officers check and validate the photos and fines are then automatically sent to the offender. The images are stored for use in any legal disputes and statistics for evaluation.

STARS has been in use in Bologna since 2004, when the experimental phase was introduced. In 2008 funds provided by a national project made it possible to purchase new cameras and protective structures for newly monitored junctions. With MIMOSA the Municipality of Bologna intended to activate the structures and strengthen the system, by:

- Analysing and selecting locations,
- Fitting out junctions: activating camera structures, connecting them to traffic light hardware, installing sensors,
- Making technical improvements and maintaining the equipment,
- Supporting the enforcement activity, requiring a considerable amount of human resources and data storage.

The goal was to improve and fine-tune the system's hardware and software and maintain the tools and instruments already available.

PICTURE A.2.1.1 The STARS System

Source: Municipality of Bologna

The picture above shows and example of traffic light equipped with STARS. Every traffic light has a sign informing drivers that STARS is in use.

B Measure Implementation

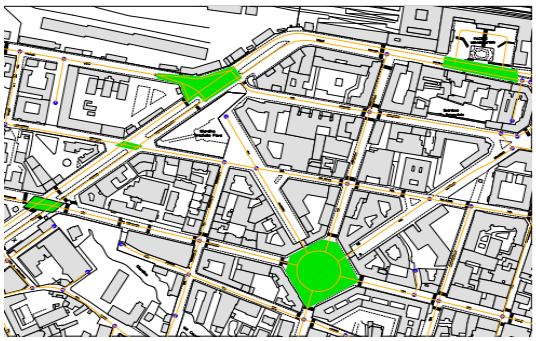
B1 Innovative Aspects

Use of new technology/ new conceptual approach - The first installations proved that STARS technology is the most efficient cost/benefit response to the problem of drivers going through red lights. However, an online system, directly connected to the Municipal Police headquarters, and a new IP camera were tested to seek out possible improvements for use once the Municipality's fibre optic network was available on site.

B2 Research and Technology Development

RTD work consisted of a preliminary study aimed at defining traffic black spots around the city of Bologna. The study helped identify crossings where road safety intervention was needed, including the installation of the STARS system. A black spot is a term used in road safety management to describe a place where road traffic accidents have historically been concentrated. Black spots were detected with reference to the location types shown as follows:

NODE	*	The node is an intersection point where two or more arcs meet.
ARC		The arc is a series of points, joined by straight line segments, that start and end at a node.
COMPLEX CROSSING		Set of arcs and nodes that together represents an intersection



Black spots were detected with reference to the following themed maps:

(i) number of accidents
(ii) accidents with casualties,
(iii) casualty rate,
(iv) injury rate,
(v) accidents with pedestrians,
(vi) accidents with cyclists.

Data was processed in two different ways:

a. Specific themed representation with reference to the universe of disposable data: this formed the basis for priority assignation of all road safety reports addressed to the Municipality;

b. Themed representations with reference to locations where the specific theme has taken on particular importance.

The first analysis showed a great number of locations with a high number of accidents (Reference 1). Based on these locations, it was decided where to concentrate infrastructural and administrative interventions, taking into account the Municipality's financial resources and operating capacities. The priority was not only to focus on fatalities,but also on other elements considered during the initial analysis, such as the total number of accidents and injury rates. Priority criteria were chosen so that intervention would guarantee the greatest possible reduction in fatal accidents as well as the greatest possible reduction in the total number of accidents and injuries.

30 priority locations were identified, divided as follows:

i) locations with the following conditions, based on the reported priority order:

1) recidivism of casualties between 2002-2004

2) recidivism of casualties between 1999-2004

ii) locations with the following conditions, based on the reported priority order:

1) greatest number of accidents between 2002-2004

2) greatest number of accidents during 2004

3) greatest amount of injuries between 2002-2004.

Tables on crossings with recidivism of casualties (years 2002-2004) and the greatest number of accidents and injuries are avilable in Reference point 3.

Based on this analysis, the STARS system was positioned as part of the planned interventions in order to reduce traffic accidents. Considering financial resources, 15 video-controlled crossings were set up, corresponding to 24 intersections controlled by STARS (one camera can check more than one intersection): Saffi Malvasia, Lenin Po, Mattei Martelli, San Donato Del Lavoro, San Donato Repubblica, Carducci Dante Dagnini Orti, Masi Leandro Alberti, Shakespeare Peglion, Beroaldo Andreini, Murri Gandino, M.E. Lepido Cavalieri Ducati, Togliatti De Pisis, Sabotino Vicini, Laura Bassi Mezzofanti.

B3 Situation before CIVITAS

Italy's National Plan for Road Safety states that 83% of road accidents are caused by incorrect driver behaviors and 35% of fatalities are caused by speeding or jumping traffic lights, especially near pedestrian crossings. Under the Urban Road Safety Plan, Bologna implemented pilot sites (crossings) with an automatic enforcement system (named STARS) to detect and issue fines to vehicles jumping red lights. Before the introduction of STARS it was difficult to punish all illegal driver behaviour at crossings: traffic police could only sanction traffic offences they saw in person.

Improvements to the system were funded by a national project. The new cameras became operative at the start of CIVITAS – MIMOSA.

B4 Actual Implementation of the Measure

A description is given below of the Measure implementation stages over the years covered:

Part 1 **Equipping Crossings** (2008-2012):

- installation of new stations for cameras; the Municipality of Bologna opened new video-controlled crossings, obtaining a total of 15 video-controlled junctions (2008);

- definition of specifications for the purchase of new stations and the transformation of some existing stations from analog to digital (2012)

Part 2 Enforcement at the junctions equipped with STARS (2009-2012)

- enforcements were put into place throughout the Measure implementation;
- the Municipal Police Department analyzed the possibility of extending the number of junctions equipped with STARS, identifying those with the highest number of accidents (2010)

Part 3 Maintenance activities (2009-2012)

- maintenance activities were carried out for the system and on-street cameras;
- a specific office was set up to manage maintenance for all ITS systems in the city. This was aimed at improved monitoring for the system and better overall organization.

B5 Inter-Relationships with Other Measures

The Urban Traffic Safety Plan (2006-2008), part of the PGTU (Urban Traffic Plan), set out the Municipality of Bologna's measures for improving traffic safety conditions. This objective,particularly in favour of more vulnerable categories - pedestrians and cyclists, was pursued through different actions: Measure 5.1, aimed at vulnerable users and interventions to improve crossing safety; Measure 5.2 on safer routes to school, aimed at young people; and Measure 8.5, focusing on reducing improper driver behaviours at crossings. All the measures mentioned above had their own targets and domain of application, with specific indicators that evidenced the measure's impact.

It is certainly true that all these measures pursued the common objective of improving road safety. In this sense the number of accidents recorded throughout the Municipality of Bologna can be assumed as a bundled indicator, resuming the general improvement on road safety to which these three measures certainly contributed.

C Impact Evaluation Findings

C1 Measurement Methodology

The Measure evaluation was based on *unproblematic* data in terms of availability and accuracy in order to give homogeneous and comparable indicators. Variations in safety conditions were evaluated considering the following relationships:

- changes in driver behaviours through fines for dangerous driving: the reduction in the number of fines meant a greater sense of responsibility and a reduced risk of accidents;
- the variation in the danger levels of roads according to the number of road accidents; a reduction in these numbers meant an improvement in objective safety conditions at the monitored crossings.

The measurement was based on the number of fines recorded by the crossing control system and the action carried out by the Municipal Police in case of road accidents causing injury and damage.

Considering that STARS was introduced before Mimosa and that during Mimosa the system was being implemented, evaluation was carried out separately in order to evaluate the merits of the automatic enforcement system in reducing accidents, injuries and fatalities. Consideration was given both to the effect of the STARS system in general and the particular effect of adding other installations during the Mimosa project.

C1.1 Impacts and Indicators

The following indicators were chosen to show changes in driver behavior and the danger level of roads.

TABLE C1.1.1 Measure 8.5 local indicator

Indicator	Evaluation area	Evaluation category	Impact	Indicator	Source of data
1	Society	Acceptance	Acceptance	Trend of fines	Municipal Police

TABLE C1.1.2 common core indicator

Indicator	Evaluation area	Core indicator	Impact	Indicator	Source of data
2	Transport	20	Transport safety	No. of injuries and fatalities caused by accidents at each monitored junction	Statistics from Municipal Police

TABLE C1.1.3: Bundled indicator -5.1 - 5.2 - 8.5

Indicator	Evaluation area	Evaluation category	Impact	Indicator	Source of data
3*	Transport	Safety	Transport safety	No. of injuries and fatalities due to accidents throughout the Municipality*	Statistics from Municipal Police

*Bundled indicator (Measures 5.1; 5.2 and 8.5)

Detailed description of the indicator' methodologies:

Indicator 1 -'Number of fines for each road crossing/junction'

Frequency: monthly; *Unit*: number of fines; *Domain*: number of vehicles crossing the monitored junction.

It is important to note that this is a problematic indicator. Before STARS was activated, all fines were issued manually in a traditional way, by police officers. A comparison between the before (manual) situation and after (automatic) situation was not possible, because the number of fines and thus infringements would be underrepresented. However, it is interesting to summarise the developments in the numbers, in order to show if and when drivers adapted their behaviour, and if after the first peak in fines they began to behave correctly.

Indicator 2 -'Number of injuries and fatalities caused by accidents at each monitored junction'

Frequency: yearly; *Unit*: number of injuries and fatalities; *Domain*: number of vehicles crossing the monitored junction.

The Municipality's objective was to decrease the number of accidents and increase correct behaviours. In order to evaluate the severity of the events, the Municipality distinguished between people injured and killed.

Indicator 3 -bundled 'Number of accidents, injuries and fatalities throughout the Municipality'

This indicator was the result of many features which were not always connected or closely related to the Mimosa project (e.g. areas where no mitigation measures are implemented, or could be easily influenced by other casual circumstances). Measures 5.2 (Safer roads to school) and 5.1 (Urban Traffic Safety Plan), aimed at improving urban safety, also influenced the indicator. As a consequence it can be considered a "bundled" indicator.

Unit: number of accidents, injuries and fatalities throughout the Municipality; *Domain*: the Municipality of Bologna.

C1.2 Establishing a Baseline

Indicator 1- 'number of fines for each road crossing'

Data was obtained considering each crossing separately betwen 2003 (when all fines were manual) and 2008. Because of their low number, fines issued manually after STARS implementation are not reported since they do not significantly change the results.

Indicator 2 -'number of injuries and fatalities caused by accidents at each monitored crossing'

Data on accidents and injuries was reported separately for each crossing. In order to estimate the effects of the Measure, the evaluation considered deltas between the number of accidents/injuries before and after the system was implemented, showing differences from

before the installation and considering that STARS systems were installed in different years. This is why the Municipality decided to not follow the approach of comparing numbers in 3-year-periods because of the loss of homogeneity.

Indicator 3 – 'Bundled- number accidents, injuries and fatalities throughout the Municipality'.

The number of accidents, injuries and fatalities was continuously monitored by the Municipality of Bologna. In order to evaluate the baseline, the trend of values between 1991 and 2008 was included, considering only accidents with injuries and/or fatalities.

C1.3 Building the Business-As-Usual Scenario

Making sure that traffic regulations are observed is a crucial concept in local administrations' safety programs. Several cities in Italy are introducing enforcement systems (particularly at traffic lights), and statistical data says that where there are strict controls, the number of accidents decreases.

General driver behaviour has been influenced since the introduction of STARS. Drivers couldn't exactly remember where the system was installed, but they were informed of the existence and location of the system at many crossings in Bologna. Thus the Measure also influenced data for crossings where the system was not installed.

Indicator 1 number of fines for each road crossing

The introduction of STARS totally modified the scenario in Bologna from the initial installations onwards. This is shown (see below) by the trend of manual fines issued at monitored crossings, which substantially decreased from 2004 onwards (all crossings). This might depend on different factors, such as a lower number of manual police checks and the first changes in driver behaviours.

The average value of fines issued during 2003 and 2004 can therefore be assumed as the business-as-usual reference value.

Indicator 2 number of injuries and fatalities caused by accidents at each monitored crossing

Without the introduction of automatic enforcement systems, as occurred in the past, police controls would have been insufficient to guarantee continuous monitoring and encourage drivers to behave differently at crossings. Therefore it is possible to think that accident statistics would have exceeded EU limits.

The BaU was calculated using the average number of fines and accidents before the implementation of STARS at each crossing (considering available data).

Indicator 3 –bundled- Number of accidents, injuries and fatalities throughout the Municipality

The trend of accidents, injuries and fatalities before the Mimosa project (see Measure results) underlines the stabilization of values during the years before 2008 (accidents between 5,700-5,800 units). The business-as-usual scenario was considered the state-of-the-art without the implementation of the interventions.

It has therefore been assumed that without the implementation of the Measure, accident data would not have changed during the BaU years; it has been assumed to be equal to the average of 3 years before 2008.

C2 Measure Results

The results are presented under sub headings corresponding to the evaluation areas society and transport.

C2.1 Economy

Not applicable.

C2.2 Energy

Not applicable.

C2.3 Environment

Not applicable.

C2.4 Transport

Indicator 2 number of injuries and fatalities caused by accidents at each monitored crossing

As with the number of fines issued, the evaluation effects were also analysed separately for (i) accidents/injuries at crossings where STARS was implemented before Mimosa and (ii) for crossings where the system was implemented during Mimosa. In the tables below the number of accidents and injuries after implementation of the system is highlighted in yellow.

TABLE C2.4.1 Number of accidents and injuries at each road crossing (STARS installations before Mimosa)

Crossings			Sept-02/ Aug-03	Sept-04/ Aug-05	Sept-05/ Aug-06	Sept-07/ Aug-08	Sept-08/ Aug-09	Sept-09/ Aug-10	Sept-10/ Aug-11	one year after- one year before	Δ%	August 2011- one year before	Δ%
1	Saffi	Accidents	17	13	5	3	2	3	7	**-12**	**-70,59%**	**-10**	**-58,82%**
	Malvasia	Injuries	28	16	8	3	2	3	8	**-20**	**-71,43%**	**-20**	**-71,43%**
2	Lenin	Accidents	10	5	5	7	4	6	8	**-5**	**-50,00%**	**-2**	**-20,00%**
	Po	Injuries	17	8	8	10	7	9	13	**-9**	**-52,94%**	**-4**	**-23,53%**
3	Mattei	Accidents	8	6	5	3	5	2	2	**-3**	**-50,00%**	**-4**	**-75,00%**
	Martelli	Injuries	16	7	7	3	8	5	3	**-4**	**-57,14%**	**-4**	**-81,25%**
4	San Donato	Accidents	11	11	7	10	4	4	2	**-1**	**-9,09%**	**-9**	**-81,82%**
	Del Lavoro	Injuries	13	18	9	16	6	11	2	**-2**	**-11,11%**	**-16**	**-84,62%**
CROSSINGS 1-4	**TOTAL ACCIDENTS**									**-21**	**-47,73%**	**-25**	**-56,82%**
	TOTAL INJURIES									**-35**	**-50,00%**	**-44**	**-62,86%**

Source: TeMA calculations using Municipality of Bologna data

The table above shows results obtained with the initial implementation of the STARS system. Accidents and injuries were reduced significantly comparing one year before to one year after and comparing August 2011 to one year before implementation.

TABLE C2.4.2 Number of accidents and injuries at each road crossing (STARS equipped during Mimosa)

Crossings			Sept-05/ Aug-06	Sept-07/ Aug-08	Sept-08/ Aug-09	Sept-09/ Aug-10	Sept-10/ Aug-11	one year after-one year before	Δ%	August 2011-one year before	Δ%
	San Donato	Accidents	5	2	3	2	3	**0**	**0,00%**	1	50,00%
5	Repubblica	Injuries	6+1fatalty	4	5	2	3	**-2**	**-50,00%**	-1	-25,00%
6	Carducci	Accidents	7	8	6	5	2	**-3**	**-37,50%**	-6	-75,00%
	Dante	Injuries	10	14	7	6	7	**-8**	**-57,14%**	-7	-50,00%
7	Dagnini	Accidents	3	5	1	4	0	**-1**	**-20,00%**	-5	-100,00%
	Orti	Injuries	2+1fatalty	6	1	5	0	**-1**	**-16,67%**	-6	-100,00%
8	Masi	Accidents	2	6	2	2	2	**-4**	**-66,67%**	-4	-66,67%
	Leandro Alberti	Injuries	3	7	2	2	2	**-5**	**-71,43%**	-5	-71,43%
9	Shakespeare	Accidents	4	0	0	3	2	**3**	**Not definable**	2	not definable
	Peglion	Injuries	8	0	0	4	3	**4**	**Not definable**	3	not definable
10	Beroaldo	Accidents	5	2	3	3	3	**1**	**50,00%**	1	50,00%
	Andreini	Injuries	6	2	3	7	5	**5**	**250,00%**	3	150,00%
11	Murri	Accidents	3	5	4	2	1	**-3**	**-60,00%**	-4	-80,00%
	Gandino	Injuries	3	6	5	2	2	**-4**	**-66,67%**	-4	-66,67%
12	M.E.Lepido	Accidents	4	1	0	1	9	**0**	**0,00%**	8	800,00%
	Cavalieri Ducati	Injuries	5	6	0	1	12	**-5**	**-83,33%**	6	100,00%
13	Togliatti	Accidents	3	3	2	5	4	**2**	**66,67%**	1	33,33%
	De Pisis	Injuries	5	7	2	7	5	**0**	**0,00%**	-2	-28,57%
14	Sabotino	Accidents	2	3	2	3	1	**0**	**0,00%**	-2	-66,67%
	Vicini	Injuries	2	5	2	5	2	**0**	**0,00%**	-3	-60,00%
15	Laura Bassi	Accidents	4	5	4	2	4	**-3**	**-60,00%**	-1	-20,00%
	Mezzofanti	Injuries	5	10	4	2	4	**-8**	**-80,00%**	-6	-60,00%
CROSSINGS 5-15	**TOTAL ACCIDENTS**							**-8**	**-20,00%**	**-9**	**-22,50%**
	TOTAL INJURIES							**-24**	**-35,82%**	**-22**	**-32,84%**

Source: TeMA calculations using Municipality of Bologna data

TABLE C2.4.3 Total accidents and injuries at all monitored crossings

		one year after-one year before	Δ%	August 2011-baseline (august 2008)	Δ%	August 2011-one year before	Δ%
ALL CROSSINGS	TOTAL ACCIDENTS	-29	-34,52%	-13	-20,63%	-34	-40,48%
	TOTAL INJURIES	-59	-43,07%	-28	-28,28%	-66	-48,18%

At traffic lights where STARS was installed, a comparison of data from August 2011 and the baseline (August 2008, when not all crossings were equipped) shows a 21% reduction in accidents and 28% in injuries. The reduction increases considering data from one year before installation and August 2011, showing a total reduction of 40% in accidents and 48% in injuries.

These results were obtained in a context of slightly but constantly decreasing traffic flows seen in Bologna during recent years.

The following table summarizes the results obtained and gives a comparison with the results obtained from the baseline and the business-as-usual considerations.

TABLE C2.4.4 Transport results

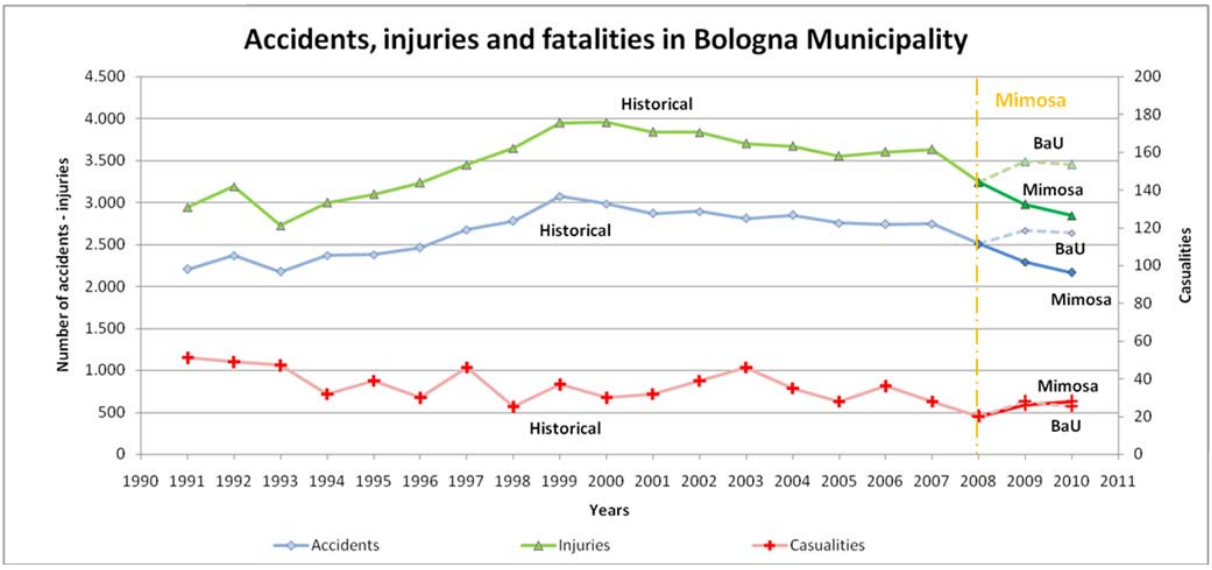
Indicator		Before (august 2008)	BaU (average before installations)	After (August 2011)	Difference: After – Before	Difference: After – BaU
No. of injuries and fatalities caused by accidents- all crossings	Accidents	63	87	50	-20,63%	-42,53%
	Injuries	99	133	71	-28,28%	-46,62%
No. of injuries and fatalities caused by accidents -only crossings equipped during Mimosa project	Accidents	40	41	31	-22,50%	-24,39%
	Injuries	67	61	45	-32,84%	-26,23%

The data shows how the number of accidents and injuries decreased significantly with the introduction of STARS, and the trend seems to continue for the years thereafter. The scenario without Mimosa would have been the same as the past years even if STARS had already been implemented at some crossings during the years before Mimosa; therefore the situation had already changed at crossings where the system was only implemented during the Mimosa period.

Indicator 3- Bundled 'Number of accidents, injuries and fatalities throughout the Municipality'

The data shows a significant reduction in values, with 21.1% fewer accidents from 2010 to 2007 (the last year without any Mimosa measure) and 21.65% fewer people injured in the same period. Tables for data shown in the diagram are given in Reference point 4. Data does not include pedestrian involvement, because they are not part of the target group for this Measure.

FIGURE C2.4.1: Number of accidents, injuries and fatalities throughout the Municipality, results



Source: Istat

C2.5 Society

Indicator 1 'number of fines for each road crossing'

The table shows data for each road crossing; fines issued manually before STARS activation are shown in dark grey; fines issued under the STARS system (from the year of installation) are shown in white/light grey(*).

As explained before, the table maintains the distinction between crossings equipped with STARS before 2008 (crossing numbers 1 to 4) and crossings where STARS was activated during Mimosa (after 2008).

TABLE C2.5.1 Number of fines for each road crossing/junction – Crossings 1-4

CROSSING/YEAR		2003	2004	2005	2006	2007	2008	2009	2010	2011
1	VITTORIO VENETO - SAFFI	3	2	320	212	26	18	0	0	0
	MALVASIA - SAFFI	66	63	296	169	80	373	9	0	0
2	LENIN - EMILIA LEVANTE	5	9	1.270	1.009	1.147	211	9	6	0
	PO - EMILIA LEVANTE	5	0	1.024	531	260	61	4	4	0
3	MATTEI - BASSA	3	2	583	1.704	653	201	0	0	0
	MATTEI - MARTELLI	1	1	556	1.653	606	204	4	0	0
4	S.DONATO – LAVORO	3	1	6	5	1	54	179	0	0
	LAVORO - SAN DONATO	0	0	531	2.612	2.085	320	4	0	0

Source: TeMA calculations using Municipality of Bologna data

(*) Road crossings where coil breakdowns/malfunctions occurred are shown in yellow.

The table above shows that with the introduction of the STARS system, the number of fines for each crossing increased significantly. Continuous monitoring allows Municipal Police to check intersections 24 hours a day and to punish *all* illegal behaviors. In the table, yellow boxes indicate years when coil breakdowns/malfunctions occurred at crossings. This problem occurs due to a lack of system maintenance, and it must be considered in data

interpretation. However, there is no negative impact on the Measure implementation because drivers are unaware of technical problems/breakdowns with the system.

TABLE C2.5.2 Number of fines for each road crossing/junction – Crossings 1-4 -TOTAL

CROSSING/YEAR		2003	2004	2005	2006	2007	2008	2009	2010	2011
CROSSINGS 1-4	***TOTAL FINES (STARS)***	***-***	***-***	***4.580***	***7.890***	***4.857***	***1.442***	***209***	***10***	***-***
	Δ % (compared to year before)				**72%**	**-38%**	**-50%**	**-91%**	**-95,2%**	***- 100%***
	FINES BEFORE STARS ACTIVATION (MANUAL)	**88**	**81**	**6**	**5**	**1**	**-**	**-**	**-**	**-**
	TOTAL FINES (STARS + MANUAL)	**86**	**78**	**4.586**	**7.895**	**4.858**	**1.442**	**209**	**10**	**-**
	Δ % (compared to year before)			56%	72%	-38%	-71%	-98%	-67%	**-100%**

The table below takes into account eleven crossings equipped with STARS under the Mimosa project. Data from 2003 to 2007 is historical; values after 2008 are fines recorded during Mimosa implementation.

TABLE C2.5.3 Number of fines for each road crossing – Crossings 5-15

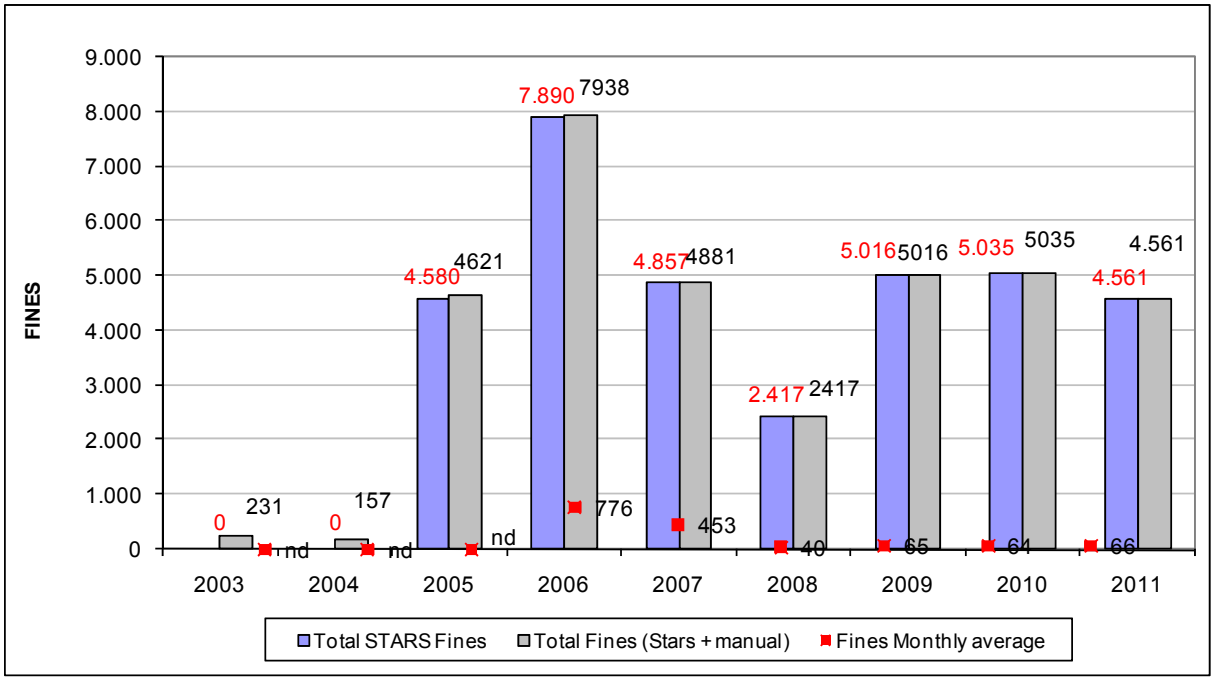
CROSSING/YEAR		2003	2004	2005	2006	2007	2008	2009	2010	2011
5	S.DONATO - REPUBBLICA	2	3	1	0	0	34	74	38	0
6	CARDUCCI - DANTE (DIR.S.STEFANO)	10	6	2	3	3	127	593	745	713
	CARDUCCI - DANTE (DIR.S.MAZZINI)	9	6	2	4	1	77	436	428	472
7	ORTI - DAGNINI (DIR.CENTRO)	3	5	0	2	0	22	100	65	209
	ORTI - DAGNINI (DIR.PERIFERIA)	4	4	0	2	0	0	33	26	0
8	MASI - L. ALBERTI	3	3	0	4	3	18	114	0	0
	L.ALBERTI – MASI	1	0	0	0	0	16	27	27	0
9	SHAKESPEARE - PEGLION (DIR.PERIF.)	1	1	1	0	0	153	859	719	227
	SHAKESPEARE - PEGLION (DIR.CEN.)	2	0	0	0	0	39	144	180	30
10	ANDREINI - BEROALDO	7	5	1	4	1	24	32	27	13
11	MURRI – GANDINO	3	2	1	0	0	12	98	84	0
12	M.E.LEPIDO - C.DUCATI	19	11	7	6	2	20	69	54	51
	M.E.LEPIDO – SALUTE	10	5	5	3	1	12	95	58	271
13	TOGLIATTI - DE PISIS (DIR. CENTRO)	4	1	2	6	2	37	503	725	156
	TOGLIATTI - DE PISIS (DIR. PERIFERIA)	5	1	5	3	2	72	237	196	278
14	SABOTINO - VICINI (DIR. P.TA S.ISAIA)	35	18	4	5	5	201	1.145	1.189	1346
	SABOTINO - VICINI (DIR. P.TA S.FELICE)	7	4	2	0	1	64	165	363	554
15	L.BASSI – MEZZOFANTI	2	1	0	1	1	25	59	62	214
	MEZZOFANTI - LAURA BASSI	18	3	2	0	1	22	24	39	27

Source: TeMA calculations using Municipality of Bologna data

The graph below shows results obtained from the eleven crossings equipped with STARS during 2008, plus the results obtained considering all crossings in the Municipality of Bologna. After 2008 manual fines were no longer calculated, considering their different order of magnitude. This explains why the two columns are exactly the same from 2008 onwards.

The graph refers to the table available in Reference point 5)

FIGURE C.2.5.1 Fines before and after STARS activation (all crossings)



The number of fines greatly increased after the initial installation (between 2004, when all fines were manual, and 2005, when STARS was first activated), showing how the traditional Police Department controls were insufficient. After 2006, theyear with the maximum number of fines, despite the small number of monitored crossings, driver behaviour improved. The number of fines increased again after 2008, when new crossings were equipped with STARS when the Mimosa project was introduced. Despite coil breakdowns, which interrupted monitoring activity at some crossings, the number of fines seems to have stabilised between 2009 and 2011.

The following table summarizes the results obtained and compares results obtained from the baseline before and the business-as-usual considerations.

TABLE C2.5.4 Society results

Indicator	Before (2008)	B-A-U (average 2003-2004)	After (2011)	Difference: After-Before	Difference: After – BaU
Trend of fines (all crossings)	2.417	194	4.561	+89%	+2251%
Trend of fines (crossings equipped during Mimosa)	1.029	114	4.561	+343%	+3901%

Source: Municipality of Bologna

Considering the developments of the numbers, the initial conclusion is that the Municipality improved the number of fines issued. The table below shows the monetization of fines from 2003 to 2011. This value does not indicate actual income for the Municipality because of fines which were unpaid or disputed, but it is significant when comparing the order of magnitude from before and after the implementation of Mimosa.

TABLE C2.5.5 Trend of fines - monetization

	2003	2004	2005	2006	2007	2008	2009	2010	2011
TOTAL FINES all crossings	231	157	4.621	7.938	4.881	2.417	5.016	5.035	4.561
TOTAL €	15.766	21.595	637.698	1.095.444	697.983	345.631	752.400	755.250	702.394

Source: TeMA calculations on average data

The introduction of STARS radically changed the scenario in Bologna, making it possible to monitor and punish incorrect driver behaviours that otherwise would not have been recorded *but committed nonetheless*. Therefore, in order to significantly interpret driver behaviours, the business as usual scenario is not significant. It is however significant when considering the effective impossibility of police officers physically monitoring all infringements and consequently the importance of introducing automatic enforcement systems.

In order to make considered evaluations, it is necessary to monitor the level of STARS fines imposed from 2009 onwards (one year after the complete STARS activation). As reported above, the number of fines stabilised during 2009 -2010 and 2011, and this probably indicates that drivers did not significantly change their behaviour. It is important to underline that an improved approach to Measure results could be obtained by crossing fines from a single intersection with its own traffic data recorded by the loop used for the STARS system. This kind of approach would make it possible to compare the number of irregular behaviours to volumes of traffic flow.

C2.6 Cost-Benefit Analysis

The STARS project was evaluated using a cost-benefit analysis (CBA). The CBA considered the following stakeholders: Authorities (Municipality of Bologna), private vehicle users and residents, with their own costs and benefits.

The peculiarity of this Measure was its highly random character, strongly dominated by chance. It is obvious that the quantity of injuries or fatalities is not completely dependent on the number of accidents. As an example, a single crash alone might happen at a specific crossing in a specific year, but what if the specific accident involved a bus with many people on board. In this case forecasts based on historical data considering accidents and averages of people injured would be completely far from reality. Considering the relative difficulty of forecasting whether Measure 8.5 will progress, CBA assumptions were undertaken using a cautious approach which involved understimating benefits and overestimating costs. Following the net present value formula, costs and benefits were selected from an established period from 2009 to 2020:

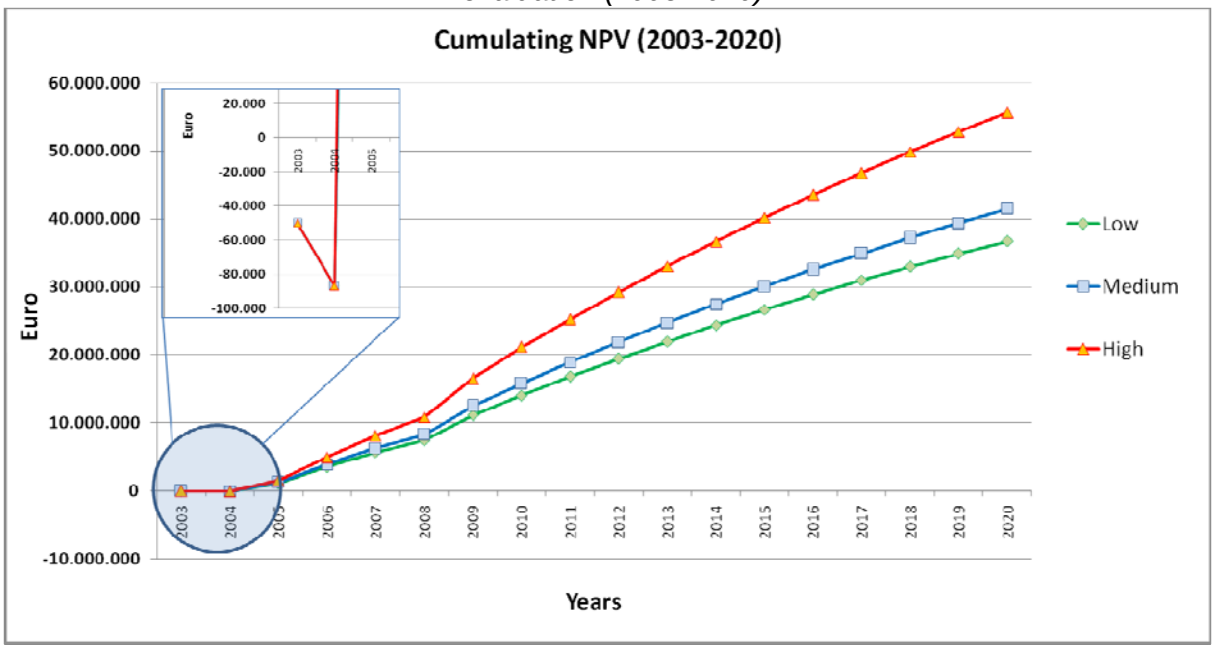
- Costs: Cost of analysing the worst crossings in terms of safety for drivers and pedestrians; initial investments for fitting crossings with cameras (costs of boxes and cameras themselves; each crossroad had a fixed structure on the traffic light where the camera was placed; cost of ordinary system maintenance (replacing old or broken cameras, changing damaged boxes on traffic lights, changing coils broken by road works).
- The Benefits related to: increased number of fines; decrease in accidents (based on indicator 2 or 3), decreased injuries and fatalities. Three types of scenario were built considering the data related to the decrease in accidents. Because no detailed data

was available on the severity of accidents, the values were considered equal to slight injuries for one scenario; considering that this value is not exact, a sensitivity analysis was done using v/3 as the lower boundary (second scenario) and v*3 as the higher boundary (third scenario), with v = value for slight casualties.

The CBA analysis considered all years of the STARS 'lifetime', not only the period of Mimosa (2008-2012). The Mimosa CBA was designed to investigate the advantages and disadvantages of the project itself and whether it could be replicated in other cities. It appeared reasonable to consider all costs sustained by the Municipality for the complete implementation of the system and consequentially all the benefits produced, not only the part of the project implemented during Mimosa.

The net present value was evaluated first of all by summing all cost and benefit items for each year. The values obtained were brought back to the present using the *social discount rate.* As suggested by CBA guidelines, for a sensitivity analysis the value of this economic indicator was varied between 0.02, 0.035 and 0.055. Applying these social discount rates to the three scenarios defined (with reference to the values/cost of road accidents), it was possible to obtain nine NPV values, all with a **significant positive value**, underlining the unquestionable economic benefit of the Measure during the 18 years of evaluation, despite the very conservative assumptions. The graph below shows the three NPV calculations obtained with the medium social discount rate (0.35).

FIGURE C2.6.1: Calculation of Net Present Value of STARS Measure during period of evaluation (2003-2020)



Source: CBA-TeMA

C3 Achievement of Quantifiable Targets and Objectives

No.	Target	Rating
1	To reduce accidents at crossings; to reduce the number of people killed or injured	★★

NA = Not Assessed O = Not Achieved ★ = Substantially achieved (at least 50%)

★★ = Achieved in full ★★★ = Exceeded

The targets and objectives of the Measure can be considered to have been achieved in full. The indicator trends show a significant reduction in accidents and related injuries during the years of the Mimosa project. Considering STARS was already implemented at 5 crossings in 2004, the further reduction of 20% in accidents and the 90% increase in fines issued comparing 2008 and 2011 while the Measure was in force, means that the system had positive effects on driver behaviour.

C4 Up-Scaling of Results

Potential up-scaling of this Measure (installing cameras at every crossing) would not necessarily improve safety. After the initial installments, improved driver behavior was seen even where the enforcement system was not present; the positive results were achieved by covering the black spots only. On the contrary, extending enforcement to hundreds of crossings might generate problems regarding the acceptance of the system and the perception of a punishing attitude by the Municipality. This situation has occurred in other Municipalities and debate over the acceptance of the enforcement system is very current in Italy.

Despite this, as reported in the section ‘actual implementation of the measure’, the Municipal Police Department evaluated the possibility of extending the number of junctions equipped with STARS, by identifying junctions with a higher number of accidents. This evaluation, and its potential effects, was studied by the Municipality of Bologna, which decided to increase the number of junctions equipped with STARS (to be realized after the Mimosa project).

C5 Appraisal of Evaluation Approach

The indicators used to evaluate safety improvements generated by the STARS system (the number of accidents and injuries) correctly reflected the evolution of the scenario and helped guide Municipality decisions. These indicators were also continuously monitored to identify potential new applications for the system. Regarding the trends of fines, the before data (manual fines before the ITS system) is not significant as regards considerations on driver behavior and the effects on safety. In fact previous data is important in showing how police controls were insufficient not only to punish dangerous behaviors but above all to indicate where incorrect driving habits were concentrated.

If another city were to implement this kind of system, a test period would be the best solution for obtaining valid ‘before’ data, comparable with the data obtained during implementation of the Measure: as the Municipality begins to use the system, it starts to record potential fines without issuing them.

C6 Summary of Evaluation Results

The key results are as follows:

- **Key result 1** - accidents reduced by 21% at all crossings equipped with STARS;
- **Key result 2** - injuries reduced by 28% at all crossings equipped with STARS;

By introducing this new automatic technology, the number of fines issued for incorrect behaviours at crossings increased significantly, by 88% (comparing 2011 with 2008).

C7 Future Activities Relating to the Measure

Thanks to the success of the Measure, the Municipality decided to implement the system by purchasing new cameras, shifting from analogue to digital operation and implementing the stations equipped with STARS (to be realized after MIMOSA).

D Process Evaluation Findings

D0 Focused Measure

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

2	Most important reason
6	Second most important reason
3	Third most important reason

These choices take reference from the checklist reported 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

No deviations from the original plan

D2 Barriers and Drivers

D2.1 Barriers

Overall barriers

- **Coil breakdowns/malfunctions caused by road works and weather conditions.** These problems blocked normal system operations and the possibility of photographing (and thus recording) the infringements. In addition, from the general public's point of view, knowledge of these malfunctions might cancel out the deterrent effect of the measure and reduce faith in public instruments and institutions.
- **Lack of economic resources** needed to solve maintenance problems and breakdowns occurring due to road works and normal wear and tear. Some of the

normal system operations were interrupted at road crossings while waiting for funds to proceed with repairs.

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

- **'The Traffic Light Killer'- a negative** campaign in the Italian press criticised the implementation of this kind of measure and technology. This was due to the fact that there were some bad examples in other Italian cities which led to criminal sentences against the operator of the enforcement system. The impact of this barrier, which only occurred in the initial months of the Measure (local newspapers did not help, calling STARS 'The traffic light killer'), was that it gave people the idea that the Municipality only installed the equipment to earn money 'illegally' through fines. This resulted in a higher number of disputes over fines.

D2.2 Drivers

Overall Drivers

- **Positive feedback from the public –** Despite the initial impressions and perplexities (also related to the second barrier presented above), positive feedback on the system from the public due to the social and safety benefits (fewer deaths and injuries) had a positive impact on the operation process, helping to carry out the Measure activities.

D2.3 Activities

Overall activities

With reference to the third barrier presented above, the Municipality undertook two kinds of actions:

- **Setting the 'amber' phase -**The duration of the 'amber' phase of the traffic lights was set at to 4 seconds (annual review of the regularized system). Sometimes the impression is that the 'amber' phase is really short. Consequently, when drivers approach traffic lights, they do not know what to do: accelerate through the crossing or stop, with the fear of being hit by vehicles behind them. This action was taken in order to increase the precision of the system, avoiding any disputes over fines related to the length of the 'amber' phase. The consequence was that feedback on the system from the public remained positive (STARS is perceived as a reliable and precise certificated system). Certifying the 'amber' phase duration led to a decreased number of disputes over fines.
- **Installation of non-compulsory road signs before the monitored crossings –** This action was taken in order to inform drivers when the automatic enforcement system was installed at particular traffic lights. This kind of information is designed to make the public aware that the Measure objective is to reduce accidents, injuries and fatalities at crossings, not to earn money through fines.

An action related to the first barrier presented above was also implemented:

- **An office was set up to manage all ITS systems**. The aim was to help solve the maintenance problems experienced by the Municipality of Bologna during the Measure implementation, to better monitor the functioning of the systems and improve the overall organisation without repeating tasks or wasting time. Maintenance activities were stepped up during the last year of the Measure implementation. It should be noted that before the repairs there was nonetheless no negative impact on the

Measure implementation. STARS is a “moving” system: cameras were moved around monitored crossings depending on traffic needs and the public did not know about the system’s technical problems/breakdowns.

D3 Participation

D3.1 Measure Partners

- **Measure partner 1 – Municipality of Bologna – COBO** Municipality of Bologna technicians were involved in the project and validation activities, while the Municipal Police Department issued fines.

D3.2 Stakeholders

- **Car drivers/motorists –** by driving incorrectly, these stakeholders are responsible for most accidents. The Measure aimed to ‘educate’ road users by showing them that the objective of the tool was to improve road safety, using a reliable and precise certificated system.

D4 Recommendations

D4.1 Recommendations: Measure Replication

- **Low investments comparing to benefits-** The Measure could be adopted by other Public Administrations with relatively low investments (fitting traffic lights with photographic equipment and maintaining it) compared to the potential benefits. Moreover, the Measure would be welcomed due to the direct economic impact from the number of fines that the Administration might collect. This effect is also a way of assigning to the private transport system the social costs that it generates.
- **Encourage a more conscious use of the car -** The efficiency of the STARS system can be improved in contexts where there is a greater degree of freedom for motorists to respect the rules of the road. The STARS system is suitable for urban environments where motorists are generally inattentive to the rules of the road (generally countries where mass motorization is a more recent phenomenon). The Measure can produce immediate effects without resorting to civic (road) education policies aimed at a higher objective: changing driver behaviour in the medium/long term.

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

- **Invest in communication strategies for the public -** The aim of this kind of measure is to improve road safety. In this particular case, however, the fact of punishing incorrect and dangerous behaviour is easily interpreted as a simple way for the Municipality to earn money. Public Administrations must demonstrate how the fines are only issued as a last resort when, despite all the communications/information provided (e.g. press campaigns, non-compulsory road signs before monitored crossings, variable message boards) incorrect behaviours persist.

F Annex

(1) The main results are as follows:

- Black spots with the greatest number of total accidents were concentrated in the city centre and just outside the city centre. In each of these locations there were between 19 and 37;
- Black spots with the greatest number of accidents involving pedestrians and cyclists were located in the central and semi central area. Here there were between 3 and 5 accidents (2002-2004). These kinds of accidents were not concentrated, but occurred in a wider area throughout the city;
- Between 1999-2004, 166 people were killed on urban roads. 19 of these fatalities occurred in 9 locations (crossings or street arcs); in every one of these locations there were 2 fatal accidents.

Example of graphic analysis showing the total number of accidents

Source: Municipality of Bologna

(2)

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

(3) Tables on crossings with recidivism of casualties (2002-2004) and the greatest number of accidents and injuries.

Crossings with recidivism of casualties (2002-2004)

	Street/crossing	Stretch of road	Accidents	Injuries	Fatalities
1	VIALE GIOSUE' CARDUCCI	VIA DANTE	22	28	2
2	VIA CROCIONE	VIA PIETRO FIORINI	3	3	1
3	VIA GIUSEPPE MASSARENTI	VIA GIAMBOLOGNA	4	4	0
4	VIA LEANDRO ALBERTI	VIA ERNESTO MASI	7	7	2
5	VIALE ANGELO MASINI	FROM VIA BAROZZI TO VIA BAROZZI	5	5	0
6	VIA TOSCANA	FROM VIA PERGOLESI TO VIA SETTE LEONCINI	8	10	1
7	GIOVANNI GOZZADINI STREET	FROM PASCOLI STREET TO DEL BARACCANO SQUARE	6	6	1
8	GIUSEPPE MASSARENTI STREET	FROM BENTIVOGLI STREET TO PAOLO FABBRI STREET	8	10	0

Crossings with the greatest number of accidents and injuries

	Street/crossing	Stretch of road	incidents	injuries	Fatalities
9	VIA AUGUSTO MURRI	VIALE ALFREDO ORIANI	28	38	0
10	SANTO STEFANO GATE		26	30	0
11	ST ISAIA GATE		26	31	0
12	VIA EMILIA PONENTE	VIA MARZABOTTO	22	30	0
13	PIETRAMELLARA - DON MINZONI		22	27	0
14	VIA URBANA	VIA TAGLIAPIETRE	21	31	0
15	ST FELICE GATE		20	34	0
16	VIALE DELLA REPUBBLICA	VIA LUIGI RASI	12	13	0
17	VIA AUGUSTO MURRI	VIA ERNESTO MASI	16	23	0
18	ROTONDA ITALIA	VIALE ROBERTO VIGHI	9	11	0
19	VIA DEL LAVORO STREET	VIA VEZZA	9	10	0
20	VIALE ANGELO MASINI	FROM VIA BAROZZI TO PIAZZA XX SETTEMBRE	13	14	1
21	VIA WILLIAM SHAKESPEARE	VIA VITTORIO PEGLION	12	22	0
22	VIA S.DONATO	VIA ISABELLA ANDREINI	18	31	0
23	VIA CIMABUE	VIA FRANCESCO BARACCA	13	21	0
24	VIA FILIPPO BEROALDO	VIA ISABELLA ANDREINI	12	19	0
25	MARCO POLO ROUNDABOUT		13	20	0
26	VIA GIACOMO MATTEOTTI	VIA FRANCESCO ALBANI	15	23	0
27	VIA FRANCESCO ZANARDI	VIA AMEDEO PARMEGGIANI	14	21	0
28	SARAGOZZA GATE		16	23	0
29	VIA STALINGRADO	VIA CESARE GNUDI	14	20	0
30	VIA BEROALDO	VIA ELEONORA DUSE	12	17	0

(4) Number of accidents, injuries and fatalities throughout the Municipality of Bologna, results

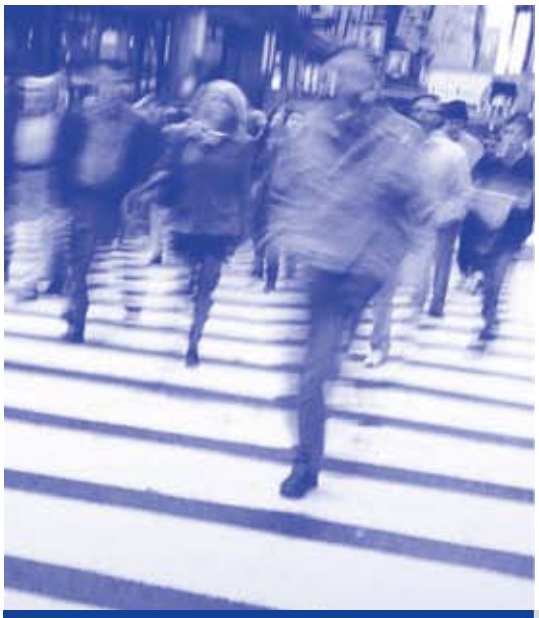
Year	Accidents with injuries or fatalities (1)	Number of people killed (2)	Number of people injured	*Pedestrians involved*		
				Fatalities	*Injured people*	*Total*
1991	2.204	51	2.942	17	258	275
1992	2.367	49	3.189	9	281	290
1993	2.174	47	2.727	16	283	299
1994	2.370	32	2.998	13	288	301
1995	2.376	39	3.098	12	288	300
1996	2.463	30	3.235	8	299	307
1997	2.675	46	3.448	18	317	335
1998	2.778	25	3.645	11	282	293
1999	3.071	37	3.949	6	372	378
2000	2.982	30	3.955	15	334	349
2001	2.869	32	3.841	10	294	304
2002	2.895	39	3.837	6	365	371
2003	2.810	46	3.703	16	302	318
2004	2.849	35	3.672	6	343	349
2005	2.755	28	3.554	8	358	366
2006	2.740	36	3.602	13	349	362
2007	2.743	28	3.630	6	333	339
2008	2.508	20	3.241	7	360	367
2009	2.288	26	2.976	*9*	*344*	*353*
2010	2.164	28	2.844	*9*	*329*	*338*
2011 (3)	Pending	pending	Pending	pending	Pending	pending

(1) Data does not include accidents with no injuries or fatalities; (2) Death occurred within 30 days of accident; (3) ISTAT Data is only available after many months; Source: Istat

5) Number of fines for each road crossing/junction – Crossings 5-15-TOTAL

CROSSING/YEAR		2003	2004	2005	2006	2007	2008	2009	2010	2011
CROSSINGS 5-15	***TOTAL FINES (STARS)***	-	-	-	-	-	***975***	***4.807***	***5.025***	***4.561***
	Δ % (comparing to year before)							393%	***4,5%***	***-9,2%***
	FINES BEFORE STARS ACTIVATION (MANUAL)	**145**	**79**	**35**	**43**	**23**	**-**	**-**	**-**	
	TOTAL FINES STARS + MANUAL	**145**	**79**	**35**	**43**	**23**	**975**	**4.807**	**5.025**	**4.561**
	Δ % (compared to year before)		-46%	-49%	17%	-50%	4139%	393%	5%	-9%
ALL CROSSINGS	***TOTAL FINES (STARS)***	-	-	***4.580***	***7.890***	***4.857***	***2.417***	***5.016***	***5.035***	***4.561***
	Δ % (compared to year before)							108%	0,4%	-9,4%
	FINES BEFORE STARS ACTIVATION (MANUAL)	**231**	**157**	**41**	**48**	**24**	**-**	**-**	**-**	**-**
	TOTAL FINES STARS + MANUAL	**231**	**157**	**4.621**	**7.938**	**4.881**	**2.417**	**5.016**	**5.035**	**4.561**
	Δ % (comparing to year before)		-32%	2843%	72%	-39%	-50%	108%	0%	-9%

Source: TeMA calculations using Municipality of Bologna data



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Bologna 8.5 Stars: Automatic Enforcement of Traffic Lights- Cost-benefit analysis

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

Date: 13 February 2013

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Table of Content

I. List of Abbreviations

BaU	Business-as-usual
BOL	Bologna Municipality
CBA	Cost-Benefit Analysis
STARS	Sanzionamento Transiti Abusivi Rosso Semaforico (system for red light intersection control and automatic enforcement)
PA	Public Administration

1 Introduction

The Municipality of Bologna wants to improve road safety and to reduce the number of accidents. The city has therefore implemented an automatic enforcement system at traffic lights called STARS to detect traffic light offences and to issue fines. In accordance with its Urban Road Safety Plan, Bologna has installed the STARS system at 24 pilot sites. The activities under CIVITAS are designed to support the enforcement activity requiring a considerable amount of human resources and data storage. STARS is a system for red light intersection control and automatic enforcement that consists of a photographic camera positioned in protective cases. .

STARS has been implemented since 2004 at 2 intersections in Bologna as part of an experimental phase. Under the MIMOSA project, Bologna Municipality intended to strengthen the system by installing additional structures for cameras and completing tests on the use of video-controlled systems. This not only supports stronger enforcement but also consistently updates data collection of black spots (places where road traffic accidents have historically been concentrated).

In contrast to the MRT analysis, the CbA takes into consideration the STARS project from its initial implementation in 2004 up to the final year of Mimosa 2011[1], therefore including the pre-MIMOSA phase. This approach is justified given that measure's effectiveness can't be evaluated merely starting from the beginning of Mimosa. STARS first implementation in 2004 had already positively influenced citizen's behavior driving behavior for fear of fines

Measure Objectives

(A) High level / longer term:

- Improvement of quality of life

(B) Strategic level:

- To improve Innovative Online Transport Systems to reduce illegal behaviour at intersections.
- Compliance with driving rules

(C) Measure level:

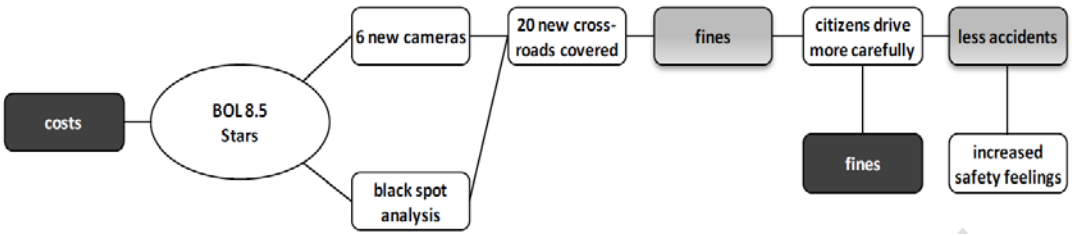
- To reduce accidents at intersections; to reduce the number of people killed or injured.

[1] 2012 data is not yet available

2 Costs and Benefits

The figure below shows, the cause and effect chain produced by Measure 8.5 as the first step of the evaluation.

Figure 2.1: Cause- and effect chain for BOL 8.5 STARS: Automatic Enforcement of Traffic Lights



The table 2.1 summarizes costs and benefits for each stakeholder group.

Table 2.1: Costs and benefits for different stakeholder groups of measure BOL 8.5

Stakeholder Group	Cost	Benefit
Public Administration	Cost for analysis of Black Spots Financial investment for equipment of crossings Cost for maintenance of system	Gain produced by more fines Decreasing number of accidents and injuries
Private vehicles users		Increasing of safety feeling
Citizens		Increasing of safety feeling

The Measure has a highly random characteristic, strongly dominated by the case. It is evident that the quantity of injuries or fatalities is not completely dependent on the number of accidents. For example, at a specific intersection a single crash may happen only once in a specific year, but what if the specific accident involves a bus with a lot of people on board. In that case forecasts based on historical data, that consider accidents and averages of people

injured would not reflect the reality of the situation.

Considering the related difficulty in forecasting measure 8.5 progressing, the CBA assumptions have conservatively underestimated the benefits and costs.

2.1 Costs

In this paragraph the main measures costs have been considered with every cost reported having its own methodology in the following paragraphs. The following list summarizes all the costs considered:

- Cost for the first evaluation analysis of the worst crossings in terms of safety for drivers and pedestrians;
- Initial investments for the equipment of selected intersections with cameras;
- Cost for maintenance of system.

Analysis of black spots

The intersection analysis requires more safety conditions than has been reported in the MRT. This has not been taken into account as the Municipality usually collects and archives data about accidents, their reasons and injuries/deaths. It is reasonable to believe that no outside resources have been hired to complete the research. Considering the subject appointee of the study is already part of the Municipality, it has been hypothesized that his/her salary will be paid anyway.

Furthermore, , even if the cost of the analysis was taken into account, it would not have a relevant cost compared to the installation/maintenance of the system[2].

Initial investments

Initial investments relate to costs of the actual cameras and camera boxes. Each intersection identified as a black spot has a fixed structure (on the traffic light) where a camera has to be placed.

[2] This statement can be considered valid if accidents and their location are already collected by Public Administration and it is available an historical trend. Contrariwise costs cannot be considered irrelevant.

Figure 2.4: Example of STARS application at traffic light

The STARS system is located at 15 intersections (15 boxes, one for every intersection) and 6 cameras which alternate at traffic lights.

Cost for maintenance

Initial investments need constant maintenance to remain efficient. For this reason this cost has been assumed in the analysis. Ordinary/extraordinary maintenances costs have been considered:

- Cameras renewal (of old or broken ones),
- Changing boxes damaged on traffic lights,
- Changing coils broken by road works.

Cost for maintenance should take into account the cost of employees who do the physical work, given that probably he/she works already for P.A. and so he/she doesn't represent an additional cost. However, to be on the safe side, employee maintenance's costs have been estimated as an average staff cost of 20.000 €/year (a part-time contract).

2.2 Benefits

In the following paragraph the main benefits are analyzed and evaluated, as follows:

- Increase in number of fines;
- Decrease of accidents
- Decrease of injuries and fatalities

Increasing in number of fines

Since the STARS system implementation, the number of fines recorded has grown significantly (STARS is active 24 hours a day and allows a continuous check of intersections) demonstrating how the traditional Police is often not able to cover all the territory and incentivise drivers to behave differently. This aspect has been considered as a benefit as it does not represent a cost for the driver if he/she drives properly.

Decreasing of accidents, injuries and fatalities

There has been a downward trend of accidents at intersections equipped with the STARS devices. As crashes decrease, so too do injuries and fatalities, especially if the comparison is done for the same intersections. [3].

The drop in accidents implies less costs for Public Administration in terms of road first aid, hospital assistance and the eventual re-establishment of a working intersection. Consequently the decrease in accidents can be considered a general benefit.

Increasing in safety feelings

An increase in the feeling of safety feeling has not been taken into account in the analysis costs given the order of magnitude of other benefits and the fact that it's difficult to put a value on it.

[3] The assert that less accidents implies less injuries and fatalities is not always true, for example on highways there are less accidents but more dangerous and with more deaths. The statement is true for comparisons between the same typology of roads and all the more reason if intersections analysed are the same before and after the device equipment.

3 Analysis methodology for costs and benefits

The methodologies chosen for evaluating costs and benefits included in the CBA are reported in the following paragraphs.

It must be noted that STARS is not a Measure born directly from Mimosa as it has been in operation since 2004 when it was piloted at two intersections. Following positive results in its first year, two other intersections were equipped the subsequent year in 2005. The remaining 11 points have been completed since the start of the MIMOSA project.

As declared in the Introduction, the CBA analysis takes into account the whole period of the STARS "life", not only the period of Mimosa (2008-2012). The reason for this methodology is because Mimosa wants to investigate the advantages or disadvantages of the project and the repeatability of the project in other cities. Therefore,it is reasonable to consider all costs sustained by the Municipality for the complete implementation of the system and consequentially all the benefits produced.

3.1 Initial investments

Initial investments reflect the cost of traffic light equipment during the period 2004-2008. With 15 intersections covered, the STARS system reaches a total of 27 branch roads. Every intersection has its own box arranged to host the camera and Police establish the shift work of cameras[4].

Every camera box costs 6.000 euro and the value of the camera is 9.000 euro (taken as constant during all period of evaluation[5]):

$$Cost_{boxes} = 6.000 * n_{boxes}$$

$$Cost_{cameras} = 9.000 * n_{cameras}$$

3.2 Cost for maintenance

Costs for ordinary and extraordinary maintenance are evaluated with an average annual

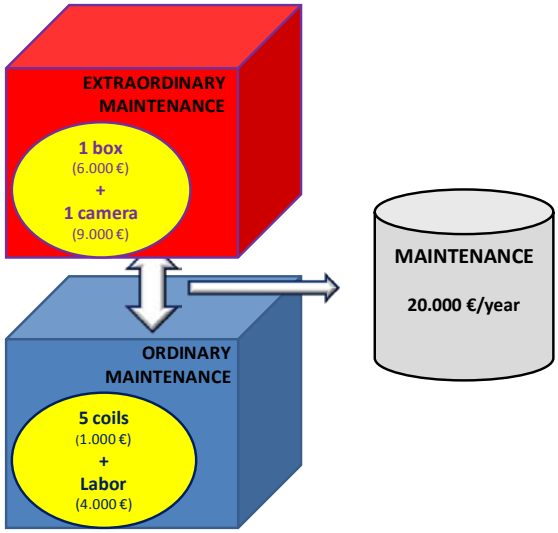
[4] Drivers do not know if a intersection has a camera inside or not, because they do not know Police planning, so any way their behaviour is influenced is in a positive way.

[5] This hypothesis is justified by the lower cost of technologies registered year after year, therefore a constant value equal to the initial one is a good approximation.

expenditure of 20.000 euros. The appraisal is a very conservative estimate of Public Administration costs as 20.000 euros includes the annual purchase of one new camera, one camera box, the substitution of 4 coils and the related re-installation labor costs[6].

STARS system has another peculiarity given the maintenance aspects: its positive contribution to safer roads continues even if not all cameras/coils work correctly. Asmentioned in note 6, drivers behaviors are influenced anyway as they are unaware if the system works or not.

Figure 3.1: Cost of ordinary/extraordinary maintenance



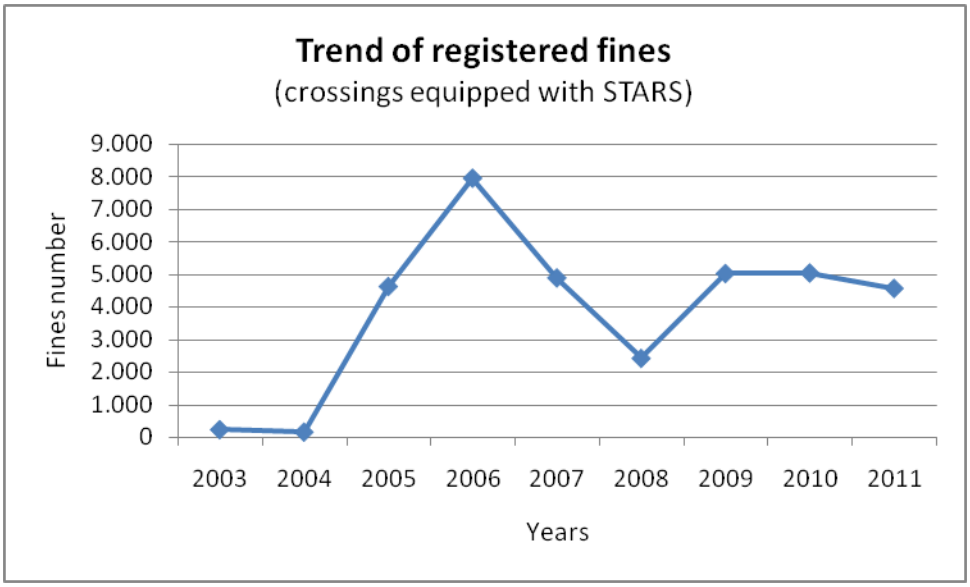
3.3 Increasing in fines number

The STARS system as explained in the first paragraph of this paper, is one which allows for a continuous checking of intersections with a camera assessing vehicles' red passages. The six cameras works on shift in 15 different stations and not all fifteen STARS intersections can operate simultaneously (only 6 at the same time). Obviously the continuous monitoring of roads allows for a sensible increase in the number of fines.

The trend shown below is the number of fines recorded at STARS intersections between 2003-2011: the table only wants to show the sensible difference in number of fines emitted before and after the system introduction of (more than 1000%).

[6] The cost for the maintenance during the last 7 years of evaluation were lower than the estimate. (considering that during the first years of implementation no extraordinary costs occurred), but a precautionary evaluation can be more useful considering the system will be subject to ageing.

Graph 3.1: Recorded fines trend (2003-2010)



** The devices equipment had been done for 2 intersections in 2003, for 2 in 2004 and for the remaining ones in 2008.*

The profit for the Municipality Administration has been evaluated by multiplying the number of annual fines recorded for the cost by a single violation. Since some fines are questioned and are not paid, only 95% of the recorded ones have been considered in the analysis.

$$Gain = \sum_{2004}^{2020} 95\% * fines_{year\ i} * cost$$

Fines have different amounts depending on the time slot when the infraction has been committed and the time spent to pay [7].

Fines are available only in aggregate, only the standard cost[8] has been included in the CBA evaluation.

3.4 Decrease in accidents, injuries and fatalities

The decrease in accidents, injuries and fatalities is evaluated by attaching monetary value to every kind of physical accident that happens to a person involved in a crash, as indicated in the CBA guidelines. The table below shows the cost associated to every typology of injuries, according to the the HEATCO study (February 2006).

[7] If the infraction has been committed before 7:00 am or later than 10:00 pm, the amount fine is 130% of the "standard" one. Citizens have 60 days for the payment, in case of delays the amount is doubled.

[8] As standard cost the following values have been considered: 143 € (2008), 150 € (2009-2010), 154 € (2011), source Bologna Municipality Police.

Table 3.1: Cost of every typology of damage per single person.

Country	Fatality	Severe injury	Slight injury
Italy	1.658.800 €	213.092 €	16.356 €

Source: Bologna Municipality Police

Taking into account the annual decrease in the number of accidents the CBA analysis gives every crash a monetary value which summarizes all costs connected to material damages, administrative costs, insurances costs and expenditures for police/fireman.

Data collected by the Police of BOL Municipality does not distinguish if an injury is severe, slight or if a fatality happened; the database only quotes if the accidents involve victims or "general" injuries. The same consideration can be done for national statistic data. Regarding the percentage appraisal between strong or light injuries, a study by the Health Service Agency Regione Lazio, indicates a percentage of 9,4% for severe injuries (red and yellow code for the in-patient at emergency ward).

Following this criteria, severe and slight injuries have been estimated also for the Municipality of Bologna.

Figure 3.2: Method used for the appraisal of slight and severe injuries.

Number of fatalities at intersections checked by STARS system occurred sporadically during the six years of monitoring (only two times). They also have typically accidental characteristics (difference between severe injury or death often by chance) . Even though a death is obviously relevant, it has not been taken into account as it's very difficult to estimate the frequency with which they occurred (especially if the historical values are so inconsistent). Furthermore, every possible assumption could imply a sensible mistake considering the order of magnitude of the single fatality cost[9]. In any case, the absence of fatalities in CBA can be considered as a cautionary approximation that underestimates STARS benefits: ignoring the number of deaths is equal to hypothesizing that no difference

[9] The cost of a single fatality is equal to eight severe injuries.

occurred between Mimosa and BAU scenario. STARS implementation does not worsen intersection safety so if any death occurred, probably it would have happened even if the system were not active. It is reasonable to presume that the number of fatalities in BaU scenario could be at least the same as the Mimosa scenario, as detailed later on in the next chapter.

4 Computing the Business-as-usual Scenario

BaU's scenario predicts the future consequence if this Measure was not applied in the City. To build BaU implies some assumptions and hypothesis, as follows:

- initial investments for the implementation of cameras and boxes are not considered because they are unique to STARS, same goes for maintenance of equipment;
- fines are evaluated considering historical trends available since 2003: data starting in 2004 is affected as it was under STARS influence. Drivers had probably changed their general behavior at traffic lights following the first installation of the STARS system as they do not know exactly how many control stations were placed. This aspect is explicit, considering fines between 2003 and 2005 at crossings were not yet equipped with STARS: a 72% reduction in fines was recorded (41 during 2005 as opposed to 148 in 2003).

Table 4.1: trend of fines between 2003 and 2005 in crossings equipped with STARS in 2008

CROSSING/YEAR		**2003**	**2004**	**2005**
4	S.DONATO – LAVORO	3	1	6
5	S.DONATO – REPUBBLICA	2	3	1
6	CARDUCCI - DANTE (DIR.S.STEFANO)	10	6	2
	CARDUCCI - DANTE (DIR.S.MAZZINI)	9	6	2
7	ORTI - DAGNINI (DIR.CENTRO)	3	5	0
	ORTI - DAGNINI (DIR.PERIFERIA)	4	4	0
8	MASI - L. ALBERTI	3	3	0
	L.ALBERTI – MASI	1	0	0
9	SHAKESPEARE - PEGLION (DIR.PERIF.)	1	1	1
	SHAKESPEARE - PEGLION (DIR.CEN.)	2	0	0
10	ANDREINI - BEROALDO	7	5	1
11	MURRI – GANDINO	3	2	1
12	M.E.LEPIDO - C.DUCATI	19	11	7
	M.E.LEPIDO – SALUTE	10	5	5
13	TOGLIATTI - DE PISIS (DIR. CENTRO)	4	1	2
	TOGLIATTI - DE PISIS (DIR. PERIFERIA)	5	1	5
14	SABOTINO - VICINI (DIR. P.TA S.ISAIA)	35	18	4
	SABOTINO - VICINI (DIR. P.TA S.FELICE)	7	4	2
15	L.BASSI – MEZZOFANTI	2	1	0
	MEZZOFANTI - LAURA BASSI	18	3	2
TOTAL		**148**	**80**	**41**

Source: Bologna Municipality Police

The table below shows the number of fines for every intersection relating to the construction of BaU's scenario: grey boxes are the years when STARS was not active at the intersection and yellow boxes show the years when the system was already implemented. The second group of cells has obviously been estimated for the BAU scenario: a trend forecast of fines has been compiled using the average values before lights equipment. As shown at the end of the table, this approach to the problem cannot analyze the influence of STARS. By using these values for BaU, it is probable that a sub estimation of the number of fines emitted each year is committed. Without any STARS camera present, fines would be be closer to those values from 2003. As a result of this and the fact that the volumes of fines produced under Mimosa are bigger, more than 2000% (4000 instead of 150), the BaU sanctions have been estimated based on their order of magnitude (the same value of 2003), without any trend or future prediction.

Table 4.2: trend of fines between 2003 and 2011 in BaU's scenario

INTERSECTIONS	2003	2004	2005	2006	2007	2008	2009	2010	2011
VITTORIO VENETO - SAFFI	3	2	3	3	3	3	3	3	3
MALVASIA – SAFFI	66	63	65	65	65	65	65	65	65
LENIN - EMILIA LEVANTE	5	9	7	7	7	7	7	7	7
PO - EMILIA LEVANTE	5	0	3	3	3	3	3	3	3
MATTEI – BASSA	3	2	3	3	3	3	3	3	3
MATTEI – MARTELLI	1	1	1	1	1	1	1	1	1
S.DONATO – LAVORO	3	1	6	5	1	3	3	3	3
LAVORO - SAN DONATO	0	0	0	0	0	0	0	0	0
S.DONATO – REPUBBLICA	2	3	1	0	0	2	2	2	2
CARDUCCI - DANTE (DIR.S.STEFANO)	10	6	2	3	3	5	5	5	5
CARDUCCI - DANTE (DIR.S.MAZZINI)	9	6	2	4	1	4	4	4	4
ORTI - DAGNINI (DIR.CENTRO)	3	5	0	2	0	2	2	2	2
ORTI - DAGNINI (DIR.PERIFERIA)	4	4	0	2	0	2	2	2	2
MASI - L. ALBERTI	3	3	0	4	3	3	3	3	3
L.ALBERTI – MASI	1	0	0	0	0	0	0	0	0
SHAKESPEARE - PEGLION (DIR.PERIF.)	1	1	1	0	0	1	1	1	1
SHAKESPEARE - PEGLION (DIR.CEN.)	2	0	0	0	0	0	0	0	0
ANDREINI - BEROALDO	7	5	1	4	1	4	4	4	4
MURRI – GANDINO	3	2	1	0	0	1	1	1	1
M.E.LEPIDO - C.DUCATI	19	11	7	6	2	9	9	9	9
M.E.LEPIDO – SALUTE	10	5	5	3	1	5	5	5	5
TOGLIATTI - DE PISIS (DIR. CENTRO)	4	1	2	6	2	3	3	3	3
TOGLIATTI - DE PISIS (DIR. PERIFERIA)	5	1	5	3	2	3	3	3	3
SABOTINO - VICINI (DIR. P.TA S.ISAIA)	35	18	4	5	5	13	13	13	13
SABOTINO - VICINI (DIR. P.TA S.FELICE)	7	4	2	0	1	3	3	3	3
L.BASSI – MEZZOFANTI	2	1	0	1	1	1	1	1	1
MEZZOFANTI - LAURA BASSI	18	3	2	0	1	5	5	5	5
	231	157	123	130	106	151	151	151	151
Fines considered	**231**	**157**	**230**	**230**	**230**	**230**	**230**	**230**	**230**

Source: TeMA elaboration of data from Bologna Municipality Policy

The table below resumes BaU's trend of accidents: data after installation of Stars is the average value of crashes registered the year before.

Table 4.3: trend of accidents in BAU scenario between 2003 and 2020.

	ACCIDENTS BaU	2003	2004	2005	2006	2007	2008	2009	2010	2011	…	2020
1	Saffi Malvasia	17	17	17	17	17	17	17	17	17	…	17
2	Lenin Po	10	10	10	10	10	10	10	10	10	…	10
3	Mattei Martelli	8	7	6	7	7	7	7	7	7	…	7
4	San Donato Del Lavoro	11	11	11	11	11	11	11	11	11	…	11
5	San Donato Repubblica	4	4	4	5	4	2	4	4	4	…	4
6	Carducci Dante	8	8	8	7	8	8	8	8	8	…	8
7	Dagnini Orti	4	4	4	3	4	5	4	4	4	…	4
8	Masi Leandro Alberti	4	4	4	2	4	6	4	4	4	…	4
9	Shakespeare Peglion	2	2	2	4	2	0	2	2	2	…	2
10	Beroaldo Andreini	4	4	4	5	4	2	4	4	4	…	4
11	Murri Gandino	4	4	4	3	4	5	4	4	4	…	4
12	M.E.Lepido Cavalieri Ducati	3	3	3	4	3	1	3	3	3	…	3
13	Togliatti De Pisis	3	3	3	3	3	3	3	3	3	…	3
14	Sabotino Vicini	3	3	3	2	3	3	3	3	3	…	3
15	Laura Bassi Mezzofanti	5	5	5	4	5	5	5	5	5	…	5
BAU	**TOTAL**	**90**	**89**	**88**	**87**	**89**	**85**	**89**	**89**	**89**	**…**	**89**

Source: TeMA elaboration of Bologna Municipality data

Injuries are evaluated based on the average values recorded before STARS's installation. This value has been assumed to be constant during the period of analysis (2004-2020), as it has been done for Mimosa's scenario.

Table 4.4: trend of injuries in BAU scenario between 2003 and 2020.

INJURIES BaU	2003	2004	2005	2006	2007	2008	2009	2010	2011	…	2020
Saffi Malvasia	28	28	28	28	28	28	28	28	28	…	28
Lenin Po	17	17	17	17	17	17	17	17	17	…	17
Mattei Martelli	16	12	7	12	12	12	12	12	12	…	12
San Donato Del Lavoro	13	16	18	16	16	16	16	16	16	…	16
San Donato Repubblica	5	5	5	6	5	4	5	5	5	…	5
Carducci Dante	12	12	12	10	12	14	12	12	12	…	12
Dagnini Orti	4	4	4	2	4	6	4	4	4	…	4
Masi Leandro Alberti	5	5	5	3	5	7	5	5	5	…	5

Shakespeare Peglion	4	4	4	8	4	0	4	4	4	…	4
Beroaldo Andreini	4	4	4	6	4	2	4	4	4	…	4
Murri Gandino	5	5	5	3	5	6	5	5	5	…	5
M.E.Lepido Cavalieri Ducati	6	6	6	5	6	6	6	6	6	…	6
Togliatti De Pisis	6	6	6	5	6	7	6	6	6	…	6
Sabotino Vicini	4	4	4	2	4	5	4	4	4	…	4
Laura Bassi Mezzofanti	8	8	8	5	8	10	8	8	8	…	8
TOTAL	**137**	**136**	**133**	**128**	**136**	**140**	**136**	**136**	**136**	**…**	**136**

Source: TeMA elaboration - Bologna Municipality Police data

Injuries after 2010 installation of STARS (the yellow boxes underline the first year of complete measure implementation in the real scenario) are obtained as the average values dating from during the years before installation.

Fatalities have not been take into account as in the Mimosa scenario. .

5 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[10]:

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

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. In order to quantify the Net Present Value, single costs and benefits have been defined.

5.1 Initial investments

Initial investments are represented by the installation of 6 cameras and 15 boxes where the cameras were alternated (15 locker, 2 in 2003, 2 in 2004 and 11 during 2008). No further investments have been assumed after 2011, costs between 2012 and 2020 relate exclusively to maintenance activity.

[10] CIVITAS POINTER (2009).

Table 5.1.1: Initial investments for STARS system (boxes and cameras)

	2003	2004	2005	2006	2007	2008	2009	2010	2011
Cameras purchased	2					4			
Unitary cost (camera) (€)	9.000					9.000			
Boxes	2	2				11			
Unitary cost (box) (€)	6.000	6.000				6.000			
INVESMENT (€)	**30.000**	**12.000**	**0**	**0**	**0**	**102.000**	**0**	**0**	**0**

Source: TeMA elaboration - Bologna Municipality Police data

5.2 Cost for maintenance

Ordinary maintenance costs have been estimated based on regular administration of periodical coils renewal. Frequently these delicate instrumentations are subject to breaks caused by asphalt substitution, pipe maintenance and ordinary use. In the CBA, a cost of 5.000 € has been assumed for annual maintenance, including new coils and the related work for substitution.

Costs of extraordinary maintenance are difficult to evaluate just because these costs are random. . The present CBA assumes this cost as not irrelevant: 15.000 € represents an exaggerated maintenance cost (the annual cost of one camera and one box to replace the older ones). The value is intentionally overestimated[11] considering the future ageing of the system.

Table 5.2.1: Costs of maintenances during evaluation period (2003-2020)

MAINTENACE	2003	2004	2005	2009	2010	2011	2012	2013	2014	…	2020
ORDINARY (€)		5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	…	5.000
EXTRAORDINARY (€)	0	0	0	0	0	0	16.000	16.000	16.000	…	16.000
COST	**0**	**5.000**	**5.000**	**5.000**	**5.000**	**5.000**	**21.000**	**21.000**	**21.000**	**…**	**21.000**

Source: TeMA elaboration

Cost of personnel used for STARS has been estimated as 3 daily hours, equal to an average cost of an employee with a part-time contract (20.000 €/year).

5.3 Decreasing of accidents, injuries

Accidents and injuries have been evaluated in Mimosa's future prediction as the average of values registered over the STARS duration (for the first two intersections the average value

[11] The value is high because since 2004 to 2011 the maintenances costs were lower than future expected. It is also true the system actually is new and with years probably it will be more subject to time wearing effects.

includes 2005-2010): this value has been deemed constant throughout the evaluation period because no better prediction can be done.

Table 5.3.1: Accidents registered during Mimosa and their future prediction.

ACCIDENTS MIMOSA	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	…	2020
Saffi Malvasia	17	17	13	5	5	3	2	3	5	5	5	…	5
Lenin Po	10	10	5	5	6	7	4	6	6	6	6	…	6
Mattei Martelli	8	7	6	5	4	3	5	2	4	4	4	…	4
San Donato Del Lavoro	11	11	11	7	6	10	4	4	6	6	6	…	6
San Donato Repubblica	4	4	4	5	4	2	3	2	3	3	3	…	3
Carducci Dante	8	8	8	7	8	8	6	5	6	6	6	…	6
Dagnini Orti	4	4	4	3	4	5	1	4	3	3	3	…	3
Masi Leandro Alberti	4	4	4	2	4	6	2	2	2	2	2	…	2
Shakespeare Peglion	2	2	2	4	2	0	0	3	2	2	2	…	2
Beroaldo Andreini	4	4	4	5	4	2	3	3	3	3	3	…	3
Murri Gandino	4	4	4	3	4	5	4	2	3	3	3	…	3
M.E.Lepido Cavalieri Ducati	3	3	3	4	3	1	0	1	1	1	1	…	1
Togliatti De Pisis	3	3	3	3	3	3	2	5	4	4	4	…	4
Sabotino Vicini	3	3	3	2	3	3	2	3	3	3	3	…	3
Laura Bassi Mezzofanti	5	5	5	4	5	5	4	2	3	3	3	…	3
TOTAL	**90**	**89**	**79**	**64**	**65**	**63**	**42**	**47**	**54**	**54**	**54**	**…**	**54**

Source: Municipality data and TeMA elaboration.

Table 5.3.2: Injuries registered during Mimosa and their future prediction.

INJURIES MIMOSA	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	…	2020
Saffi Malvasia	28	28	16	8	4	3	2	3	6	6	6	…	6
Lenin Po	17	17	8	8	9	10	7	9	9	9	9	…	9
Mattei Martelli	16	12	7	7	5	3	8	5	6	6	6	…	6
San Donato Del Lavoro	13	16	18	9	11	16	6	11	11	11	11	…	11
San Donato Repubblica	5	5	5	6	5	4	5	2	2	2	2	…	2
Carducci Dante	12	12	12	10	12	14	7	6	7	7	7	…	7
Dagnini Orti	4	4	4	2	4	6	1	5	3	3	3	…	3
Masi Leandro Alberti	5	5	5	3	5	7	2	2	2	2	2	…	2
Shakespeare Peglion	4	4	4	8	4	0	0	4	2	2	2	…	2
Beroaldo Andreini	4	4	4	6	4	2	3	7	5	5	5	…	5
Murri Gandino	5	5	5	3	5	6	5	2	4	4	4	…	4
M.E.Lepido Cavalieri Ducati	6	6	6	5	6	6	0	1	1	1	1	…	1
Togliatti De Pisis	6	6	6	5	6	7	2	7	5	5	5	…	5
Sabotino Vicini	4	4	4	2	4	5	2	5	4	4	4	…	4
Laura Bassi Mezzofanti	8	8	8	5	8	10	4	2	3	3	3	…	3
TOTAL	**137**	**136**	**112**	**87**	**92**	**99**	**54**	**71**	**70**	**70**	**70**	**…**	**70**

Source: Municipality data and TeMA elaboration.

Benefits in accident reduction has been calculated based on the difference between the two scenarios and multiplying this value for the cost of a single event. The cost of one accident is not available from the insurance company. For this reason it has been assumed that the cost of an accident is the same value used for a slight injury (16.356 €). For a more sensible

analysis, the value has been considered as a central value of the accident cost, the upper bound has been estimated by multiplying three times the central value and the lower bound has been divided by three.

Table 5.3.3: Calculation of benefits caused by reduction of accidents between 2003-2020.

Accidents	2003	2004	2005	2006	2007	2008	2009	2010	2011	…	2020
Mimosa	90	89	79	64	65	63	42	47	54	…	54
BaU	90	89	88	87	89	85	89	89	89	…	89
Difference	0	0	9	23	24	22	47	42	35	…	35
Cost	16.356	16.356	16.356	16.356	16.356	16.356	16.356	16.356	16.356	…	16.356
Gain	0	0	147.204	376.188	392.544	359.832	768.732	686.952	572.460	…	572.460
Low cost	5.452	5.452	5.452	5.452	5.452	5.452	5.452	5.452	5.452	…	5.452
Low gain	0	0	49.068	125.396	130.848	119.944	256.244	228.984	190.820	…	190.820
High cost	49.068	49.068	49.068	49.068	49.068	49.068	49.068	49.068	49.068	…	49.068
High gain	0	0	441.612	1.128.564	1.177.632	1.079.496	2.306.196	2.060.856	1.717.380	…	1.717.380

Source: TeMA elaboration.

Benefits in term of injuries saved have been calculated starting from the differences occurred between the two scenarios and multiplying the value to cost of every typology of casualty (slight or severe). The calculation table below (Table 5.3.4) and results takes into account the percentage of slight and severe injuries, as reported in chapter 4.

SEVERE	9,4%
SLIGHT	90,6%

Table 5.3.4: Calculation of benefits caused by reduction of injuries between 2003-2020.

INJURIES	2003	2004	2005	⋮	2008	2009	2010	2011	2012	⋮	2020
MIMOSA	137	136	112	…	99	54	71	70	70	…	70
BAU	137	136	133	…	140	136	136	136	136	…	136
Difference	0	0	21	…	41	82	65	66	66	…	66
Severe	0	0	2	…	4	8	6	6	6	…	6
Cost severe	213.092	213.092	213.092	…	213.092	213.092	213.092	213.092	213.092		213.092
Benefit severe	**0**	**0**	**426.184**	**…**	**852.368**	**1.704.736**	**1.278.552**	**1.278.552**	**1.278.552**	**…**	**1.278.552**
Slight	0	0	19	…	37	74	59	60	60	…	60
Cost slight	16.356	16.356	16.356	…	16.356	16.356	16.356	16.356	16.356	…	16.356
Benefit slight	**0**	**0**	**310.764**	**…**	**605.172**	**1.210.344**	**965.004**	**981.360**	**981.360**	**…**	**981.360**
Total benefit	**0**	**0**	**736.948**	**…**	**1.457.540**	**2.915.080**	**2.243.556**	**2.259.912**	**2.259.912**	**…**	**2.259.912**

Source: TeMA elaboration

5.4 Increasing in number of fines

The number of fines registered during the STARS implementation represent a benefit for PA. As shown above, they increase significantly during period 2004-2010. In the Mimosa scenario, the trend of fines has been evaluated assuming a decrease in sanctions caused by a "natural" adaptation of drivers who modify their behaviors resulting in a decrease in fines (conservative estimation that underestimates benefits). Furthermore, since some fines are questioned, the totality has been reduced by 95%.

Table 5.4.1: Trend of fines expected in Mimosa's scenario between 2011 and 2020.

FINES	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	…	2020
MIMOSA	231	157	4.621	7.938	4.881	2.417	5.016	5.035	4.500	4.500	4.000	4.000	…	2.500
MIMOSA (95%)	231*	157*	4.390	7.541	4.637	2.296	4.765	4.783	4.275	4.275	3.800	3.800	…	2.375

**Data before STARS represent manual fines, for this reason data have not been multiplied by 95%*

Source: TeMA elaboration of Bologna Municipality Police data

BaU contraventions as mentioned in Chapter 4, have been considered constant during the period 2004-2011 and their future evolution can be considered constant too.

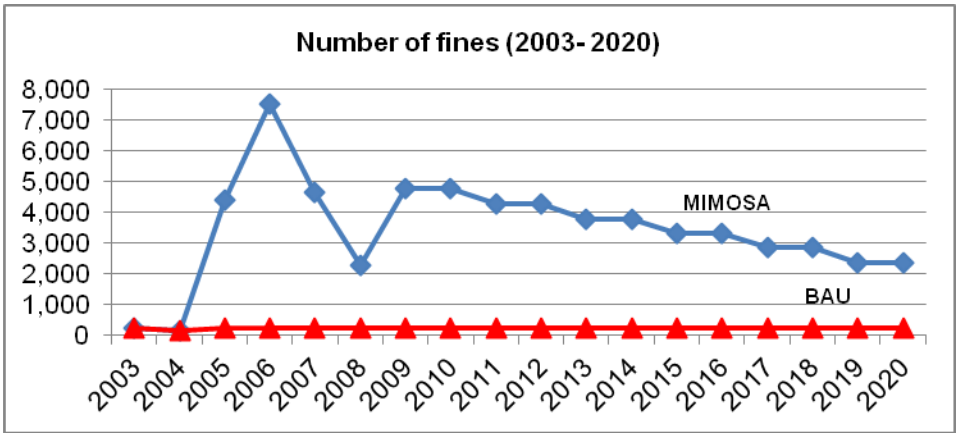
Table 5.4.2: Trend of fines expected in BAU's scenario between 2011 and 2020.

FINES	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	…	2020
BAU	231	157	230	230	230	230	230	230	230	230	230	230	…	230

Source: TeMA elaboration

The Graph below shows the trends elaborated.

Graph 5.4.1 : Comparison between fines in Mimosa and BaU scenario.



The Public Administration gain has been evaluated starting from the differences in fines emitted between the two scenarios (Mimosa and BAU) and multiplying the value for the average cost of a single fine.

Table 5.4.3: Calculation of benefits caused by increasing of fines between 2003-2020.

CROSSING	2003	2004	2005	2006	2007	2008	2009	2010	2011	…	2020
MIMOSA (95%)	231	157	4.390	7.541	4.637	2.296	4.765	4.783	4.275	…	2.375
BAU	231	157	230	230	230	230	230	230	230	…	230
Differences	0	0	4.160	7.311	4.407	2.066	4.535	4.553	4.045	…	2.145
Cost	100	100	100	120	120	143	150	150	154	…	175
GAIN	**0**	**0**	**416.000**	**877.320**	**528.840**	**295.438**	**680.250**	**682.950**	**622.930**	**…**	**375.375**

Source: TeMA elaboration

5.5 NET PRESENT VALUE

Net present value has been evaluated taking into account all annual costs and benefits. The values obtained have been brought back to the present using the *social discount rate.* As suggested by CBA guidelines, for a sensitivity analysis, the value of this economical indicator has been varied between 0,02, 0,035 and 0,055.

As mentioned above, three types of scenario have been built, so NPV has been calculated in nine ways.

The table below shows the results obtained with different values of social discount rate. All cases have a **significant positive value of NPV**, underlining the unquestionable economic convenience of the measure over the 18 year evaluation period.

CBA 8.5			YEARS												
			2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	…	2019	2020	
COST	INITIAL INVESTMEN		30.000	12.000	0	0	0	102.000	0	0	0	0	…	0	0	
	EMPLOYEE		20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	…	20.000	20.000	
	MAINTENANCE		0	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	21.000	…	21.000	21.000	
BENEFIT	REDUCTION OF ACCIDENTS NUMBER	Low cost	0	0	49.068	125.396	130.848	119.944	256.244	228.984	190.820	190.820	…	190.820	190.820	
		Medium cost	0	0	147.204	376.188	392.544	359.832	768.732	686.952	572.460	572.460	…	572.460	572.460	
		High cost	0	0	441.612	1.128.564	1.177.632	1.079.496	2.306.196	2.060.856	1.717.380	1.717.380	…	1.717.380	1.717.380	
	REDUCTION OF INJURY NUMBER		0	0	736.948	1.457.540	1.506.608	1.457.540	2.915.080	2.243.556	2.259.912	2.259.912	…	2.259.912	2.259.912	
	INCREASING OF FINES		0	0	416.000	877.320	528.840	295.438	680.250	682.950	622.930	622.930	…	375.375	375.375	**NPV**
Social Discount Rate	0,035	Accident low cost	-50.000	-37.000	1.177.016	2.435.256	2.141.296	1.745.922	3.697.173	2.922.346	2.749.718	2.642.790	…	1.907.647	1.843.137	**36.742.316**
		Accident medium cost	-50.000	-37.000	1.275.152	2.686.048	2.402.992	1.985.810	4.192.330	3.349.864	3.093.936	2.975.367	…	2.169.050	2.095.700	**41.478.419**
		Accident high cost	-50.000	-37.000	1.569.560	3.438.424	3.188.080	2.705.474	5.677.803	4.632.418	4.126.588	3.973.099	…	2.953.258	2.853.389	**55.686.729**
	0,02	Accident low cost	-50.000	-37.000	1.177.016	2.435.256	2.141.296	1.745.922	3.751.543	3.008.929	2.872.822	2.801.711	…	2.239.959	2.196.038	**39.396.575**
		Accident medium cost	-50.000	-37.000	1.275.152	2.686.048	2.402.992	1.985.810	4.253.982	3.449.114	3.232.450	3.154.287	…	2.546.898	2.496.958	**44.484.707**
		Accident high cost	-50.000	-37.000	1.569.560	3.438.424	3.188.080	2.705.474	5.761.300	4.769.667	4.311.334	4.212.016	…	3.467.714	3.399.720	**59.749.102**
	0,055	Accident low cost	-50.000	-37.000	1.177.016	2.435.256	2.141.296	1.745.922	3.627.084	2.812.596	2.596.282	2.448.016	…	1.545.485	1.464.915	**33.695.014**
		Accident medium cost	-50.000	-37.000	1.275.152	2.686.048	2.402.992	1.985.810	4.112.855	3.224.059	2.921.292	2.756.082	…	1.757.261	1.665.650	**38.027.301**
		Accident high cost	-50.000	-37.000	1.569.560	3.438.424	3.188.080	2.705.474	5.570.167	4.458.446	3.896.322	3.680.280	…	2.392.589	2.267.857	**51.024.161**

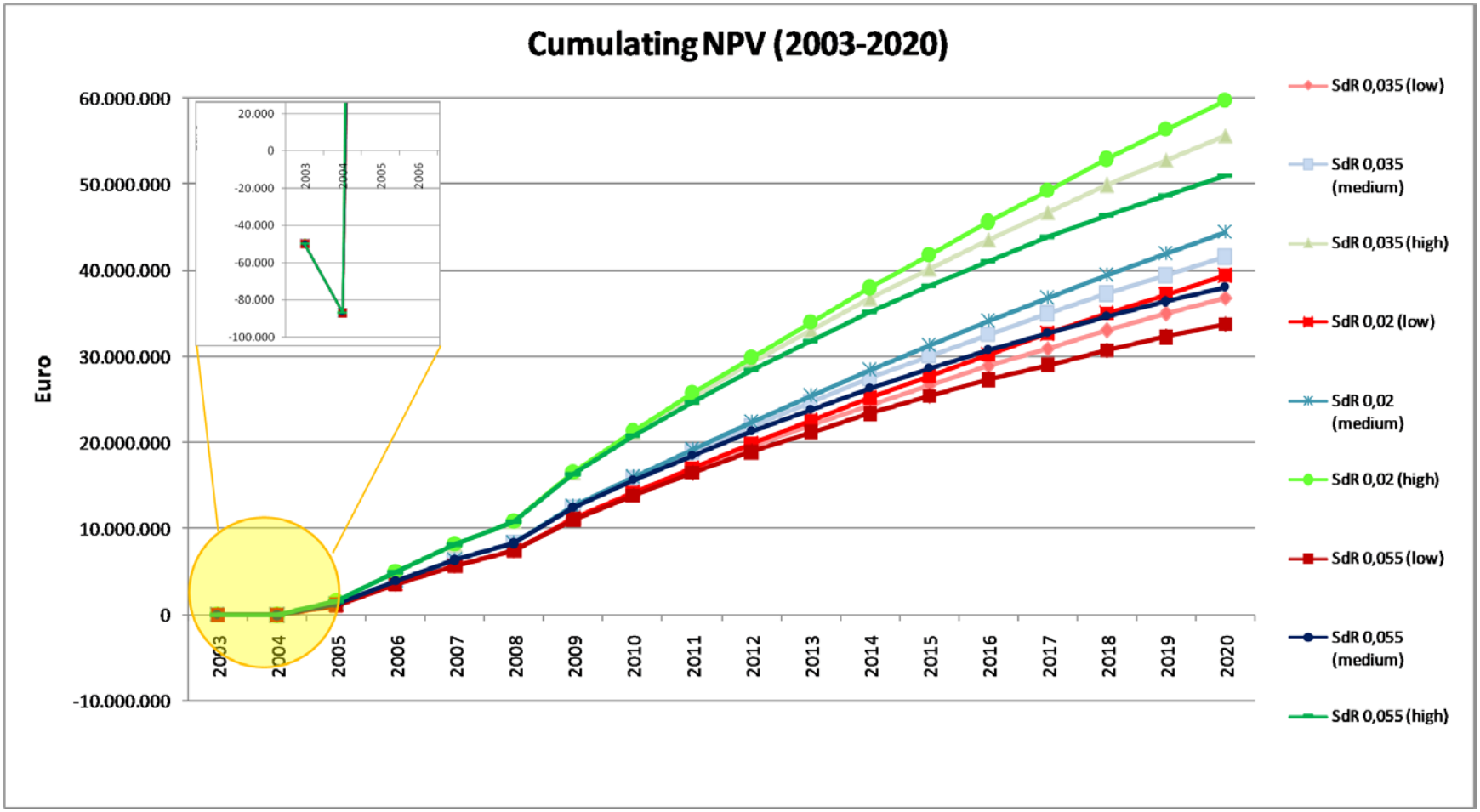


Figure 5.5.1: Calculation of Net Present Cost of STARS measure during period of evaluation (2003-2020).

6 Conclusion

As mentioned above, the overall CBA followed a precautionary approach (overestimating costs and under valuating benefits). Note that no differences in the number of accidents between 2003-2004 have been considered. This simple but precautionary approach is due to the lack of significant data. If differences occurred, it's certain that with STARS, the road safe conditions would not have got worse. Despite this cautionary approach, the net present value of the CbA is irrefutable, because investment and the maintenance cost of the Measure are significantly lower than the gain produced by fines and accidents reductions. The Measure aimed to 'educate' road users by showing them that the objective of the tool was to improve road safety, using a reliable and precise certificated system.

Furthermore, CbA demonstrates the measure could be adopted by other Public Administrations with relatively low investments (fitting traffic lights with photographic equipment and maintaining it) compared to the potential benefits. The Measure would be attractive due to the direct economic impact arising from the number of fines that the Administration might collect. This effect is also a way of assigning to the private transport system the social costs that it generates. The efficiency of the STARS system can be improved in contexts where there is a greater degree of freedom for motorists to respect the rules of the road. The STARS system is suitable for urban environments where motorists are generally inattentive to the rules of the road. The Measure can produce immediate effects without resorting to civic (road) education policies aimed at a higher objective: changing driver behaviour in the medium/long term.